

**DIETARY EVALUATION OF SUNFLOWER (*Helianthus annuus*) SEED CAKE WITH  
AND WITHOUT MAXIGRAIN® SUPPLEMENTATION IN BROILER CHICKENS**

**BY**

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ZARIA**

**SEPTEMBER, 2021**

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**A DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES,  
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**DEPARTMENT OF ANIMAL SCIENCE,  
FACULTY OF AGRICULTURE,  
AHMADU BELLO UNIVERSITY,  
ZARIA**

**SEPTEMBER, 2021**

## DECLARATION

I declare that the work in this research dissertation entitled **DIETARY EVALUATION OF SUNFLOWER (*Helianthus annuus*) SEED CAKE WITH AND WITHOUT MAXIGRAIN<sup>®</sup> SUPPLEMENTATION IN BROILER CHICKENS** was carried out by me in the Department of Animal Science, Faculty of Agriculture, Ahmadu Bello University, Zaria under the supervision of Prof. S. Duru and Prof. P. A. Onimisi. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this dissertation was previously presented for another degree or diploma at this or any other institution.

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Danjuma Yola LUKA

(Name of Student)

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Date

## CERTIFICATION

This research dissertation entitled **DIETARY EVALUATION OF SUNFLOWER (*Helianthus annuus*) SEED CAKE WITH AND WITHOUT MAXIGRAIN<sup>®</sup> SUPPLEMENTATION IN BROILER CHICKENS** by Danjuma Yola LUKA meets the regulations governing the award of the degree of Master of Science in Animal Science of the Ahmadu Bello University, and is approved for its contribution to scientific knowledge and literary presentation.

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## **DEDICATION**

This research dissertation is dedicated to my late parents Mr & Mrs Luka M. Yola and to my amiable supervisor late Prof. S. Duru for their love, support and contributions.

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## ABSTRACT

Two feeding trials were conducted to evaluate the effect of feeding diets containing graded levels of sunflower seed cake (SFSC) with and without maxigrain<sup>®</sup> supplementation on the growth performance, nutrients digestibility, haematological and serum biochemical parameters, carcass characteristics and cost benefit of producing broiler chickens. In each trial, 300 unsexed Cobb 500 day-old broiler chicks were randomly assigned to 5 dietary treatments each triplicated with 20 birds in a completely randomized design. SFSC was incorporated as a substitute for groundnut cake at 0, 5, 10, 15 and 20 kg/100kg diet. In the 1<sup>st</sup> trial, birds fed 20 % SFSC based diet performed significantly ( $P<0.05$ ) better in all growth parameters measured at both starter and finisher phases. Total feed intake ranged from 1251.17 to 1503.29 g/bird which increased with levels of SFSC from 0 to 20 kg/100kg diet. Birds fed diets with 10 and 20 % SFSC had significantly ( $P<0.05$ ) better values for feed conversion ratio while birds fed diets with 10, 15 and 20 % SFSC had better feed cost per kg gain. At the finisher phase, birds fed 20 % SFSC based diet had significantly ( $P<0.05$ ) higher final weight (2594.66 g/bird) and total weight gain (1509.54 g/bird) which accounts for 13.81 and 19.86% improvement in final weight and total weight gain respectively. Birds fed the control diet, 10 and 20 % SFSC based diets had the best values of 2.39, 2.67 and 2.33 for FCR and ₦284.26, ₦307.72 and ₦264.62 for feed cost per kg gain. Significant ( $P<0.05$ ) differences were observed for % DM, % CP, % CF and % NFE apparent digestibilities. Haematological and serum biochemical parameters were significantly ( $P<0.05$ ) influenced by graded levels of SFSC but were within normal range values reported for healthy birds. Carcass traits and internal organs weight were significantly ( $P<0.05$ ) influenced by graded levels of SFSC. Birds fed 20 % SFSC based diet gained ₦994.70 gross margin with a return per Naira invested of ₦1.92. This accounts for 11.06 % reduction in feed cost and 20.52 %

economic gain. In the 2<sup>nd</sup> trial, final weight was significantly ( $P<0.05$ ) higher in birds fed the control diet and 20 % SFSC based diet supplemented with maxigrain<sup>®</sup> while weight gain was significantly ( $P<0.05$ ) higher in birds fed the control diet, 10, 15 and 20 % SFSC based diets supplemented with maxigrain<sup>®</sup>. Total feed intake was significantly ( $P<0.05$ ) higher in birds fed 10, 15 and 20 % SFSC based diets supplemented with maxigrain<sup>®</sup>. FCR was best in birds fed control and 20 % SFSC based diet supplemented with maxigrain<sup>®</sup> while birds fed the control diet, 15 and 20 % SFSC supplemented with maxigrain<sup>®</sup> had better feed cost per kggain. Apparent nutrients digestibility was better in birds fed the control diet and 20 % SFSC based diet except for NFE while carcass traits were significantly ( $P<0.05$ ) influenced by maxigrain<sup>®</sup> supplementation on graded levels of SFSC. Birds fed 20 % SFSC based diet gained ₦712.93 gross margin while birds fed the control diet gained ₦689.69 gross margin with a return per Naira invested of ₦1.68 and ₦1.65 respectively. It can be concluded that, 20 % SFSC incorporated as a substitute for groundnut cake in broiler chickens diets reduced feed cost by 11.06 % and improved growth performance by 19.86 % and economic gain by 20.52 % without detrimental effect on nutrients digestibility, blood parameters and carcass yield. Thus, 20 % SFSC can be incorporated in broiler starter and finisher diets by farmers and feed millers.

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## **CHAPTER ONE**

### **1.0**

### **INTRODUCTION**

#### **1.1 Background of the Study**

Sunflower seed cake (SFSC) is the by-product of the sunflower oil extraction industry. The extraction of sunflower oil from whole or decorticated sunflower seeds can be performed by two methods. The first and most efficient method of oil extraction uses a chemical solvent (hexane) at high temperatures to obtain sunflower oil and sunflower meal (SFM) as a by-product. The second method is characterized by mechanically-pressing sunflower seeds to obtain sunflower oil resulting in a by-product known as sunflower seed cake (SFSC). The sunflower oil extraction industry produces substantial amounts of sunflower seed cake. In terms of production, it is the 4<sup>th</sup> most important oil seed after soybean, rapeseed and cottonseed (Oil World, 2011). Sunflower seed cake is available worldwide with world production at 13.5 million tons in 2010-2011 (Oil World, 2011).

Sunflower seed cake is commonly produced with 60 - 65 % protein core (kernel) and 35 - 40 % hulls (shell). It is a valuable and safe product whose protein, fibre and oil contents are highly variable due to the genetics of the cultivar and plant characteristics (seed composition, hulls/kernel ratio, dehulling potential, growth and storage conditions) and on the processing method (dehulling, mechanical and/or solvent extraction). Hence when formulating diets with sunflower seed cake, one should always take into account the actual analytical composition of the batch used, rather than table values (NRC, 1994; Golob *et al.*, 2002). Its protein content ranges from 23 % for some non-dehulled, mechanically extracted seed cake, to more than 40 %

for highly decorticated, solvent extracted meals. However, usual ranges for protein are 29 - 33 % for non-dehulled seed cake and 35 - 39 % for dehulled and partially dehulled seed cake. Its amino acid profile is rich in sulphur-containing amino acids, particularly methionine, but its lysine content is low (1.24 % protein). Sunflower seed cake is considered to be lysine-deficient for several monogastric species (Steen, 1989; Villamide *et al.*, 1998; McNab, 2002; Poncet *et al.*, 2003). The fibre content is directly linked to the presence of hulls: crude fibre ranges from 27 - 31 % for non-dehulled seed cake and from 20 - 26 % for dehulled and partially dehulled sunflower seed cake. The lignin content is important in the 9 - 12 % range, even for dehulled seed cake (Sredanovic *et al.*, 2012). As a result of such a high share of hulls in sunflower seed cake with about 20 - 25 % cellulose and 8 - 10 % lignin, the nutritive value of sunflower seed cake is drastically reduced in poultry nutrition (Delic *et al.*, 1992; Attia *et al.*, 1998; Slavica *et al.*, 2006; Ali *et al.*, 2011). Solvent-extracted sunflower meal contain about 2 - 3 % residual oil, but mechanically-extracted sunflower seed cake may contain up to 30 % oil depending on the amount of pressing. This oil content gives expeller sunflower seed cake a higher gross energy (22 MJ/kg or more vs. 19 MJ/kg for solvent-extracted meal), but these sunflower seed cake contain less protein than solvent-extracted sunflower meal (Oliveira *et al.*, 2012). Sunflower seed cake is also a valuable source of calcium, phosphorus and B vitamins (Grompone, 2005).

The high fibre and low lysine content of sunflower seed cake tends to restrict its high incorporation level in broiler chickens diets which may negatively influence growth performance, nutrient digestibility and carcass quality (Smith, 1968; INRA, 2004; Biesiada-Drzazga *et al.*, 2010). Hence, addition of exogenous enzymes is usually proposed to be added to poultry diets to improve the nutrients bioavailability from different feedstuffs via enzyme supplementation (El-Deek *et al.*, 1999). Thus, some exogenous enzymes may be added to broiler

chickens diets containing sunflower seed cake to aid fibre digestion (carbohydrases) or to solubilize phytic phosphorus (phytase), thereby reducing their negative effects on broiler chickens performance (Raza *et al.*, 2009).

## **1.2 Justification of the Study**

The spiraling cost and scarcity of conventional feed ingredients is causing a steep increase in the prices of compounded poultry feeds leading to a corresponding rise in production costs with the resultant low marginal profit for the poultry farmer. Hence, it is imperative to resort to other means of alleviating the problem of high feed cost without impairing the performance of the birds (Abeke, 2008). In this direction, the most practical and economic approach to effectively reduce feed cost is the development of feed formulation using good quality alternative feed ingredients that are comparatively cost effective, safe, locally available and not directly competed for by man and the industry (Bawa *et al.*, 2003; Ogundipe *et al.*, 2003).

In this regards, by-products derived from the industrial processing of agricultural products have attracted the attention of researchers (Duru and Dafwang, 2010). Thus, it is essential to ascertain the quality and nutritive value of these alternative feed ingredients in order to diversify and expand the feedstuff resources that can replace one another for poultry feed formulation. One of such alternative feed ingredient is sunflower seed cake.

Sunflower seed cake is a valuable and safe product with substantial amounts of protein of relatively cheap source and of good quality that can be used as a substitute to replace the more conventional and expensive protein sources such as soybean meal and groundnut cake in poultry diets (Soliman, 1997). Sunflower seed cake can be a good source of energy for broiler chickens and as reported by Geron (2007), its use in feed formulation for animals can reduce production

costs and contribute to sustainable animal production by reducing environmental contamination and improving the conservation of natural resources.

Major benefits of using sunflower seed cake in poultry diets is its cheap price when compared to soybean meal or groundnut cake. Another interesting trait of sunflower seed cake is the absence of intrinsic anti-nutritional factors that may affect production performance and feed utilization. Hence, it does not require heating or special attention before being fed to birds (Gheyasuddin *et al.*, 1970; El-Barbary, 1997).

Since, sunflower seed cake contains substantial concentrations of cell-wall material and a high level of fibre that could affect the nutritive value of the seed cake, the use of an exogenous enzyme may be justified to improve the accessibility of cell contents to digestive enzymes (Brenes *et al.*, 2008). Recently, supplementation of enzymes in poultry diets has considerably increased, but few investigations are available on the influence of enzyme supplementation on utilization of sunflower seed cake in broiler chicken's diets.

In many instances, the contradictory reports on the nutritive value of sunflower seed cake have impeded its broad use as an alternative protein feedstuff even in geographical areas where sunflower seed cake is produced cheaply and in substantial amounts. Therefore, this study was aimed at evaluating the utilization of sunflower seed cake with and without maxigrain<sup>®</sup> supplementation in broiler chickens diets.

### **1.3 Objectives of the Study**

The broad objective of the study was to evaluate graded levels of sunflower seed cake as a substitute for groundnut cake in broiler chickens diets.

The specific objectives were:

- i. to determine the proximate composition, anti-nutritional factors and essential amino acid profile of sunflower seed cake.
- ii. to evaluate the effect of feeding diets containing graded levels of sunflower seed cake on the growth performance, nutrient digestibility, haematological and serum biochemical parameters and carcass characteristics of broiler chickens.
- iii. to evaluate the influence of feeding diets supplemented with maxigrain<sup>®</sup> on graded levels of sunflower seed cake on the growth performance, nutrient digestibility, haematological and serum biochemical parameters and carcass characteristics of broiler chickens.
- iv. to determine the cost benefit of production of broiler chickens fed diets containing graded levels of sunflower seed cake with and without maxigrain<sup>®</sup> supplementation.

#### **1.4 Research Hypothesis**

The following null hypotheses were postulated to guide the study and were tested at  $P < 0.05$  level of significance. The alternate hypothesis states the opposite.

- i. Feeding diets containing graded levels of sunflower seed cake has no significant effect on growth performance, nutrient digestibility, haematological and serum biochemical parameters and carcass characteristics of broiler chickens.
- ii. Feeding diets supplemented with maxigrain<sup>®</sup> on graded levels of sunflower seed cake has no significant effect on growth performance, nutrient digestibility, haematological and serum biochemical parameters and carcass characteristics of broiler chickens.
- iii. Feeding diets containing graded levels of sunflower seed cake with and without maxigrain supplementation has no significant effect on the cost benefit of broiler chicken production.

## **CHAPTER TWO**

### **2.0**

### **LITERATURE REVIEW**

#### **2.1 Role of Poultry in Protein Supply and the National Economy**

Poultry are birds reared for their meat, eggs or both and in some cases for cock fighting, religious rituals, show or games (Alaku, 2010). Oluyemi and Roberts (2000) also define poultry as any bird reared or hunted for a useful purpose is a member of the bird group collectively known as poultry. Thus, the word poultry according to Ayivor and Hellins (1982) is used as a general name for several kinds of birds that are useful mainly as food animal to man. Alaku (2010) also pointed out that poultry include such birds as the domestic fowl, the common duck, ostrich, pheasant, goose, guinea fowl, pigeons, turkey and Japanese quail. The author observed that, of all these poultry, the domestic fowl or chicken is by far the most widely raised kind of poultry as their meat and eggs are enjoyed as food all over the world. Commercial chicken farming is of two types; meat or broiler chicken farming and egg farming. A breed that is good for one type of farming might not be satisfactory for the other. A poultry farmer wants a fast growing, tender, meaty chicken that can be marketed at a younger age (Wikipedia 2013).

Poultry production is the management of birds mainly for economic and nutritional purposes (Alaku, 2010). Therefore, in Nigeria, poultry production is an important industry that provides the needed source of animal protein (meat and eggs) to the teeming population. Over the years, there is an increasing shift of the poultry production to broiler chicken production (Oluyemi and Roberts, 2000). Broiler chickens are fast growing birds which reach market weight of 1.8 kg to 2.5 kg in 6 - 8 weeks. Broiler chickens convert feed into food products quickly and efficiently.

Their high rate of productivity results in relatively high nutrient needs and their growth pattern is expected to continue because of the inherent efficiency in feed conversion. It is therefore certain that if this continues, it will go a long way in meeting the protein needs of the Nigerian populace which has been on the increase.

Alaku (2010) highlighted some of the advantages of poultry in terms of nutritional and economic or social reasons to include provision of high quality animal protein rich in amino acid, minerals and vitamins to balance the human diet, high level of productivity, short generation interval, major source of income, source of employment, pest control, fast return on investment, supply of manure and fertilizer for both domestic and industrial uses and also as a good source of non-protein nitrogen that can be incorporated into ruminants diet. They are also important in meeting social and traditional obligations and as gift animals especially among the very poor who cannot afford larger animals. Broiler chickens have proven to be efficient converters of feed to meat with the most favourable feed conversion ratio compared to other animals. Layers also play an important role in providing continuous supply of eggs which serve as food (Colin *et al.*, 2004).

The importance of poultry to the national economy cannot be overemphasized, as it has become the most popular livestock industry for the small to medium scale poultry farmers that have greatly contributed to the economic development of the country. (Adebayo and Adeola, 2005). The poultry industry has a variety of businesses such as hatchery, breeder farms, broiler chicken production, layers/egg production, poultry equipment and feed industries. No doubt, poultry have a significant effect on national economy. An earlier report by Okonkwo and Akubuo (2001) shows that about 10 % of the Nigerian population are engaged in poultry production, though mostly as subsistence farmers with small to medium-sized farms.

## **2.2 Constraints to Poultry Production in Nigeria**

Alaku (2010) observed that Nigeria's poultry industry could not enjoy any sustained development for various reasons that includes; unstable government and conflicting agricultural policies; inability of animal breeders to develop indigenous breeds and strains of birds adaptable to our native environments; inability of animal nutritionists to give us standard rations that can feed our animals in varying ecological conditions. As a result, Kidd (2000) opined that the main task of poultry nutritionists is to know the best nutrients required for greater breast meat yield as well as the best feed conversion ratio in different environmental conditions. Adebayo and Adeola (2005) in their study had earlier observed that input, finance, infrastructure, access to veterinary services, labour and government policy were constraints being faced by poultry farmers.

Sadly, for the past decades, many large operators in the industry have been forced out of the business due to various problems ranging from shortage and rising cost of feed, high cost of day-old chicks, inefficiency of veterinary services and drugs (Adebayo and Adeola, 2005). As a result, Ojo (2003) reported that the industry has fallen short of its mandate for animal protein supply as Nigerians consume only 15 g/caput of animal protein per day as against 35 g/caput recommended by FAO (1997).

## **2.3 Poultry Nutrition**

Nutrition encompasses the procurement, ingestion, digestion, transport to the cell, metabolism, absorption of chemical elements which serve as food for their growth and development and excretion (Dass, 1994). Nutrient is any single class of food or groups of food that aids in the support of life and makes it possible for birds to produce meat and eggs (Parkhurst and Mountney, 1997). Also, nutrients are those substances that are obtained from feeds that can be

used by the animal, and made available in the suitable form to its cells, organs and tissues; and according to their function and chemical nature. Nutrients are classified into; carbohydrates, proteins, lipids, vitamins, minerals and water (Singh, 2005). Any food consumed is used first to provide the energy necessary to maintain a normal body temperature, to provide the body movements necessary to survive and to provide energy for the production of body secretions and the repair of body tissues and second for growth and finally for reproduction. Any additional nutrients are stored in the bird as fat.

Nutrition therefore answers questions about nutrients, what is their source, what are the levels required, their function and interaction for healthy growth and development (Aduku 2012). Nutrition also focuses on how disease condition and problems can be prevented using diet. In addition, nutrition involves identifying certain disease conditions or problems caused by dietary factors such as poor diet (malnutrition), food allergies and metabolic diseases.

Therefore, the science of nutrition involves providing a balance of nutrients that can best meet the animal's need for growth, maintenance and production. Thus, in formulating diets for broiler chickens, the following nutrients are essential; energy, protein, fats and oils, vitamins and minerals while water is provided without restriction (Lesson, 2000). This implied the provision of rations which are complete and balanced nutritionally.

#### **2.4 Nutrient Requirements of Broiler Chickens**

The requirement for any nutrient is the amount of that nutrient which must be supplied in the ration to meet the needs of a normal healthy bird. Such level of nutrient must be capable of meeting requirements for maintenance and productive performance of birds (Olomu, 1995). The intake of nutrient is defined by the nutrient levels in the feed and the amount of feed consumed.

Nutrient requirement is defined as the minimal amount of nutrients that birds must have to permit optimum performance which can be measured in terms of growth, egg production, feed efficiency, and hatchability. According to Singh (2005), the requirement of nutrients differ depending on the type and age of poultry being fed as well as the purpose for which they are fed. Similarly, NRC (1994) observed that considerable variability still exist in the nutrient requirements of birds because their needs vary for different ages, sex, productive status, genetic background, environmental temperatures, disease and parasite, activity level, stressors, management systems and because of variations in quality of feed ingredients, nutrient inter-relationships, nutrient imbalance, improper mixing, and a number of other variables.

However, poultry are more sensitive to nutrient needs and balance than mammals as a result of faster body development and digestive process, fast respiration and circulation, thereby leading to rapid rate of growth and early maturity. Because their rapid growth makes them sensitive to nutritional deficiencies. Poultry are frequently used as laboratory animals in nutritional experiments (Parkhusrt and Mountney, 1997).

Broiler chickens have a nutritional requirement which must be calculated with care to ensure maximum productivity. Turaki (2005) stressed that the nutrient requirements for broiler chickens are mainly based on the assessment of energy and protein, which are the two major components of diet. The author further emphasized that a number of other nutrients are required in smaller amounts that are however, very essential to ensure optimum growth. McDonald *et al.* (1998) stated that broiler chickens eat feed which gives them the elements (energy) necessary for the functioning of their bodies.

An understanding of nutrient requirements and utilization is important in evaluating feedstuff for

ration formulation. Thus, the nutrient requirements of poultry involves any or combination of carbohydrates, proteins, lipids, minerals, vitamins and certain unidentified growth factors (Dass, 1994).

## **2.5 Broiler Chicken Production**

Broiler chickens are male or female chickens reared and marketed for meat. Alaku (2010) noted that members of this group grow rapidly and attain market weight within 6 to 8 weeks of age. Depending on the size and age, a meat chicken can be further classified as fryer or a roaster. However, whether a fryer or roaster all meat chickens are generally called broilers.

Feed accounts for about 60 - 70 % cost of producing broiler chickens. Mortality rate should not exceed 5 % to minimize the cost of day-old chicks. It is important to feed broiler chickens at two stages of their production, starting and finishing stages, and as a result, two types of broiler chicken diets should be formulated in accordance with these stages; broiler starter and broiler finisher diets. It has been reported by Oluyemi and Robert (2000) that broiler chickens are fed starter diets for the first 4 weeks and finisher diets for the rest of their lives. Ideally the change of feed should be gradual. This can be achieved by mixing the feed that is being introduced with the one that is already fed.

Protein and energy are very important in feed to be consumed by broiler chickens. Loosli *et al.* (1999) found that protein level in broiler starter diet should be from 20 % to 24 % with an energy level of 2800 kcal ME/kg diet and 19 to 20 % with energy level of 3000 kcal ME/kg diet for broiler finisher diet. The high protein content of broiler starter as stated by Are *et al.* (2010) is to promote rapid growth rate and in order to improve the carcass quality of broiler chickens. According to Singh (2005), birds are forced to fatten by widening the calorie/protein ratio during

the later part of their rearing. The author also pointed out that the protein content of broiler finisher diet is 20 % with a metabolizable energy level of 2900 kcal ME/kg diet. A calorie/protein ration of 150 to 155 is desirable. It is however important to provide light during brooding and early growing period of broiler chickens. Therefore, their house should not be darkened to reduce the activities of the birds, so that the feed consumed is not wasted in roaming around and instead, is utilized in putting up weight. Low intensity light has subduing effect on poultry. They spend a greater proportion of their time resting and putting their feed to weight gain. In addition, they are less prone to pecking and cannibalism (Singh, 2005)

## **2.6 Management Systems in Broiler Chickens Production**

The key success to any broiler chicken production depends on its management system. The system of management according to Oluyemi and Robert (2000) define the extent to which birds are exposed to sunshine or ultraviolet rays and pasture and it also describes the housing pattern. Jordan and Pattison (1999) observed that diseases and climatic factors are the main limitations to modern husbandry in tropical areas. Successful poultry management therefore requires the effective utilization of poultry husbandry skills.

Broiler chickens are reared traditionally on deep litter (Oluyemi and Roberts, 2000). The housing used in this system is the simplest to construct and operate. Walls could be wooden or preferably concrete. In the tropics, it is advisable to use dwarf walls of 1-1.5m height. A strong wire netting should be placed on the wall to reach the roof. This wire should be strong enough not only to keep the birds in but also to ward off vermin and predators (Alaku, 2010). The author however, recommended the use of some materials as litters to include; wood shavings; chopped stalks of maize, millets and sorghum; chopped rice straw; dried leaves, groundnut shells ; dried cow

manure; rice husked and saw dust.

Many poultry diseases can be prevented by good management practices, including sanitation, adequate feeding, well-ventilated houses etc. However, some poultry disease, particularly viral and bacterial disease could easily and rapidly spread and result in a high death toll (Are *et al.*, 2010). The authors however, stressed that the most reasonable approach to the control of these disease is by vaccination. Birds should be vaccinated at the appropriate time. As a result, Singh (2005) noted that newcastle disease (lasota) strain vaccine should be given to day-old chicks which make them resistant against this disease for their short life. IBD vaccination is done at 10 to 14 days and repeated at 20 to 24 days of age in drinking water. Vaccination schedule suitable to Nigeria has been described by NVRI (2000).

## **2.7 Effect of Environmental Conditions on Broiler Chickens Production**

Climatic elements contribute to the problems of animal production through their interactions (Alaku, 2010). The author further pointed out that the variable that affect animal production include ambient temperature, air humidity, rainfall, air movement (air velocity) or wind speed, solar radiation (intensity), barometric pressure and ionization. Of all these, the most important factors with direct effects on animals are the ambient temperature, relative humidity and air movement or wind speed.

Broiler chickens reared at ambient temperature with range of 20<sup>0</sup>C to 19<sup>0</sup>C are somewhat heavier than similar flock reared with the ambient temperature of 19<sup>0</sup>C to 35<sup>0</sup>C but with the efficiency in feed conversion (Gama, 2002). According to Oluyemi and Roberts (2000), thermal stress is a great economic threat to the poultry industry. Heat waves result in heavy losses through heat prostration in some part of the world. Thus, Randall (1998) considered adverse environmental

condition as a common cause of death 5 to 7 days of age. Consequently, Jordarn and Pattison (1999) found that heat stress in broiler chickens may be caused by high environmental temperatures or poor ventilation in the houses containing large number of intensive kept stock.

Oluyemi and Roberts (2000) however, reported that the adverse effects of heat stress on poultry are well documented. According to them, egg production, egg weight, egg shell thickness, feed intake, feed efficiency, fertility in the male, hatchability, growth rate and mortality are all liable to be affected by heat stress. Are *et al.* (2010) noted that the effects of changes in climate on growth of birds include: At high temperatures, feed intake in chicks is reduced, leading to reduced level of growth. Conversely, at low temperatures, there is reduced feed efficiency, as more nutrients are needed for body maintenance leading to reduced growth.

Some of the measures to combat heat stress in broiler production are concerned with the construction of house. Others are the treatment given to the bird itself (Oluyemi and Roberts, 2000). As a result, the authors advised that a higher rate of ventilation is required in the house because broiler chickens are stocked at a higher rate than pullet chicks. The rate of ventilation should be at maximum

## **2.8 Non-Conventional Feedstuffs in Poultry Nutrition**

Alternative feedstuffs are often referred to as non-conventional feedstuffs because they have not been used traditionally in animal feed or they are not normally used in commercial animal diets (Jakmola, 2005). These include all types of feedstuffs from animal (termite, silkworm, maggot, grub earthworm, snail, tadpoles etc), plant by-products (jack bean, cottonseed meal, cajanus, rice bran, palm kernel cake, brewers waste etc) and by-products from animal sources and processing of food for human consumption such as animal dung, offal, visceral, feathers, fish silage, bone,

blood (Devendra, 1988). However, only a narrow range of these raw materials are used in poultry feed formulations because of the problem of collection, transportation, processing, storage, high fibre content or low energy value, presence of certain anti-nutritional or toxic factors, seasonal availability and irregular supply and variability in nutrient quality.

Non-conventional feedstuffs are known to sometimes contain anti-nutritional factors which lower their biological value and poor digestion when fed raw to monogastric animals (Dublecz, 2003; Viera *et al.*, 2003; Umar *et al.*, 2007). The anti-nutrients contained in alternative feed resources are known to interfere with digestion, absorption and utilization of nutrients (Warenham *et al.*, 1994; Ogundipe *et al.*, 2003; Akande *et al.*, 2010).

Added to the above constraints, more importantly there is a lack of reliable data on their nutritive quality, feeding value and safe or effective levels of inclusion. Only conventional feed ingredients such as maize, soybean meal, groundnut extractions and fish meal have been evaluated with a fair degree of accuracy and reliability but database is limited for other ingredients. Hence, there is always an urgent need to develop database for non conventional feed ingredients on nutrient contents, digestibility, availability of different nutrients and safe or effective level of inclusion and the presentation form of feed for feeding (Mandal *et al.*, 2006).

## **2.9 Factors Limiting the Use of Non-Conventional Feed Ingredients by Poultry**

### **2.9.1 Feed formulation**

It is widely recognized that in developing African and Asian countries, existing feed resources in many circumstances are either under utilized and wasted or used inefficiently (Abeke *et al.*, 2003). Most of these alternative feedstuffs have obvious potential, but their use has been

negligible owing to constraints imposed by certain factors that pose negative effects on poultry performance (Bawa *et al.*, 2003). Two major criteria in determining the regular use of non-conventional feedstuffs in poultry diets are grouped based on nutritional and technical aspects.

### **2.9.2 Nutritional aspect**

Most non-conventional feedstuffs contain anti-nutritional factors that interfere with the utilization of dietary nutrients. Some of such anti-nutritional factors include tannin in sorghum, phytic acid in sesame seed, gossypol in cottonseed, glucosinolate in Indian mustard etc. Also, most non-conventional feedstuffs used in poultry diets contain high amounts of non-starch polysaccharides that cannot be hydrolyzed by simple stomach animals (Morgan and Bedford, 1995). These non-starch polysaccharides (NSPs) are polymeric carbohydrates which differ in composition and structure from starch (Morgan and Bedford, 1995). They also possess chemical crosses that linked them together thereby making them difficult to be hydrolyzed by simple stomach animals like poultry (Adams and Pough, 1993; Annison, 1993). Other nutritive factors limiting the use of non-conventional feedstuffs in poultry diet include: variability or inconsistency in nutrient quality, limited information on the availability of nutrients and the need for nutrient supplementation to improve the nutritive value of the feedstuff used.

### **2.9.3 Technical aspect**

Technical limitations to the use of non-conventional feedstuffs in poultry diet include seasonality and unreliability of supply of some alternative feedstuffs. This is so because some feedstuffs are not available all year round and as such poultry farmers may have to resort to feeding conventional feed sources for which an ever increasing competition with humans exists. Other technical limitations include the bulky nature of feed materials, limited research and

development facilities for determining nutrient composition and inclusion levels in poultry diets and the cost incurred in processing the feedstuff to enhance utilization (Velmurugu, 1990).

## **2.10 Strategies to Improve the Quality of Non-Conventional Feedstuffs for Incorporation in Poultry Diets**

### **2.10.1 Feed processing**

Feed processing is important when diets containing anti-nutrients are being fed to monogastric animals (Akande *et al.*, 2010). Feed processing can help to reduce the level of anti-nutrients in plant feed sources to levels that can be tolerated by animals particularly in monogastric nutrition (Fasuyi and Aletor, 2005). According to Hossain *et al.* (2011), utilization of non-conventional feed materials by birds can be improved by proper processing to enhance their nutritive values. Huisman and Tolman (1992) and Sing and Panda (1992) reported that processing methods such as heat treatment, autoclaving, water extraction, sun drying and cooking can be employed to improve the utilization of non-conventional feedstuffs containing anti-nutrients when fed to birds. Other methods include use of enzymes (Classen and Bedford, 1991), salting, blanching and ammonia treatment (Classen, 1996) sterilization and ensiling (Leeson and Summers, 2001).

### **2.10.2 Nutrient supplementation**

Diet formulation with non-conventional feedstuffs containing high level of tannin can inhibit endogenous enzyme action, thereby slowing down digestibility in broiler chickens (Velmurugu, 1990); it can also bind nutrients in feed material (Narahari and Rajini, 2003). The use of exogenous enzymes such as xylanase, glucanase, proteases, phytase etc; fats or oil to reduce dustiness of dusty non-conventional feedstuffs and sometimes to increase the calorie value of

low energy diets have been in practice. Some of the enzymes that have been used over the past several years in the feed industry include cellulase ( $\beta$ -glucanases), xylanases and associated enzymes, phytases, proteases, lipases, and galactosidases (Annison and Choct, 1993). Some commercial packages have been introduced into the Nigerian market such as Maxigrain<sup>®</sup>, Rovabio<sup>®</sup>, Allzyme<sup>®</sup>, Vegpro 5X<sup>®</sup>, Fullzyme<sup>®</sup> etc. Enzymes in the feed industry have mostly been used for poultry to neutralize the effects of the viscous non starch polysaccharides used in poultry feeds (Allen *et al.*, 1995). These anti-nutritive carbohydrates are undesirable, as they reduce digestion and absorption of all nutrients in the diet, especially fat and protein (Adams and Pough, 1993).

The use of fats and oil has also been explored especially when dusty non-conventional feedstuffs are incorporated in rations; they also complement calorie value of low calorie non-conventional feedstuffs. Synthetic amino acids like methionine and lysine, vitamin-mineral premix, growth promoters, fishmeal and other plant protein sources such as soybean meal which has more qualitative plant protein with better amino acid profile can help to enhance the nutritional quality of the feed produced from non-conventional feedstuffs (Rosen, 2006).

## **2.11 Distribution of Sunflower Seed Cake**

Sunflower seed cake is available worldwide. World production was 13.5 million tons in 2010 - 2011 (Oil World, 2011). The European Union (EU-27) is the main producer and importer: it produced 3.3 million tons and used 5.7 million tons in 2009 - 2010. Other main producers and exporters were Ukraine (2.5 million tons), Russia (2.3 million tons) and Argentina (1.21 million tons). Turkey, Israel and Egypt are the main importers after EU (FAS, 2011).

## **2.12 Processing Methods of Sunflower Seed**

### **2.12.1 Dehulling**

Sunflower seeds from oil types contain about 20 - 30 % hulls, which are often removed before oil extraction. This is because of their deleterious effects on oil presses: they hinder or lower oil extraction and reduce the quality of both oil and cake (Kartika, 2005). Reducing the hull content by 1 % improves pressing capacity by 2.5 %. A well-managed dehulling process yields seeds with 8 - 12 % hulls remaining on the kernels (Campbell, 1983). Dehulling is done after cleaning the seeds and drying them down to 5 % moisture, which facilitates kernel-hull separation (Kartika, 2005). The usual process consists of cracking the seeds by the mechanical action of centrifugal or pneumatic shellers. It can also be done by abrasion (Carré, 2009). The resulting blend is winnowed to separate the hulls from the kernels. Some sunflower seed varieties have thinner hulls that are more difficult to remove. In this case, dehulling is not recommended as it may result in oil loss, and increases extraction costs without enhancing oil and sunflower seed cake quality (Campbell, 1983; Grompone, 2005).

### **2.12.2 Oil extraction**

Once winnowed, the kernels undergo mechanical pressing through screw-presses (expellers), resulting in a "cake" containing 15 - 20 % of oil. This cake can subsequently be extracted with a solvent (usually hexane) to yield more oil. While solvent extraction is the most common industrial process, mechanical extraction is used by producers of specialty oils and smallholder farmers in both developed and developing countries, for example in Zimbabwe (Mandibaya *et al.*, 1999). In the European Union, regulations forbid the use of solvents for the production of feed ingredients used in organic farming (European Commission, 2007), so only mechanically-

extracted sunflower seed cake can be used for organic animal production.

### **2.12.3 Conditioning**

Fresh sunflower seed cake must be dried for optimal storage. It can be ground, broken into small pieces or pelletized, for easier handling and stored by adding a suitable binder such as molasses or fats under high pressure in pelletizer or extruder (Grompone, 2005).

### **2.13 Nutritional Quality of Sunflower Seed Cake**

Table 2.1 shows the nutrients composition of sunflower seed cake. Solvent extraction results in a lower fat content, while dehulling decreases the fibre content, yielding a meal richer in protein. There are fully decorticated meals (high protein, low fibre), partially decorticated cake and non-decorticated cake (low protein, high fibre) with no clear separation between these grades. Like other protein feeds such as fish meal or soybean cake, sunflower seed cake is usually graded and sold on the basis of its protein content, for example "28", "29", "37", etc. In USA, the protein level and process of manufacture must be mentioned in order to inform users about the quality of the sunflower seed cake (NCPA, 2008). The colour of sunflower seed cake ranges from grey to black depending on the degree of dehulling (cakes with less hulls are lighter) and on the extraction process (Naidu, 2008).

The fibre and lignin content of sunflower seed cake tends to reduce nutrient digestibility, and its energy values are lower than those of soybean cake. It is suitable for ruminants and rabbits, but only for pigs and poultry with low energy requirements (animals at maintenance, laying hens) or specific fibre requirements (sows) (CETIOM, 2003). In other monogastrics, such as broiler chickens or growing pigs, the cost-effectiveness of including sunflower seed cake depends on the

**Table 2.1: Nutrient Composition of Sunflower Seed Cake**

<b>Authors</b>	<b>DM %</b>	<b>CP %</b>	<b>EE %</b>	<b>CF %</b>	<b>Ash %</b>
Afifi (1972)	90.11	32.42	1.49	23.37	5.91
Rad and Keshavarz (1976)	93.80	36.30	0.40	18.22	7.06
Samy (1979)	91.20	26.41	7.34	29.68	5.46
Singh and Prasad (1979)	91.60	36.00	1.50	18.33	7.75
Lee and Lee (1982)	90.10	28.40	7.40	20.30	6.30
Valdivie <i>et al.</i> (1982)	91.02	31.48	16.40	16.37	6.82
Abdel Malaak (1989)	88.56	40.30	-	18.00	-
Zatari and Sell (1990)	89.32	29.72	12.53	28.73	5.52
Dessouky (1996)	90.23	32.60	-	18.40	-
San Juan and Villamide (2001)	-	33.14	2.77	25.21	7.00
Rostagno <i>et al.</i> (2005)	89.09	31.40	-	23.00	-
Senkoylu and Dale (2006)	90.20	32.30	18.78	11.54	6.29
Nassiri Moghaddam <i>et al.</i> (2012)	88.00	30.00	2.50	21.20	-
Liu <i>et al.</i> (2015)	91.48	33.52	3.11	27.23	6.85
Average	90.36	32.42	6.74	21.39	6.49

quality of the cake and on the availability and price of better sources of protein and lysine. It must be reiterated that sunflower seed cake is a highly variable ingredient where protein, fibre and fat cover a much larger range than in many common feeds.

#### **2.14 Amino Acids Profile of Sunflower Seed Cake**

Amino acids contents of sunflower seed cake as reported by several researchers are shown in Table 2.2. Data of amino acid pattern in sunflower seed cake showed that although it is limiting in lysine, methionine, cysteine, and tyrosine, it seemed to have good concentrations of arginine, glutamic acid and aspartic acid. Corresponding investigation of many researchers (Thomas *et al.*, 1965; Marinov *et al.*, 1973; Singh and Prasad, 1979) reported that lysine is considered the most limiting amino acid in sunflower seed cake protein. Green *et al.* (1987) pointed out that true digestibility of most essential amino acids in sunflower seed cake were similar to or greater than those of soybean cake especially lysine which is more digestible in soybean cake (87.9 %) than in sunflower seed cake (72.2 %). In this connection, Dessouky (1996) reported that sunflower seed cake is high in some amino acids such as aspartic acid, arginine and glutamic acid contents and low in others like lysine, tyrosine, methionine and cysteine contents. Moreover, the previous author added that lysine seemed to be the first limiting amino acid of sunflower seed cake.

#### **2.15 Effect of Processing on the Nutritive Value of Sunflower Seed Cake**

The methods of processing of sunflower seed cake seem to be the key factor affecting its nutritive value (Alagawany *et al.*, 2015). Also, these authors found that treating sunflower seed with excessive temperature reduced the protein quality. Moreover, Senkoğlu and Dale (1999) pointed out that dry heating of sunflower seed cake at 121°C caused marked destruction of some amino acids such as lysine in the seed cake. On the contrary, methionine was unaffected by the

**Table 2.2: Amino Acids Profile of Sunflower Seed Cake**

Amino acids	Valdivie <i>et al.</i> (1982)	Zhang and Parsons (1994)	Dessouky (1996)	San Juan and Villamide (2001)	Senkoylu and Dale (2006)	Liu <i>et al.</i> (2015)
Indispensable amino acids, %						
Arginine	2.87	2.76	2.31	1.94	2.48	2.62
Histidine	0.99	0.83	0.78	0.78	0.77	0.93
Isoleucine	1.54	1.42	1.38	1.41	1.25	1.34
Leucine	2.31	2.35	2.31	2.03	2.02	2.09
Lysine	1.39	1.43	0.87	1.12	1.14	1.48
Methionine	0.61	0.57	0.62	0.70	0.68	0.75
Phenylalanine	1.71	1.61	0.62	1.30	1.44	1.39
Threonine	1.34	1.29	1.21	1.22	1.15	1.25
Tryptophan	-	-	-	-	0.41	0.37
Valine	1.85	1.87	0.42	1.68	1.58	1.76
Dispensable amino acids, %						
Alanine	1.75	-	1.96	1.35	-	1.62
Tyrosine	0.82	0.76	0.69	0.65	0.80	0.76
Proline	-	1.64	1.69	1.32	-	1.20
Serine	1.51	1.48	1.71	1.28	-	1.42
Aspartate	3.40	2.28	3.21	2.87	-	3.01
Cysteine	0.61	0.56	0.59	0.53	0.66	0.56
Glutamine	6.85	7.21	7.20	6.14	-	6.80
Glycine	2.19	1.87	1.89	1.96	1.77	2.00

heat treatment. The nutritive value of protein in sunflower seed cake increased with decrease in processing temperature (Senkoylu and Dale, 1999). The same authors observed that sunflower seed cake processed at 155°C in the cooker and 144°C in the conditioner had less available tryptophan, lysine and arginine than that produced at 111°C and 122°C in the cooker and conditioner respectively. On the same context, Rad and Keshavarz (1976) studied the nutritional value of sunflower seed cake which was processed at 105 - 125°C in the cooker and at 80 - 130°C in the conditioner. The authors noted that the metabolizable energy (ME), net protein value (NPV) and available lysine in sunflower seed cake decreased with increased processing temperature. On the other hand, Zhang and Parsons (1994) revealed that true digestion coefficients of amino acids in sunflower seed cake decreased when autoclaving time increased. The authors observed digestibility values of lysine in sunflower seed cake as 86, 54, 43 and 35 % when sunflower seed cake autoclaved for 0, 30, 60 and 90 minutes respectively.

According to Ravindran and Blair (1992) and San Juan and Villamide (2000) high temperature associated with mechanical pressing damages the protein, destroys amino acids, and decreases their availability. Sunflower seed cake exposed to 1000W microwave irradiation for six minutes resulted in increased in vitro gas production parameters and improvement of nutritive value such as metabolizable energy, organic matter digestibility and short chain fatty acids content of sunflower seed cake. This method can be used as cost effective method for improved nutritional value of oilseed cake (Maheri-Sis *et al.*, 2011).

## **2.16 Potential Constraints of Sunflower Seed Cake**

A major benefit of sunflower seed cake is that it does not have anti-nutritional factors such as those found in soybean, cottonseed and rapeseed meals. For that reason, it is considered to be a

safe feed for all species. Its only limitations being its fibre content and amino acid deficiencies. However, residues and contaminations from sunflower cultivation, harvest and post-harvest operations may be of concern.

### **2.16.1 Contamination of sunflower seed cake during processing**

Sunflower seed cake may be contaminated during harvest and post-harvest operations: risk factors are pesticides residues, hexane residues, dioxin contamination resulting from the utilization of anticaking agents, mycotoxin development due to poor drying before storage and salmonella (FEDIOL, 2010).

### **2.16.2 Anti-nutritional factors of sunflower seed cake**

Sunflower seed cake is a good source of crude protein average 32.42 %, but the presence of polyphenolic compounds restricts its use in poultry and animal feed. Chlorogenic acid (CGA) is the major molecule of polyphenolic compounds in sunflower seed cake as demonstrated by many researchers (Leung *et al.*, 1981; Pedrosa *et al.*, 2000). Sabir *et al.* (1974), Lusas (1985) and Salem (1990) reported that the percent of CGA is 70 % of total phenolic constituents in sunflower seed cake. Irrespective of CGA, sunflower seed cake contains other phenolic compounds such as caffeic, rosmarinic and ferulic acids, as well as myricetin and rutin, all these compounds present in quantities of less than 0.15 ppm. De Leonardis *et al.* (2005; 2006) reported that phenolic compounds of sunflower seed cake included seven molecules like chlorogenic, caffeic, protocatechuic, o-cinnamic, ferulic and syringic acids. CGA is a phytochemical molecule which is the ester of caffeic acid (CA) and quinic acid (QA). Also, CA and QA are found in sunflower polyphenolic compounds with CGA. The concentrations of CGA, QA and CA isolated from sunflower seed cake samples were 2.70, 0.38 and 0.20 %, respectively.

CGA causes an observable reduction in the digestibility and bioavailability of the protein content of sunflower seed, on the other hand, CGA is a vital compound of the hydroxycinnamates, components that are ubiquitous in plants and have interesting biological properties, such as antioxidant activities (Clifford, 2000; Žilić *et al.*, 2010). But from another point of view, the phenolic compounds including CGA which is present in sunflower seed cake were not toxic as stated by Sosulski *et al.* (1972) who reported that there are no known toxic impacts for CGA in sunflower seed cake. On the other hand, the CGA in sunflower seed cake causes a brown and green discoloration in feeds at alkaline pH (Gonzalez-Perez *et al.*, 2002). The phenolic compounds in sunflower seed cake are stated till now to be not toxic for farm animals. However, CGA could become a key barrier to its utilization in feed products as forming color factors but not as a toxic component. Also, the average value of CGA in sunflower seed cake was found to be 2.27 % (Dessouky, 1996). Trevino *et al.* (1998) did not detect any adverse effect of CGA on the nutritive value of the diet in broiler chickens. Luckett *et al.* (1999) isolated from sunflower seeds a peptide with 14 amino acids, termed sunflower trypsin inhibitor (SFTI-1), which could also have a negative effect on the performance of birds. Methionine and choline addition are needed to counteract the harmful effect of CGA when sunflower seed cake is used in poultry diet (Swick, 1999).

## **2.17 Growth Performance of Broiler Chickens Fed Diets Containing Sunflower Seed Cake**

Several studies have been reported to evaluate the use of sunflower seed cake at different inclusion levels in broiler chickens diets (Waldroup *et al.*, 1970; Levic *et al.*, 1998; Sredanovic *et al.*, 2005; Abbas and Yagoub, 2008; Peric *et al.*, 2010). Feed efficiency gradually decreased with sunflower seed cake diet compared to corn-soybean diet. Also, in their studies,

supplementation of lysine to sunflower seed cake diet improved feed conversion ratio but did not quite restore it to that given by the corn-soybean diet. Moreover, sunflower seed cake could successfully replace one-third of soybean cake, while replacing two-thirds of soybean cake by sunflower cake, slightly depressed the growth rate of broiler chickens (Afifi, 1972).

A study by Ologhobo (1991) observed decreased body weight gain when substituting sunflower seed cake for soybean cake at 50, 75 and 100 % in broiler chickens diets during an 8 weeks feeding trial. On the other hand, Rad and keshavarz (1976) stated that about 50 % of soybean cake protein could be replaced by sunflower seed cake protein without drastic effect on growth rate of broiler chicks. This is equal to the use of 17.5 % sunflower seed cake in the diet which supplied 7 % of the dietary protein. Lee and Lee (1982) confirmed the findings by Valdivie *et al.* (1982) and observed no significant difference in feed efficiency of Shaver broiler chickens fed diets containing 50, 100, 150 or 200 g/kg of sunflower seed cake till 56 days of age. Increasing sunflower seed cake up to 250 g/kg diet supplemented with lysine and methionine supported equal or better weight gain of broiler chickens than the control diet. However, the worst value of feed conversion ratio was recorded with the diet containing 250 g/kg sunflower seed cake (Musharaf, 1991). The findings on sunflower seed cake inclusion in broiler chickens diets are controversial. The inclusion of 10 or 20 % sunflower seed cake significantly decreased body weight gain. Dagher *et al.* (1980), Lee and Lee (1982) and Abid *et al.* (1990) used sunflower seed cake successfully in broiler chicken diets up to 20 % without adverse impact on growth rate.

Jackson and Dalibard (1995) evaluated the performance of broiler chickens fed diets containing soybean cake, sunflower seed cake and canola meal, and all diets formulated based on crude protein or ideal protein. The same authors found that the replacement of soybean cake by

sunflower seed cake did not compromise broiler chicken performance when the diet was formulated on ideal protein basis. Some researchers have consistently reported positive growth performance and feed utilization results when sunflower seed cake is added to broiler chicken rations. Findings from an early study by Salih and Taha (1989) showed that live weight and body weight gain as well as feed intake and feed efficiency were similar in all treatments when broiler chickens were fed with diets containing different levels of sunflower seed cake at 0, 10, 20 or 40 %. Zadari and Sell (1990) fed broiler chickens with 0, 100 or 200 g/kg of sunflower seed cake diets from 1 to 42 days of age. The findings of their study suggested that the inclusion of 100 or 200g of sunflower seed cake per kg diet improved feed conversion ratio. El-Zubeir and Ibrahim (1991) and Ibrahim and El-Zubeir (1991) found that feed intake and feed conversion efficiency of broiler chickens were similar in all investigated groups containing up to 30 % sunflower seed cake. Also, growth parameters (body weight gain, feed intake, and feed conversion ratio) revealed that sunflower seed cake can be used in broiler chickens diets up to 30 % with no adverse impact on growth rate (Rajesh *et al.*, 2006). This difference may be attributed to the quality and processing methods of sunflower seed cake or strain of the birds or animal used (Campbell *et al.*, 1989).

Studies involving the use of sunflower seed cake have confirmed, and recommended that high levels of sunflower seed cake can be used effectively in broiler chickens diets (Senkoylu and Dale, 1999). El-Sherif *et al.* (1995) demonstrated the possibility of replacing soybean cake with sunflower seed cake up to 70 % in broiler chickens diets during growing and finishing stages and supplemented with methionine, lysine and fat without adverse impacts on growth performance. The treated and untreated form of sunflower seed cake in broiler chickens diets had no drastic effects on body weight, also no significant adverse impact was observed on

growth rate and feed conversion ratio of broiler chickens at 28 or 49 days of age (Desouky, 1996).

Kocher *et al.* (2000) indicated that commercial enzyme products had some effects in diets containing high concentrations of sunflower seed cake. Birds fed sunflower seed cake based diets had a significant ( $P < 0.001$ ) higher growth rate and AME and a lower feed conversion ratio (FCR) than those fed the canola meal diets. The addition of enzymes to either canola meal or sunflower seed cake based diets had no significant effects on growth performance and AME. Moreover, Swain *et al.* (1996) reported that performance of broiler chickens was improved in high crude fibre sunflower seed cake with multi-enzyme supplementation. Also, Cowan *et al.* (1999) found an improvement in broiler chickens performance due to supplementation of pectinase enzyme in sunflower seed cake based diets. On the contrary, Mushtaq *et al.* (2006) noted that enzyme addition through 2 weeks after hatch had no remarkable impact when used in sunflower seed cake based diets.

Sunflower seed cake can be used in broiler chickens diets at levels up to 140 g/kg without adverse effects on performance or other parameters (Nassiri *et al.*, 2012). Feed intake of birds ranged from 420 to 520 g/week with increasing levels of sunflower seed cake from 0 to 75 % respectively. Moreover, feed efficiency and body weight gain were unaffected by the dietary sunflower seed cake inclusions during the fattening period. Thus, sunflower seed cake can replace soybean cake and groundnut cake up to 75 % level without adverse impacts on growth performance of broiler chickens (Adejumo and Williams, 2006).

Previous studies investigating the impacts of sunflower seed cake as a replacement for soybean cake showed inconsistent results. The inclusion of sunflower seed cake resulted in worse broiler

chickens performance in some studies (Abdelrahman and Saleh, 2007; Peric *et al.*, 2010). Also, these results are supported by Mandal *et al.* (2006) who found that the inclusion of sunflower seed cake in broiler chickens diets decreased growth performance in terms of poor feed efficiency and growth rate. However, Mandal *et al.* (2003) showed that inclusion of undecorticated sunflower seed cake at 0, 50 and 100 g/kg in broiler chickens diets replacing part of soybean cake had no significant impact on weight gain and feed consumption throughout the fattening period (starter and finisher).

In other studies, the inclusion of sunflower seed cake up to 20 % (El-Sherif *et al.*, 1997; Tavernari *et al.*, 2008) or at even higher concentrations (Rama Rao *et al.*, 2006; Mushtaq *et al.*, 2009) did not have any adverse effects on live weight or body weight gain. According to Furlan *et al.* (2001), sunflower seed cake as replacement of soybean cake, can be added up to 30 %, where feed intake and body weight gain were improved by 13.17 and 12.04 % respectively, with no detrimental effects on growth performance. On the same context, Senkoylu and Dale (2006) did not observe any significant effect on broiler chickens performance when 28 % sunflower seed cake was included in the diet. Also, the previous authors used the residue of sunflower seed cake cold-pressing, which contains 32.3 % CP and 18.78 % EE compared to sunflower seed cake. Tavernari *et al.* (2009) did not find body weight gain differences in broiler chickens fed diet contained up to 20 % sunflower seed cake, while feed intake was inversely proportional to sunflower seed cake dietary level. On the other hand, Pinheiro *et al.* (2002) reported that sunflower seed cake inclusion higher than 12 % reduced body weight gain and feed intake of broiler chickens, but the best feed intake value was achieved when sunflower seed cake was not added to the diet. Some studies stated that high inclusions of sunflower seed cake up to 20 % in grower and finisher broiler chickens diets had no impact on feed conversion ratio (Aftab, 2009;

Peric *et al.*, 2010).

The inclusion levels of sunflower seed cake at 6 and 8 % in grower diet of broiler chickens had no effects on growth parameters, while at 10 and 16 % in finisher diet, body weight gain was statistically affected. Body weight gain significantly ( $P<0.05$ ) improved with dietary enzyme mixture (cellulase,  $\beta$ -glucanase, and xylanase) at 0.01 % through the entire experimental period. Neither sunflower seed cake nor enzyme supplementation had any effect on feed consumption (Horvatovic *et al.*, 2015).

## **2.18 Nutrients Digestibility and Intestinal Enzyme Activities of Broiler Chickens Fed Diets Containing Sunflower Seed Cake**

The digestion coefficients of DM, CP, EE and CF were not statistically different ( $P<0.05$ ) among dietary treatments due to the inclusion of sunflower seed cake. Compared with the control group, chicks fed diets incorporated with 2.5 and 5 % sunflower seed cake showed significantly ( $P<0.05$ ) lower digestion coefficients of NFE, being 82.47 and 82.42 % respectively (Ali, 1999). Kalmendal *et al.* (2011) revealed a beneficial impact of increased dietary sunflower seed cake on ileal digestibility of CP and EE despite the lower energy digestibility and DM.

The addition of 250 g/kg of high-oleic acid sunflower seed (HOASS) in the diets caused a negative effect on fat and protein digestibilities. However, the inclusion of HOASS at 150 g/kg improved some of these parameters and amino acid digestibilities. Where, the inclusion of high-oleic acid sunflower seed (250 g/kg HOASS) in broiler diet reduced ( $P<0.001$ ) fat digestibility by 7 % and amylase and lipase activities by 22 and 19 % respectively, compared with those fed the control diet. The addition of lipase and phospholipase enzymes at the inclusion level of 1

g/kg to broiler chickens diets containing high-oleic acid sunflower seed at 150 g/kg diet improved fat digestibility compared with the control diet during the period from 4 to 21 days of age. The inclusion of enzymes in the HOASS diet increased ( $P < 0.001$ ) fat digestibility and amylase and lipase activities by 5, 53, and 58 % respectively, compared with the un-supplemented HOASS diet. The greatest response in fat digestibility and digestive enzyme activities was obtained with the combination of lipase plus phospholipase (Brenes *et al.*, 2008).

The reduction in the amylase and lipase pancreatic activities by the birds fed the HOASS diet could be due to the adsorption of lipase and bile salts to the fibre present in the seed. Schneeman (1978) reported that the availability of enzymes such as lipase could be limited by their absorption into fibres such as xylan, cellulose, wheat bran, and rice bran. Evidence of this effect has also been observed in vitro by Lairon *et al.* (1985) with wheat bran. Almirall *et al.* (1995) reported the specific lipase activity to be decreased in broiler chickens after feeding barley. In fact, Arija *et al.* (1998) showed a consistently greater activity of lipase in birds fed increasing concentrations of dehulled full-fat sunflower seeds in the diets, probably because of the reduction of fibre content in their seeds. The activities of digestive enzyme including protease and  $\alpha$ -amylase in chick digesta were not significantly influenced by the different levels of full-fat sunflower seed (Salari *et al.*, 2009). But, sunflower seed cake significantly increased digesta viscosity in the ileum, while addition of exogenous enzyme to diet decreased viscosity of digesta particularly in the treatments with sunflower seed cake level. The digesta viscosity increased from the upper to the lower digestive tract (Horvatovic *et al.*, 2015). This phenomenon may be attributed to the impact of the concentration of compounds such as crude fibre that produce the high viscosity through the digestion process or probably due to the increased hydration of those compounds (Boros *et al.*, 1998).

In a subsequent study, Tavernari *et al.* (2009) observed that dry matter digestibility and coefficients of Ca and P were improved in broiler chickens fed diets with sunflower seed cake supplemented with exogenous enzymes. On the contrary, Kocher *et al.* (2000) did not observe any influence of enzyme supplementation in diets containing sunflower seed cake. One explanation for this discrepancy in results is that different sunflower seed varieties or cultivars varying in chemical composition and processing methods were used in the experiments. High sunflower seed cake concentrations in broiler chicken diets need the addition of high oil or dry fat levels in order to compensate the low energy level of sunflower seed cake. Indeed, oil is one of the most expensive ingredients in poultry diets (Araújo *et al.*, 2014).

### **2.19 Carcass Characteristics of Broiler Chickens Fed Diets Containing Sunflower Seed Cake**

Ozen and Erdem (1992) replaced soybean cake with sunflower seed cake in young chickens diets at levels of 0, 25, 50, 75 and 100 % during period 4 - 8 weeks of age. They did not find any significant differences between groups in the dressing percentage, abdominal fat and edible parts. On the contrary, Ologhobo (1991) observed that substituting sunflower seed cake for soybean cake at levels 50, 75, and 100 % decreased the percentages of carcass, dressing and total edible meat. On the other hand, El-Sherif *et al.* (1995) replaced soybean cake with 5, 10 or 15 % sunflower seed cake in broiler chickens diets during period 19 to 45 days of age and observed that carcass percentage had significantly differed among the groups. The differences in abdominal fat and carcass components among the groups were not significant.

Studies by Niemiec *et al.* (1996) observed that the slaughter performance of broiler chickens were improved with diet containing sunflower seed cake. Contrarily, Brenes *et al.* (2008) found

that the addition of 250 g/kg of high-oleic acid sunflower seed (HOASS) in the diets caused a negative effect on digestive organ sizes of broiler chickens (relative liver weight, relative duodenum, jejunum, ileum, and ceca lengths) compared to the control diet. Moreover, the same authors pointed out that the addition of enzymes such as lipase and phospholipase or its combination at the level of 1 g/kg to broiler chickens diets containing 150 g/kg HOASS diet increased the relative weight of pancreas, liver and spleen as well as the relative lengths of duodenum, jejunum, ileum and ceca compared with the un-supplemented HOASS diet during the period from 4 to 21 days of age. On the contrary, the addition of 250 g/kg of HOASS in the diets caused a negative effect on digestive organ sizes.

Salari *et al.* (2009) found that the percentage weight of gizzard, breast, thighs, gastrointestinal tract and abdominal fat were not affected by dietary treatments which contained different levels of full-fat sunflower seed; while, percent liver weight decreased significantly. Araújo *et al.* (2011) pointed out that the use of sunflower seed cake up to 15 % in broiler chickens diets did not influence growth performance and carcass yield during period 22 to 42 days of age. The inclusion of sunflower seed cake (0, 8, 16, and 24 %) in broiler chickens diets negatively influenced performance and carcass parameters (Araújo *et al.*, 2014).

Neither sunflower seed cake nor exogenous enzymes had any effect on broiler carcass parameters during the fattening period (Horvatovic *et al.*, 2015). These results are in agreement with reports from other researchers, who also did not find any response to sunflower seed cake or exogenous enzymes on carcass parameters (Tavernari *et al.*, 2008; Mushtaq *et al.*, 2009). In the work of Saleh *et al.* (2005), supplementation of cellulase to corn-soya diets of broiler chickens significantly reduced abdominal fat. However, some results suggested that enzyme addition improved carcass yield (Omojola and Adesehinwa, 2007). The use of exogenous

enzymes in poultry diets with high inclusion level of sunflower seed cake resulted in better carcass percentage (Khan *et al.*, 2006).

## **2.20 Blood Constituents of Broiler Chickens Fed Diets Containing Sunflower Seed Cake**

The inclusion of high-oleic acid sunflower seed (HOASS) in broiler chickens diet increased plasma uric acid, cholesterol and glucose concentrations by 5, 10, and 15 % respectively, and reduced serum lactate dehydrogenase and creatinine phosphokinase concentrations by 6 and 16 % respectively, compared with those fed the control diet. Moreover, the addition of 1 g/kg exogenous enzymes to broiler chickens diets containing 150 g/kg HOASS diet increased blood constituents such as plasma uric acid, calcium, serum lactate dehydrogenase, phosphokinase, total protein concentration, plasma cholesterol and glucose compared with the un-supplemented HOASS diet during the period from 4 to 21 days of age. On the other hand, the addition of 250 g/kg of HOASS in the diets caused a negative effect on blood parameters (Brenes *et al.*, 2008).

Alkaline phosphatase activity, phosphorus, calcium, glucose, triglyceride, total protein, high and low density lipoprotein concentrations were not significantly affected by inclusion of full-fat sunflower seeds at levels of 70, 140, and 210 g/kg in broiler chickens diets (Salari *et al.*, 2009). A similar trend was reported by Selvaraj and Purushothaman (2004), using the inclusion of different levels of full-fat sunflower seeds in broiler chickens diets and stated no significant effect on blood parameters of poultry. Furthermore, Cheve-Isarakul and Tangtaweewipat (1991) observed that the inclusion of sunflower seeds in poultry diets had no impact on serum cholesterol concentration. However, Rama Rao *et al.* (2004) found that the serum levels of LDL cholesterol decreased in broiler chickens receiving high fibre diets. While, the plasma parameters including total protein, albumin, globulin etc. were generally stable in the diets

which contained soybean cake replaced progressively by sunflower seed cake at 0, 25, 50 and 75 % throughout the growing period and values of these parameters were within normal benchmarks reported for healthy poultry (Adejumo and Williams, 2006).

### **2.21 Mortality Rate of Broiler Chickens Fed Diets Containing Sunflower Seed Cake**

Early research results reported by Afifi (1972) did not find any significant trend between different groups in mortality rate, when sunflower seed cake was used as a substitute for soybean cake on weight basis at levels of 0, 6, 12 and 18 % in broiler chickens diets during the growing period. Moreover, Valdivie *et al.* (1982) used sunflower seed cake at 0 and 20 % in broiler chickens diets and found that mortality rate did not significantly differ between groups. Chrappa *et al.* (1987) noted that feeding sunflower seed cake to broiler chickens had no adverse effect on mortality rate.

Salih and Taha (1989) found that mortality rate was the same in all treatment groups fed diets containing sunflower seed cake at levels of 0, 100, 200 or 400 g/kg. Also, Cheva-Isarakul and Tangtaweewipat (1991) showed that there were no significant effect of sunflower seed cake at 0, 15, 20, 25 and 30 % on mortality rate in broiler chickens. On the same context, the inclusion of sunflower seed cake in the raw or autoclaved form had no effect on mortality rate of broiler chickens (Dessouky, 1996). Ali (1999) did not observe any significant ( $P < 0.05$ ) impact due to the inclusion of sunflower seed cake in broiler chickens diets on mortality rate of chicks during the fattening period.

### **2.22 Exogenous Enzymes in Poultry Nutrition**

The complex plant materials that are commonly used as feed ingredients, such as coarsely

processed grains and high-fibre feedstuffs (e.g cereal grains, forages, crop residues, industrial by-products etc) have nutritive components that are resistant to endogenously-produced digestive enzymes. Some feed components also have anti-nutritive effects, for example phytate, which reduces bioavailability of certain minerals, and oligosaccharides and other soluble carbohydrates that increase viscosity and reduce nutrient absorption. Hence, obtaining the maximal nutritive value from such complex feedstuffs typically requires supplementation of autoenzymatic activity with alloenzymatic activity (i.e exogenously produced digestive enzymes from non-host sources) (Klasing, 1998).

Exogenous feed enzymes are typically added to animal feed to increase availability of nutrients by acting on feed components prior to or after consumption, i.e. within the gastrointestinal tract (Pariza and Cook, 2010). The effect of dietary enzyme on the animal is influenced by the type and concentration of the undesirable carbohydrate present in the feedstuff and the class and age of the livestock and poultry that consume it. Young chicks are affected to a greater degree by anti-nutritional compounds than older birds (Marquardt *et al.*, 1996). Enzymes that appear to be beneficial for non-ruminant animals are the xylanases, or more specifically the endoxylanases for the feed which contain wheat, triticale and rye and the  $\beta$ -glucanases or cellulases for those which contain barley and oats (Marquardt *et al.*, 1996).

Most commercial enzymes contain a spectrum of different enzymes including xylanases and  $\beta$ -glucanases and therefore can be used effectively with the above cereals. Nevertheless, it is essential to ensure that the enzyme preparation has the appropriate activities of the specific enzymes that are required. While supplementing poultry feed with enzymes, it is important to consider several factors as suggested by Marquardt *et al.* (1996). These factors include (i) the enzyme supplement must contain proper spectrum of enzymes, so that anti-nutritive effects of

target substrate will be neutralized. (ii) different cereals contain different amounts of enzyme-sensitive anti-nutritional factor. Therefore, the response to enzyme treatment may vary within a given cereal (i.e. barley and probably wheat). (iii) the outcome of enzyme supplementation is affected by grade, age and strain of poultry. The responses in swine are usually less dramatic than those of poultry and have not been clearly established. (iv) the activity of the enzymes must not be affected by processing or by the low pH (<4) or digestive enzymes in the gastrointestinal tract.

Ruminant animals (e.g. cattle and sheep) have the advantage of alloenzymatic digestion provided by rumen microflora, which enables ruminants to obtain nutrients from complex feed matrices that are not made available through autoenzymatic digestion (Pariza and Cook, 2010). Pigs, poultry and other monogastric animals lack the alloenzymes from rumen microflora, so for these species to derive optimal nutrient benefit from complex feed matrices, it is necessary to provide added enzyme supplementation. Enzymes may act during feed processing, while feed is present in storage and feeder bins, and also following ingestion by acting within the digestive system itself (Pariza and Cook, 2010). Therefore, the main objective of exogenous enzyme supplementation is to improve feed efficiency for monogastric animals like poultry. Some of the enzymes that have been used over the past several years or have potential for use in the feed industry include cellulase ( $\beta$ -glucanases), xylanases and associated enzymes, phytase, protease, lipase and galactosidase (Khusheeba and Sajid, 2013). For instance the combination of xylanase and  $\beta$ -glucanase has proved to be beneficial in terms of growth increment in poultry. Pettersson and Aman (2007) tested the inclusion level of a cocktail enzyme, consisting of xylanase and  $\beta$ -glucanase to an unpelleted poultry diet containing rye and wheat which resulted in a significant increase in body-weight and feed intake.

Recently, considerable interest has been shown in the use of phytase as a feed additive, as it not only increases the availability of phosphate in feed but also reduces environmental pollution (Pariza and Cook, 2010). Several other enzyme products are currently being evaluated in the feed industry, including protease to enhance protein digestion, lipases to enhance lipid digestion,  $\beta$ -galactosidases to neutralize certain anti-nutritive factors in non cereal feedstuffs, and amylase to assist in the digestion of starch in early-weaned animals (Marquardt, 1997).

### **2.22.1 Benefits of exogenous enzyme in poultry nutrition**

The rationale behind the use of enzyme technology is to improve the nutritive value of feedstuffs. All animals use enzymes in the digestion of feed; either produced by the animal itself or by the microbes present in the digestive tract. However, the digestive process is nowhere near 100 % efficient. For example, swine are unable to digest 15 - 25 % of the feed they eat (Khusheeba and Sajid, 2013). Therefore, the supplementation of the animal feed with suitable enzymes to increase the efficiency of digestion can be seen as an extension of the animal's own digestion process (Pariza and Cook, 2010). In many animal production systems, feed is the biggest single cost and profitability depends on the relative cost and nutritive value of the feeds available. Often, the limiting factor when formulating rations is the animal's ability to digest different constituent parts of the feed material differently, particularly fibre (Khusheeba and Sajid, 2013).

Despite recent advances, the nutritional value of feedstuffs is not achieved at the animal level. The inefficiency in the utilization of nutrients will result in an extra cost to the farmer (Sheppy, 2003). Thus, the feeds need to be supplemented with exogenous enzymes. The four main reasons for using exogenous enzymes in animal feed include (i) to breakdown anti-nutritional factors that

are present in many feed ingredients. Many of these substances are not susceptible to digestion by the animal's endogenous digestive enzymes, or can interfere with the normal digestion process, causing poor performance and digestive upsets (Sheppy, 2003). (ii) to increase the availability of starches, proteins, and minerals that are either enclosed within the fibre-rich cell wall or not accessible to the animal's own digestive enzymes, or bound up in a chemical form that the animal is unable to digest (e.g. phosphorus as phytic acid). (iii) to break down specific chemical bonds in feed materials that are not usually broken down by animal's own enzymes, thus releasing more nutrients. (iv) to supplement the enzymes produced by young animals, because endogenous enzyme production may be inadequate as a result of their immature digestive system (Sheppy, 2003).

In addition to improving diet utilization, enzyme supplementation can reduce the variability in nutritive value between feedstuffs and improving the accuracy of feed formulations (Khusheeba and Sajid, 2013). Experimental trials have shown that ensuring feed consistency in this way can increase the uniformity of groups of animals, thus aiding management and improving profitability. The general health status of animals can also be indirectly influenced, resulting in few non-specific digestive upsets that are frequently provoked by the fibre components in the feed (Sheppy, 2003). The inclusion of feed enzymes in poultry diets plays an important role in enhancing nutrient utilization and performance by counteracting the negative influence of targeted substrates. The role of exogenous enzymes capable of degrading non starch polysaccharides (NSP) in broiler based diets on 'viscous' grains, including wheat and barley has been elucidated by Bedford and Schulze (1998).

Research work suggested that the negative effects of NSPs can be overcome by dietary modifications through dietary supplementation with suitable exogenous enzyme preparations

(Creswell, 1994). The addition of enzymes to the diet to breakdown the NSPs, decreases intestinal viscosity and eventually improve the digestibility of nutrients by improving gut performance, feed efficiency, manure quality and increase the utilisation of cost effective alternative feed ingredients. NSP are also linked to other compounds such as peptides and proteins that can make the use of a purified enzyme designed to degrade NSP less effective.

In order to obtain maximum benefits of enzyme supplementation in poultry feeds, it is necessary to ensure that the enzymes are chosen on the basis of the feed composition. Simply put; the enzyme must be matched to the substrate. Enzyme cocktails containing more than one enzyme often improve performance compared to pure, single enzymes, assuming that cost considerations are not ignored (Fengler and Marquardt, 1988; Choct and Annison,1990). This is due to the fact that feedstuffs are complex compounds containing protein, fat, fibre and other complex carbohydrates. Merely targeting a specific substrate such as Betaglucan may not provide maximal benefits since layers of other substrates may inherently protect some of the Betaglucan. For example, Betaglucons and arabinoxylans may be bound to peptide or protein moieties in the cell wall of the feedstuff. Therefore, enzymes capable of hydrolyzing protein may enhance the activity of pentosanases and betaglucanases.

### **2.22.2 Maxigrain<sup>®</sup> supplementation in poultry diets**

Maxigrain<sup>®</sup> is a unique blend of concentrated digestive enzymes used in premixes and animal feed to improve profitability by maximizing nutrient release. Maxigrain<sup>®</sup> is a heat-stable dry enzyme blend. This is of particular importance, given the more aggressive feed processing conditions used today in many animal feedmills. Maxigrain<sup>®</sup> is a full-spectrum, highly concentrated blend of a comprehensive range of microbial-based digestive enzymes. Its unique

proprietary formula of enzyme blends provides supplementary feed enzymes, which help to degrade some of the main anti-nutritional factors (e.g. phytates and non-starch polysaccharides) present in animal feeds.

**Composition:** Maxigrain<sup>®</sup> contains the following high potency multiple digestive enzymes to enhance feed digestion, maximize feed utilization and reduce animal waste: Xylanase 10000 IU, Betaglucanase 200 IU, Cellulase 10000 IU, Phytase 2500 FTU. It also contains *Aspergillus oryzae*, *Aspergillus niger* and *Bacillus subtilis* fermentations extracts which were added to work in synergy with the animal's digestive system in breaking down layers of the feed that were previously inaccessible through digestion. This exposes more nutrient rich layers for the animal to digest: such as amino acids, energy, calcium, and phosphorus. The enzymes have a wide pH range, long-term stability and high temperature tolerance with high levels of enzymes activity enabling Maxigrain<sup>®</sup> to be successfully supplemented to animal feeds with excellent results under wide ranging conditions around the world.

**Directions for use:** 100 g/ton of feed.

**Packaging:** 100g sachets and 25 kg bag.

**Benefits:** Maxigrain<sup>®</sup> help optimize the use of non conventional feed ingredients as it improves digestion, nutrient absorption for enhanced performance and proven economic and environmental benefits. Maxigrain<sup>®</sup> also helps to compensate for the animal's poor diet with an observed reduction of undigested grains in faeces.

**Storage:** Store in cool and dry place with no direct sunlight. Maxigrain<sup>®</sup> is stable for 2 years in a dry and cool place.

## **CHAPTER THREE**

### **3.0 MATERIALS AND METHODS**

#### **3.1 Experimental Site**

Two feeding trials were conducted at the Poultry Unit of the Teaching and Research Farm of the Department of Animal Science, Faculty of Agriculture, Ahmadu Bello University, Zaria. It is located within the Northern Guinea Savannah Zone on latitude 11° 9'57.60"N and Longitude 7°38'3.48"E at an altitude of 671m above sea level. The minimum and maximum temperature ranges between 26<sup>0</sup>C and 36<sup>0</sup>C depending on the season while the mean relative humidity during the dry and wet seasons are 21 and 72 % (IARMS, 2019).

#### **3.2 Source of Sunflower Seed Cake, Processing and Procurement of Maxigrain<sup>®</sup>**

Dehulled mechanically extracted sunflower seed cake was sourced from the Product Development Research Programme of Institute for Agricultural Research (IAR), Ahmadu Bello University, Zaria. The test ingredient was milled using a hammer mill, packed in bags and properly stored in a cool and dry place prior to the commencement of the two feeding trials. Representative samples were obtained from each bag, pooled together and taken to the laboratory for proximate and chemical analysis.

Exogenous commercial enzyme (Maxigrain<sup>®</sup>) was purchased from Animal Care feed store in Kaduna metropolis, Kaduna State, Nigeria.

### 3.3 Proximate and Chemical Analysis of Sunflower Seed Cake

Sunflower seed cake samples were analyzed for proximate composition according to the methods described by A.O.A.C (2006) at the Product Development Research Programme of Institute for Agricultural Research (IAR), Ahmadu Bello University, Zaria. The proximate composition parameters that were determined include the dry matter (% DM), crude protein (% CP), crude fibre (% CF), ether extract (% EE), ash (% Ash) and nitrogen free extract (% NFE). Metabolizable energy (ME) content of sunflower seed cake was estimated based on the equation described by Ponzenga (1985):

$$\text{ME (kcal/kg)} = 37 \times \% \text{ CP} + 81.81 \times \% \text{ EE} + 35.5 \times \% \text{ NFE},$$

Anti-nutritional factors were determined for the presence and levels of tannin, phenols, alkaloids, phytates, trypsin inhibitors and flavonoids according to the methods described by Kakade *et al.* (1974), Earp *et al.* (1981), Sutardi and Buckle (1985) and A.O.A.C (2006), .

The essential amino acid profile of sunflower seed cake sample were determined using the methods described by Benitez (1989) and Maria *et al.* (2004) at the Biochemical Laboratory, Department of Zoology, University of Jos. The samples were dried to a constant weight, defatted, hydrolyzed, evaporated in a rotary evaporator and loaded into the Applied Biosystems PTH Amino Acid Analyzer.

### 3.4 FEEDING TRIAL 1: Response of Broiler Chickens Fed Diets Containing Graded Levels of Sunflower Seed Cake

A feeding trial was conducted to evaluate the effect of feeding diets containing graded levels of sunflower seed cake on the growth performance, nutrients digestibility, haematological and

serum biochemical parameters and carcass characteristics of broiler chickens. The trial was in two phases, the starter phase which lasted for 1 - 4 weeks and the finisher phase which lasted for 6 - 9 weeks.

#### **3.4.1 Experimental diets**

Five treatment diets were formulated with graded levels of sunflower seed cake incorporated as a substitute for groundnut cake in broiler starter and finisher diets at 0, 5, 10, 15, and 20 kg/100kg diet to meet the nutrient requirements of the birds according to recommendations by Aduku (2012). The laboratory result of the proximate composition of the test ingredient was also used for dietary formulations.

#### **3.4.2 Experimental design and management of birds at the starter phase (1 - 4 weeks)**

A total of 300 unsexed Cobb 500 day-old broiler chicks were purchased from Chikun hatchery at Kaduna State, north-western Nigeria. The birds were randomly assigned to 5 dietary treatment groups with 60 birds per treatment and replicated 3 times with 20 birds per replicate in a Completely Randomized Design (CRD).

The birds were housed and managed on deep litter system with partitioned pens and heat and light were provided throughout the brooding period using 200W bulbs and charcoal pots while the side walls openings were covered with polythene sheets to conserve heat in the brooding pens. The birds were fed broiler starter diets containing graded levels of sunflower seed cake at 0, 5, 10, 15, and 20 kg/100kg diet as 0 kg sunflower seed cake served as the control diet. Table 3.1 shows the ingredients composition of the broiler starter diets. All necessary routine management, vaccinations and medications were carried out as feeds and clean drinking water

**Table 3.1: Composition of Broiler Starter Diets Containing Graded Levels of Sunflower Seed Cake (1-4weeks)**

<b>Ingredients</b>	<b>Dietary Levels of Sunflower Seed Cake (kg/100kg diet)</b>				
	<b>0</b>	<b>5</b>	<b>10</b>	<b>15</b>	<b>20</b>
Maize	56.00	55.00	54.00	53.00	52.00
Groundnut cake	26.00	22.00	18.00	14.00	10.00
Soya bean meal	13.60	13.60	13.60	13.60	13.60
Sunflower seed cake	0.00	5.00	10.00	15.00	20.00
Bone ash	3.00	3.00	3.00	3.00	3.00
Limestone	0.30	0.30	0.30	0.30	0.30
Common salt	0.25	0.25	0.25	0.25	0.25
Lysine	0.30	0.30	0.30	0.30	0.30
Methionine	0.30	0.30	0.30	0.30	0.30
Biomix premix *	0.25	0.25	0.25	0.25	0.25
<b>Total</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>
<b>Calculated Analysis</b>					
ME (Kcal/kg)	2911.60	2887.68	2863.76	2839.84	2815.92
Crude protein (%)	23.27	23.24	23.21	23.15	23.15
Crude fibre (%)	5.19	5.20	5.20	5.21	5.21
Ether extract (%)	2.43	3.10	3.79	4.90	5.15
Calcium (%)	1.24	1.26	1.27	1.28	1.29
Av phosphorus (%)	0.67	0.58	0.57	0.56	0.56
Lysine (%)	1.13	1.14	1.14	1.15	1.15
Methionine (%)	0.61	0.61	0.62	0.64	0.65
Feed cost (₦/kg)	127.50	126.10	124.70	123.40	121.90

\*Biomix premix supplied the following per kg of diet: Vit. A, 10000 I.U; Vit. D, 2000 I.U; Vit K, 2mg; Vit. B1 (Thiamine), 1.8mg; Vit B2 (Riboflavin), 5.5mg; Vit B6 (Pyridoxine), 0.3mg; Vit B12, 0.015mg; Pantothenic acid, 7.5mg; Folic acid, 0.75mg; Niacin, 27.5mg; Biotin, 0.6mg; Choline chloride, 300mg; Cobalt, 0.2mg; Copper, 3mg; Iodine, 1mg; Iron, 20mg; Manganese, 40mg; Selenium, 0.2mg; Zinc, 30mg; Antioxidant, 1.25mg; M.E = Metabolisable Energy,

were offered *ad libitum* during the starter phase which lasted for 4 weeks.

### **3.4.3 Experimental design and management of birds at the finisher phase (6 - 9 weeks)**

At the end of the starter phase, all the birds were pooled together according to their treatment groups and fed a common diet for 5 days after which birds of averagely equal weights were randomised and re-allotted to their various replicates for the commencement of the finisher phase. A total of 240 broiler finisher chickens were used for the finisher phase. The birds were assigned to 5 dietary treatments groups with 48 birds per treatment and replicated 3 times with 16 birds per replicate in a Completely Randomized Design (CRD). The birds were fed broiler finisher diets containing graded levels of sunflower seed cake at 0, 5, 10, 15, and 20 kg/100kg diet as 0 kg sunflower seed cake served as the control diet. Table 3.2 shows the ingredients composition of the broiler finisher diets. All necessary routine management and medications were carried out as feeds and clean drinking water were offered *ad libitum* during the finisher phase which lasted for 6 - 9 weeks.

### **3.4.4 Growth performance parameters measured**

The birds initial and final weights were taken at the beginning and at the end of both starter and finisher phases of the feeding trial. Feed intake and body weight gain were measured on weekly basis to obtain average weekly feed intake and average weekly body weight gain per bird. Feed conversion ratio and feed cost per kg gain were calculated for both starter and finisher phases while mortality was recorded as it occurred.

Growth performance parameters were calculated using the formulas below;

$$\text{Feed intake (g)} = \text{Feed supplied (g)} - \text{Left over (g)}$$

**Table 3.2: Composition of Broiler Finisher Diets Containing Graded Levels of Sunflower Seed Cake (6 - 9 weeks)**

<b>Ingredients</b>	<b>Graded Levels of Sunflower Seed Cake (kg/100kg diet)</b>				
	<b>0</b>	<b>5</b>	<b>10</b>	<b>15</b>	<b>20</b>
Maize	58.00	57.00	56.00	55.40	54.60
Groundnut cake	23.00	19.00	15.00	11.00	7.00
Soya bean meal	7.00	7.00	7.00	7.00	7.00
Sunflower seed cake	0.00	5.00	10.00	15.00	20.00
Maize offal	7.60	7.60	7.60	7.20	7.00
Bone ash	3.00	3.00	3.00	3.00	3.00
Limestone	0.30	0.30	0.30	0.30	0.30
Common salt	0.25	0.25	0.25	0.25	0.25
Lysine	0.30	0.30	0.30	0.30	0.30
Methionine	0.30	0.30	0.30	0.30	0.30
Biomix premix *	0.25	0.25	0.25	0.25	0.25
<b>Total</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>
<b>Calculated Analysis</b>					
ME (Kcal/kg)	3012.96	3009.04	3005.12	3005.34	3004.49
Crude protein (%)	20.03	20.00	20.05	20.04	20.00
Crude fibre (%)	5.21	7.54	5.22	5.19	5.18
Ether extract (%)	2.15	2.83	3.52	4.20	4.89
Calcium (%)	1.23	1.24	1.25	1.27	1.28
Av phosphorus (%)	0.65	0.65	0.64	0.63	0.62
Lysine (%)	0.95	0.96	0.96	0.97	0.97
Methionine (%)	0.57	0.58	0.60	0.61	0.62
Feed cost (₦/kg)	118.80	117.40	116.00	114.70	113.40

\*Biomix premix supplied the following per kg of diet: Vit. A, 10000 I.U; Vit. D, 2000 I.U; Vit K, 2mg; Vit. B1 (Thiamine), 1.8mg; Vit B2 (Riboflavin), 5.5mg; Vit B6 (Pyridoxine), 0.3mg; Vit B12, 0.015mg; Pantothenic acid, 7.5mg; Folic acid, 0.75mg; Niacin, 27.5mg; Biotin, 0.6mg; Choline chloride, 300mg; Cobalt, 0.2mg; Copper, 3mg; Iodine, 1mg; Iron, 20mg; Manganese, 40mg; Selenium, 0.2mg; Zinc, 30mg; Antioxidant, 1.25mg; M.E = Metabolisable Energy,

Weight gain (g) = Final weight (g) – Initial weight (g)

$$\text{Feed Conversion Ratio} = \frac{\text{Feed intake (g)}}{\text{Weight gained (g)}}$$

Feed cost per kg gain (₦/kg) = Feed cost (₦/kg) × Feed Conversion Ratio

$$\text{Mortality (\%)} = \frac{\text{Number of dead birds}}{\text{Total number of birds}} \times 100$$

### 3.4.5 Digestibility study

Digestibility study was conducted at the end of the finisher phase of the feeding trial. Three birds were randomly selected from each treatment and kept in individual metabolic cage for faecal collection. Three days adjustment period was observed as the birds were fasted overnight prior to the commencement of the trial proper which lasted for 7 days. A measured quantity of the treatment diets were offered and the leftover feed weighed to determine average feed intake (g/bird) for each replicate while clean drinking water was provided *ad libitum*. Faecal droppings were collected daily and sun dried for 72 hours. The dried faecal samples alongside the feed samples were analyzed for proximate composition according to the method described by A.O.A.C (2006) at the Product Development Research Programme of Institute for Agricultural Research (IAR), Ahmadu Bello University. Zaria.

Apparent nutrient digestibility were determined for dry matter (% DM), crude protein (% CP), crude fibre (% CF), ether extract (% EE) and nitrogen free extract (% NFE) using the formula;

$$\% \text{ Digestibility of Nutrient} = \frac{\text{Amount of nutrient intake} - \text{Amount of nutrient output}}{\text{Amount of nutrient intake}} \times 100$$

Amount of nutrient intake (g) = feed intake × nutrient in diet

Amount of nutrient output (g) = faecal output × nutrient in faeces

### **3.4.6 Haematological and serum biochemical profile**

At the end of the finisher phase of the feeding trial, 2mls of blood samples were collected from 3 birds per treatment replicates into sterilised labelled sample bottles containing ethylene diamine tetra acetic acid (EDTA) as anticoagulant for the determination of haematological parameters which include Packed Cell Volume (PCV) which was determined by the micro haematocrit method, haemoglobin (Hb) concentration which was determined photometrically at the wavelength of 540nm, the erythrocytes (RBC) and leucocytes (WBC) counts were determined using the improved Neubauer haemocytometer and their differential counts were determined by the thin slide method (Jain, 1993). Another 2mls of blood samples were collected into sterilized labelled sample bottles without anticoagulant. The blood samples were allowed to clot and then centrifuged, serum was separated and stored at -20°C and analysed at the Clinical Pathology Laboratory, Faculty of Veterinary Medicine, Ahmadu Bello University, Zaria for the determination of parameters related to serology, lipid profile and stress markers according to the methods described by Jain (1993).

### **3.4.7 Carcass evaluation**

At the end of the feeding trial, 3 birds were randomly selected from each treatment group representing the average weight of the replicates and used for carcass analysis. The birds were fasted overnight to clear the intestinal contents thereby emptying the crop and residual ingesta but water was provided *ad-libitum*. The next morning, the selected birds were weighed to obtain live body weight before slaughtering by severing the jugular vein using a sharp knife and allowed to bleed completely. The slaughtered birds were scalded in hot water to facilitate

defeathering, dressing and evisceration. The head, neck, shank, and viscera were removed to get the dressed weight while dressing percentage was calculated using the formula:

$$\text{Dressing percentage (D \%)} = \frac{\text{Dressed weight}}{\text{Live weight}} \times 100$$

Prime cut parts weights such as back, neck, breast, wings, thighs and drumsticks were measured and expressed as percentage of dressed weight while internal organs weights such as heart, liver, full and empty gizzard, spleen, kidney, lungs, intestinal weight and abdominal fat were measured and expressed as percentage of live weight.

### **3.4.8 Economics of production**

The cost benefit of production of broiler chickens fed diets containing graded levels of sunflower seed cake were determined using gross margin and return per Naira invested at the end of the feeding trail. The gross margin of an enterprise is the difference between total revenue from production and variable cost of production and was used as a measure of profitability when fixed cost of the enterprise is negligible (Olukosi and Erahbor, 1988). The prevailing market prices of feed ingredients (kg) and other variables were used to calculate feed cost (₦/kg), cost of day-old chicks (₦/bird), cost of vaccines and and drugs (₦/dose) at the time the feeding trial was conducted. The following formulas were used:

$$\text{Gross Margin (₦)} = \text{revenue} - \text{total variable cost}$$

Where

$$\text{Revenue (₦)} = \text{average weight of bird (kg)} \times \text{cost per kg of live bird (₦/kg)} \times \text{number of birds}$$

Number of Birds = 300 - mortality

Total Variable Cost (₦) =  $\Sigma$  (cost of feeding + water + brooding + medications + wood shavings + labour + maintenance + transportation)

Cost of Feeding (₦/kg) = feed cost (₦/kg)  $\times$  average feed intake (kg/bird)  $\times$  number of birds

Return per Naira Invested =  $\frac{\text{Revenue}}{\text{Total Variable Cost}}$

### 3.4.9 Statistical analysis

All data generated were subjected to analysis of variance using the General Linear Model (GLM) procedure of Statistical Analysis System (SAS, 2008). Significant differences between treatment means were compared using Tukey's Studentized Range (HSD) Test. Differences between treatment means were considered significant at  $P < 0.05$ .

#### 3.4.9.1 Experimental model

The model equation for the first<sup>t</sup> feeding trial (Response of Broiler Chickens Fed Diets Containing Graded Levels of Sunflower Seed Cake).

$$Y_{ij} = \mu + S_i + e_{ij}$$

Where,  $Y_{ij}$  = performance of the  $j^{\text{th}}$  broiler fed the  $i^{\text{th}}$  graded level of sunflower seed cake

$\mu$  = overall mean

$S_i$  = effect of the  $i^{\text{th}}$  graded levels of sunflower seed cake

$e_{ij}$  = random error

### **3.5 FEEDING TRIAL 2: Influence of Maxigrain<sup>®</sup> Supplementation on Graded Levels of Sunflower Seed Cake in Broiler Chickens Diets**

The second feeding trial was conducted to evaluate the influence of Maxigrain<sup>®</sup> supplementation on graded levels of sunflower seed cake on growth performance, nutrients digestibility, haematological and serum biochemical parameters and carcass characteristics of broiler chickens. The trial was in two phases, the starter phase which lasted for 1 - 4 weeks and the finisher phase which lasted for 5 - 8 weeks.

#### **3.5.1 Experimental diets**

- Diet 1 = 0 kg/100kg inclusion of SFSC without maxigrain<sup>®</sup> supplementation
- Diet 2 = 5 kg/100kg inclusion of SFSC with maxigrain<sup>®</sup> supplementation
- Diet 3 = 10 kg/100kg inclusion of SFSC with maxigrain<sup>®</sup> supplementation
- Diet 4 = 15 kg/100kg inclusion of SFSC with maxigrain<sup>®</sup> supplementation
- Diet 5 = 20 kg/100kg inclusion of SFSC with maxigrain<sup>®</sup> supplementation

#### **3.5.2 Experimental design and management of birds at the starter phase (1 - 4 weeks)**

A total of 300 unsexed Cobb 500 day-old broiler chicks were used for the experiment. The birds were randomly assigned to 5 dietary treatment groups with 60 birds per treatment and replicated 3 times with 20 birds per replicate in a Completely Randomized Design (CRD).

The birds were housed and managed on deep litter system with partitioned pens and heat and light were provided throughout the brooding period using 200W bulbs and charcoal pots while the side walls openings were covered with polythene sheets to conserve heat in the brooding pens. The birds were fed broiler starter diets supplemented with maxigrain<sup>®</sup> at 0.01 kg/100kg

**Table 3.3: Composition of Broiler Starter Diets Supplemented with Maxigrain® on Graded Levels of Sunflower Seed Cake (1 - 4 weeks)**

Ingredients	Graded Levels of Sunflower Seed Cake (kg/100kg diet)				
	0	5	10	15	20
Maize	56.00	55.00	54.00	53.00	52.00
Groundnut cake	26.00	22.00	18.00	14.00	10.00
Soya bean meal	13.60	13.60	13.60	13.60	13.60
Sunflower seed cake	0.00	5.00	10.00	15.00	20.00
Bone ash	3.00	3.00	3.00	3.00	3.00
Limestone	0.30	0.30	0.30	0.30	0.30
Common salt	0.25	0.25	0.25	0.25	0.25
Lysine	0.30	0.30	0.30	0.30	0.30
Methionine	0.30	0.30	0.30	0.30	0.30
Biomix premix *	0.25	0.25	0.25	0.25	0.25
Maxigrain®	0.00	0.01	0.01	0.01	0.01
<b>Total</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>
<b>Calculated Analysis</b>					
ME (Kcal/kg)	2911.60	2887.68	2863.76	2839.84	2815.92
Crude protein (%)	23.27	23.24	23.21	23.15	23.15
Crude fibre (%)	5.19	5.20	5.20	5.21	5.21
Ether extract (%)	2.43	3.10	3.79	4.90	5.15
Calcium (%)	1.24	1.26	1.27	1.28	1.29
Av phosphorus (%)	0.67	0.58	0.57	0.56	0.56
Lysine (%)	1.13	1.14	1.14	1.15	1.15
Methionine (%)	0.61	0.61	0.62	0.64	0.65
Feed cost (₦/kg)	128.10	126.70	125.30	123.90	122.50

\*Biomix premix supplied the following per kg of diet: Vit. A, 10000 IU; Vit. D, 2000 IU; Vit K, 2mg; Vit. B1 (Thiamine), 1.8mg; Vit B2 (Riboflavin), 5.5mg; Vit B6 (Pyridoxine), 0.3mg; Vit B12, 0.015mg; Pantothenic acid, 7.5mg; Folic acid, 0.75mg; Niacin, 27.5mg; Biotin, 0.6mg; Choline chloride, 300mg; Cobalt, 0.2mg; Copper, 3mg; Iodine, 1mg; Iron, 20mg; Manganese, 40mg; Selenium, 0.2mg; Zinc, 30mg; Antioxidant, 1.25mg; M.E = Metabolisable Energy,

Enzyme name: Maxigrain®

Description: Powder (Multienzyme for optimal poultry nutrition).

Dosage: 100 g/ton of feed.

Presentation: 100g sachets & 25 kg bag.

Composition: Xylanase 10000 IU, Beta glucanase 200 IU, Cellulase 10000 IU, Phytase 2500 FTU.

diet as recommended by the manufacturer on graded levels of sunflower seed cake at 0, 5, 10, 15, and 20 kg/100kg diet and 0 kg sunflower seed cake without maxigrain<sup>®</sup> supplementation served as the control diet. Table 3.3 shows the ingredients composition of the broiler starter diets. All necessary routine management, vaccinations and medications were carried out as feeds and clean drinking water were offered *ad libitum* throughout the starter phase which lasted for 4 weeks.

### **3.5.3 Experimental design and management of birds at the finisher phase (5 - 8 weeks)**

A total of 285 broiler finisher chickens were used for the finisher phase. The birds were assigned to 5 dietary treatments groups with 57 birds per treatment and replicated 3 times with 19 birds per replicate in a Completely Randomized Design (CRD). The birds were fed broiler finisher diets supplemented with maxigrain<sup>®</sup> at 0.01 kg/100kg diet as recommended by the manufacturer on graded levels of sunflower seed cake at 0, 5, 10, 15, and 20 kg/100kg diet and 0 kg sunflower seed cake without maxigrain<sup>®</sup> supplementation served as the control diet. Table 3.4 shows the ingredients composition of the broiler finisher diets. All necessary routine management and medications were carried out as feeds and clean drinking water were offered *ad libitum* throughout the finisher phase which lasted for 5 - 8 weeks.

### **3.5.4 Growth performance parameters measured**

Same as in feeding trial 1.

### **3.5.5 Digestibility study**

Same as in feeding trial 1.

**Table 3.4: Composition of Broiler Finisher Diets Supplemented with Maxigrain® on Graded Levels of Sunflower Seed Cake (5 - 8 weeks)**

Ingredients	Graded Levels of Sunflower Seed Cake (kg/100kg diet)				
	0	5	10	15	20
Maize	58.00	57.00	56.00	55.40	54.60
Groundnut cake	23.00	19.00	15.00	11.00	7.00
Soya bean meal	7.00	7.00	7.00	7.00	7.00
Sunflower seed cake	0.00	5.00	10.00	15.00	20.00
Maize offal	7.60	7.60	7.60	7.20	7.00
Bone ash	3.00	3.00	3.00	3.00	3.00
Limestone	0.30	0.30	0.30	0.30	0.30
Common salt	0.25	0.25	0.25	0.25	0.25
Lysine	0.30	0.30	0.30	0.30	0.30
Methionine	0.30	0.30	0.30	0.30	0.30
Biomix premix *	0.25	0.25	0.25	0.25	0.25
Maxigrain®	0.00	0.01	0.01	0.01	0.01
<b>Total</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>
<b>Calculated Analysis</b>					
ME (Kcal/kg)	3012.96	3009.04	3005.12	3005.34	3004.49
Crude protein (%)	20.03	20.00	20.05	20.04	20.00
Crude fibre (%)	5.21	7.54	5.22	5.19	5.18
Ether extract (%)	2.15	2.83	3.52	4.20	4.89
Calcium (%)	1.23	1.24	1.25	1.27	1.28
Av phosphorus (%)	0.65	0.65	0.64	0.63	0.62
Lysine (%)	0.95	0.96	0.96	0.97	0.97
Methionine (%)	0.57	0.58	0.60	0.61	0.62
Feed cost (₦/kg)	119.37	117.97	116.57	115.33	114.01

\*Biomix premix supplied the following per kg of diet: Vit. A, 10000 IU; Vit. D, 2000 IU; Vit K, 2mg; Vit. B1 (Thiamine), 1.8mg; Vit B2 (Riboflavin), 5.5mg; Vit B6 (Pyridoxine), 0.3mg; Vit B12, 0.015mg; Pantothenic acid, 7.5mg; Folic acid, 0.75mg; Niacin, 27.5mg; Biotin, 0.6mg; Choline chloride, 300mg; Cobalt, 0.2mg; Copper, 3mg; Iodine, 1mg; Iron, 20mg; Manganese, 40mg; Selenium, 0.2mg; Zinc, 30mg; Antioxidant, 1.25mg; M.E = Metabolisable Energy, Enzyme name: Maxigrain®  
Description: Powder (Multienzyme for optimal poultry nutrition).  
Dosage: 100 g/ton of feed.  
Presentation: 100g sachets & 25 kg bag.  
Composition: Xylanase 10000 IU, Beta glucanase 200 IU, Cellulase 10000 IU, Phytase 2500 FTU.

### **3.5.6 Haematological and serum biochemical profile**

Same as in feeding trial 1

### **3.5.7 Carcass evaluation**

Same as in feeding trial 1.

### **3.5.8 Economics of production**

Same as in feeding trial 1.

### **3.5.9 Statistical analysis:**

Same as in feeding trial 1.

#### ***3.5.9.1 Experimental model***

The model equation for the second feeding trial (Influence of Maxigrain<sup>®</sup> Supplementation on Graded Levels of Sunflower Seed Cake in Broiler Chickens Diets).

$$Y_{ij} = \mu + S_i + E_k (S + E) + e_{ijk}$$

Where,  $Y_{ij}$  = performance of the  $j^{\text{th}}$  broiler fed the  $i^{\text{th}}$  graded level of sunflower seed cake

$\mu$  = overall mean

$S_i$  = effect of the  $i^{\text{th}}$  graded levels of sunflower seed cake

$E_k$  = fixed effect of maxigrain<sup>®</sup> supplementation

$e_{ijk}$  = random error

## CHAPTER FOUR

### 4.0 RESULTS AND DISCUSSION

#### 4.1 Proximate Composition of Sunflower Seed Cake

The result of proximate composition of sunflower seed cake is presented in Table 4.1. The result showed that the dry matter content of sunflower seed cake(90.22 %) in this study was lower than 91.48 % reported by Liu *et al.* (2015) but higher than 90.20 % reported by Senkoylu and Dale (2006). Crude protein content of sunflower seed cakewas found to be 37.19 %, which was higher than 30.00 % reported by Nassiri *et al.* (2012). The result implies that sunflower seed cake is a good source of protein. Rostagno *et al.* (2005) reported 23.00 % crude fibre for sunflower seed cake, which is higher than 10.10 % obtained in this study. Fibre helps to maintain the health of the gastrointestinal tract. The presence of an adequate level of fibre in sunflower seed cake reveals that the seed cake can be utilized as a better source of fibre for animals. Liu *et al.* (2015) also reported ether extract content of 3.11 % for sunflower seed cakewhich is lower than 19.55 % obtained in this study.

The ash content of sunflower seed cake(6.07 %) is lower than 7.00 % reportedby San Juan and Villamide (2000). The nitrogen free extract of 27.09 % in this study implies that sunflower seed cake has fair energy content. Differences in the values observed in this study with works of other researchers may be attributed to genetic differences (cultivar differences), processing methods, time of seeds harvest, environmental factors as well as agronomic practices, i.e differences in crop and soil management practices.

**Table 4.1: Proximate Composition of Sunflower Seed Cake**

<b>Proximate Parameters</b>	<b>SFSC (%)</b>	<b>GNC (%)</b>
Dry matter	90.22±0.38	90.00
Crude protein	37.19±0.49	42.00
Crude fibre	10.10±0.42	12.00
Ether extract	19.55±0.35	7.30
Ash	6.07±0.02	5.12
Nitrogen free extract	27.09±0.18	33.58

SFSC = Sunflower Seed Cake values are mean of 2 samples ± standard deviation; GNC = Groundnut Cake values are table values by NRC (1994).

#### **4.2 Anti-nutritional Factors in Sunflower Seed Cake**

The result of anti-nutritional factors in sunflower seed cake is presented in Table 4.2. The presence and levels of tannins (1.04 mg/100g), phenols (2.35 mg/100g), alkaloids (3.08 mg/100g), phytates (0.16 mg/100g), trypsin inhibitors (0.89 mg/100g) and flavonoids (65.56 mg/100g) observed in this study were low due to mechanical pressing of sunflower seeds at high temperature during sunflower oil extraction. The observations agreed with the findings of Shu'aibu (2014) who reported that heating improved the nutritional value of seeds and also destroyed all the heat labile anti-nutrients that are inherent in the seeds. Similarly, Udensi *et al.* (2008) also confirmed that processing of seeds (toasting, mechanical pressing and autoclaving) leads to products with reduced anti-nutritional contents and consequently increase some nutrients.

#### **4.3 Essential Amino Acids Composition of Sunflower Seed Cake**

The result of essential amino acids composition of sunflower seed cake is presented in Table 4.3. The result shows the levels of the four commonly limiting essential amino acids to be 1.63, 2.24, 3.00, and 1.29 g/100g for lysine, methionine, threonine and tryptophan respectively. These values were slightly higher compared to those reported by Senkoylu and Dale (2006). The lysine and methionine contents of sunflower seed cake is less than that of groundnut cake. Thus, lysine and methionine were supplemented in the experimental diets for this study. The same result was reported by Liu *et al.* (2015) who stated that the supplementation of lysine and methionine improved the nutritive value of sunflower seed cake.

The result also revealed other essential amino acids in sunflower seed cake to include arginine 4.07 g/100g, histidine 2.24 g/100g, leucine 3.32 g/100g, and phenylalanine 2.35 g/100g which

**Table 4.2: Anti-nutritional Factors in Sunflower Seed Cake**

<b>Anti-nutrients</b>	<b>(mg/100g)</b>
Tannins	1.04±0.33
Phenols	2.35±0.43
Alkaloids	3.08±0.12
Phytates	0.16±0.42
Trypsin inhibitors	0.89±0.62
Flavonoids	65.56±1.02

Values are mean of 2 samples± standard deviation

**Table 4.3: Essential Amino Acids Composition of Sunflower Seed Cake**

<b>Essential Amino Acids</b>	<b>SFSC (g/100g)</b>	<b>GNC (%)</b>
Arginine	4.07	4.35
Histidine	2.24	0.87
Isoleucine	1.90	1.27
Leucine	3.32	2.42
Lysine	1.63	1.26
Methionine	2.24	0.45
Phenylalanine	2.35	1.97
Threonine	3.00	1.01
Tryptophan	1.29	0.39
Valine	1.95	1.53

SFSC = Sunflower Seed Cake; GNC = Groundnut Cake amino acid composition are table values by NRC (1994) on as-fed basis.

accounts for 11.98 g/100g protein as the most abundant essential amino acids in sunflower seed cake samples while isoleucine, and valine content were 1.90 g/100g and 1.95 g/100g respectively. Similar results have been reported by other researchers (Thomas *et al.*, 1965; Marinov *et al.*, 1973; Singh and Prasad, 1979; Oshodi *et al.*, 1998; Adeyeye, 2004).

#### **4.4 FEEDING TRIAL 1: Response of Broiler Chickens Fed Diets Containing Graded Levels of Sunflower Seed Cake**

##### **4.4.1 Growth Performance of Broiler Chickens Fed Diets Containing Graded Levels of Sunflower Seed Cake**

###### ***4.4.1.1 Starter phase (1 - 4 weeks)***

The growth performance of broiler starter chicks fed diets containing graded levels of sunflower seed cake is presented in Table 4.4. Significant ( $P<0.05$ ) differences were observed in final weight, total weight gain, total feed intake, feed conversion ratio and feed cost per kg gain across the treatment groups.

The result shows that broiler starter chicks fed 20 % SFSC based diet significantly ( $P<0.05$ ) performed better in all the growth parameters measured compared to other birds across the treatment groups. This performance was followed by broiler starter chicks fed 10 % SFSC based diet which were significantly ( $P<0.05$ ) better than birds fed the control diet. This result may be attributed to improved diet quality and palatability couple with lysine and methionine contents of sunflower seed cake. Total feed intake of broiler starter chicks ranged from 1251.17 to 1503.29 g/bird with increased levels of sunflower seed cake from 0 to 20 kg/100kg diet. The increased feed consumption may be due to the fact that feed intake is inversely proportional to the nutrient

**Table 4.4: Growth Performance of Broiler Starter Chicks Fed Diets Containing Graded Levels of Sunflower Seed Cake (1 - 4 weeks)**

Growth Parameters	Graded Levels of SFSC (kg/100kg diet)					SEM
	0	5	10	15	20	
Initial Weight (g/bird)	44.16	44.20	43.97	44.10	43.17	0.62
Final Weight (g/bird)	687.82 <sup>d</sup>	673.65 <sup>d</sup>	849.77 <sup>b</sup>	771.58 <sup>c</sup>	900.48 <sup>a</sup>	13.87
T. Weight Gain (g/bird)	643.66 <sup>d</sup>	629.45 <sup>d</sup>	805.80 <sup>b</sup>	727.47 <sup>c</sup>	856.50 <sup>a</sup>	13.90
T. Feed Intake (g/bird)	1251.17 <sup>d</sup>	1209.67 <sup>d</sup>	1418.95 <sup>b</sup>	1309.93 <sup>c</sup>	1503.3 <sup>a</sup>	37.33
Feed Conversion Ratio	1.94 <sup>d</sup>	1.89 <sup>c</sup>	1.76 <sup>a</sup>	1.80 <sup>b</sup>	1.75 <sup>a</sup>	0.03
Feed Cost per kg gain	247.73 <sup>b</sup>	241.65 <sup>b</sup>	219.43 <sup>a</sup>	222.49 <sup>a</sup>	214.10 <sup>a</sup>	4.34
Mortality (%)	2.00	2.33	2.33	2.00	1.67	0.45

<sup>a,b,c,d</sup> = means on the same row with different superscripts are significantly different (P<0.05); SEM = Standard Error of the Mean; T = Total; SFSC = Sunflower Seed Cake

requirements of broiler starter chicks to satisfy their nutrients requirement for normal growth when fed SFSC based diets Broiler starter chicks fed 10 and 20 % SFSC based diets significantly ( $P < 0.05$ ) had better values of 1.76 and 1.75 for feed conversion ratio as a result of better feed utilization. This result agreed with the findings of Zadari and Sell (1990) who reported that broiler chickens fed 0, 100 or 200 g/kg of sunflower seed cake diet from 1 to 42 days of age had improved feed conversion ratio.

Birds fed 10, 15 and 20 % SFSC based diets had better feed cost per kg meat produced. This implied that the inclusion of SFSC up to 20 % as an alternative protein source to groundnut cake significantly improved growth performance (final weight, total weight gain, total feed intake, and feed conversion ratio) of broiler starter chicks and this agreed with the reports of Rajesh *et al.* (2006), Abdelrahman and Saleh (2007) and Peric *et al.* (2010).

No significant ( $P > 0.05$ ) differences were observed for percent mortality of broiler starter chicks across the treatment groups. Though mortalities were recorded as a result of hot weather during the feeding trial. This result agreed with the findings of Cheva-Isarakul and Tangtaweewipat (1991) who stated that there were no significant ( $P > 0.05$ ) effect of sunflower seed cake at 0, 15, 20, 25 and 30 % on mortality rate of broiler chickens.

#### **4.4.1.2 Finisher phase (6 - 9 weeks)**

The result of growth performance of broiler chickens fed diets containing graded levels of sunflower seed cake (6 - 9 weeks) is presented in Table 4.5. The result shows significant ( $P < 0.05$ ) differences across the treatment groups for all the growth performance parameters measured except percent mortality. Broiler chickens fed 20 % SFSC based diet had significantly

**Table 4.5: Growth Performance of Broiler Chickens Fed Diets Containing Graded Levels of Sunflower Seed Cake (6 - 9 weeks)**

<b>Growth Parameters</b>	<b>Graded Levels of SFSC (kg/100kg diet)</b>					<b>SEM</b>
	<b>0</b>	<b>5</b>	<b>10</b>	<b>15</b>	<b>20</b>	
Initial Weight (g/bird)	1020.47	1010.61	1054.71	1033.46	1085.15	14.00
Final Weight (g/bird)	2279.85 <sup>c</sup>	2055.06 <sup>d</sup>	2427.28 <sup>b</sup>	2333.48 <sup>c</sup>	2594.66 <sup>a</sup>	50.93
T. Weight Gain (g/bird)	1259.38 <sup>c</sup>	1051.12 <sup>d</sup>	1372.57 <sup>b</sup>	1300.02 <sup>b</sup>	1509.54 <sup>a</sup>	51.13
T. Feed Intake (g/bird)	3014.60 <sup>d</sup>	3242.80 <sup>c</sup>	3623.20 <sup>b</sup>	3774.80 <sup>a</sup>	3636.6 <sup>b</sup>	62.39
Feed Conversion Ratio	2.39 <sup>a</sup>	3.12 <sup>b</sup>	2.67 <sup>a</sup>	2.91 <sup>b</sup>	2.33 <sup>a</sup>	0.20
Feed Cost per kg gain	284.26 <sup>a</sup>	366.19 <sup>b</sup>	307.72 <sup>a</sup>	333.48 <sup>b</sup>	264.62 <sup>a</sup>	23.37
Mortality (%)	1.00	2.00	1.00	2.00	0.00	0.89

<sup>a,b,c,d</sup> = means on the same row with different superscripts are significantly different (P<0.05); SEM = Standard Error of the Mean; T = Total; SFSC = Sunflower Seed Cake

( $P < 0.05$ ) higher values for final weight (2594.66 g/bird) and total weight gain (1509.54 g/bird) compared to birds fed the control diet. This result revealed that the inclusion of 20 % SFSC in broiler finisher chickens diet significantly improved final weight by 13.81 % and total weight gain by 19.86 % respectively. This is attributed to the quality and nutritive value of sunflower seed cake which implies better feed utilization. This result agreed with the findings of El-Sherif *et al.* (1995) who observed significant ( $P < 0.05$ ) differences in final weight, total weight gain, feed conversion ratio and survival percentage of broiler chickens fed up to 70 % SFSC in broiler chickens diets during growing and finishing stages and supplemented with methionine, lysine and fat and showed no adverse impacts on growth performance.

Total feed intake significantly increased as graded levels of sunflower seed cake increased with broiler chickens fed 15 % SFSC based diet having significantly ( $P < 0.05$ ) the highest feed intake (3774.80 g/bird) when compared to other birds across other treatment groups. This result can be attributed to the fibre level of sunflower seed cake in the diets which tends to increase feed intake. This result is in agreement with the trend observed by Abid *et al.* (1990) who reported that the use of sunflower seed cake in broiler chickens diets up to 20 % improved feed intake across treatment groups.

Birds fed the control diet, 10 and 20 % SFSC based diets had the best values of 2.39, 2.67 and 2.33 for feed conversion ratio and ₦284.26, ₦307.72 and ₦264.62 for feed cost per kg gain. This result is attributed to better feed utilisation and efficiency coupled with the decreasing feed cost with an increase in graded levels of sunflower seed cake as a cost effective substitute to groundnut cake in broiler chickens diets. This result revealed that sunflower seed cake can be used in broiler chickens diets up to 20 % without detrimental effect on growth performance as supported by the reports of Rajesh *et al.* (2006).

There were no significant ( $P < 0.05$ ) difference observed for percent mortality in birds fed the control diet, 5, 10, 15 and 20 % SFSC based diets. Though mortalities were recorded as a result of hot weather temperature during the feeding trial. This result concur with the reports of Salih and Taha (1989) who observed that mortality rate was the same in all treatment groups fed diets containing sunflower seed cake at levels of 0, 100, 200 or 400 g/kg.

#### **4.4.2 Apparent digestibility of nutrients by broiler chickens fed diets containing graded levels of sunflower seed cake**

The result of apparent digestibility of nutrients by broiler chickens fed diets containing graded levels of sunflower seed cake is presented in Table 4.6. Significant ( $P < 0.05$ ) differences were observed for dry matter, crude protein, crude fibre and nitrogen free extract apparent digestibility across the treatment groups. Apparent dry matter digestibility was significantly ( $P < 0.05$ ) higher and similar in birds fed the control diet and 20 % SFSC based diet (89.81 and 87.25 %) and lowest in birds fed 5 % SFSC based diet (79.25 %). The lowest % DM digestibility observed in birds fed 5 % SFSC based diet could be associated to the digestion process of some nutrients which could have been entrapped to varying degrees inside the fibrous structures of the cell walls. The trend observed in this study disagreed with the report of Rama Rao (2006) who observed that dry matter digestibility decreased with increased levels of sunflower seed cake in the diets. Crude protein digestibility was highest in birds fed the control diet (86.58 %) and decreased significantly ( $P < 0.05$ ) amongst birds fed SFSC based diets which were similar to each other. This linear decrease with inclusion of sunflower seed cake in the diets might be linked to the lower crude protein content of sunflower seed cake when compared to groundnut cake.

**Table 4.6: Apparent Digestibility of Nutrients by Broiler Chickens Fed Diets Containing Graded Levels of Sunflower Seed Cake**

Proximate Composition (%)	Graded Levels of SFSC (kg/100kg diet)					SEM
	0	5	10	15	20	
Dry matter	89.81 <sup>a</sup>	79.25 <sup>c</sup>	86.81 <sup>b</sup>	82.83 <sup>b</sup>	87.25 <sup>a</sup>	2.03
Crude protein	86.58 <sup>a</sup>	73.02 <sup>b</sup>	81.89 <sup>b</sup>	79.62 <sup>b</sup>	80.11 <sup>b</sup>	3.53
Crude fibre	69.30 <sup>a</sup>	64.11 <sup>b</sup>	65.26 <sup>b</sup>	66.18 <sup>b</sup>	66.39 <sup>b</sup>	1.25
Ether extract	81.09	80.51	81.34	84.76	83.33	2.84
Nitrogen free extract	84.97 <sup>a</sup>	71.15 <sup>c</sup>	77.97 <sup>b</sup>	80.30 <sup>b</sup>	88.56 <sup>a</sup>	4.01

<sup>a,b,c</sup> = means on the same row with different superscripts are significantly different (P<0.05); SEM = Standard Error of the Mean; SFSC = Sunflower Seed Cake

Crude fibre digestibility was significantly ( $P < 0.05$ ) reduced by graded levels of sunflower seed cake with the highest value observed in birds fed the control diet (69.30 %) and differed significantly from birds fed SFSC based diets which were all similar. This is attributed to the physiological and nutritional effect of dietary fibre which tends to reduce digestion, diffusion and absorption of nutrients in the gut. This result agreed with the observations of Ali *et al.* (2011) who reported that the digestibility of crude protein, crude fibre, crude fat and organic matter were significantly influenced by graded levels of sunflower seed cake. Apparent digestibility of nitrogen free extract was significantly ( $P < 0.05$ ) highest in birds fed the control diet (84.97 %) and 20 % SFSC based diet (88.56 %) respectively. No significant ( $P > 0.05$ ) differences were observed for apparent digestibility of ether extract across the treatment groups. This may be due to the inability of the birds to extract oil from the intact cells during the digestion process. The discrepancy in these results may be due to cultivar differences and processing methods of sunflower seed cake (Alagawany, 2015).

#### **4.4.3 Haematological parameters of broiler chickens fed diets containing graded levels of sunflower seed cake**

The result of haematological parameters of broiler chickens fed diets containing graded levels of sunflower seed cake is presented in Table 4.7. Selvaraj and Purushothaman(2004) reported that inclusion of different levels of full-fat sunflower seeds in broiler chickens diets did not affect haematological parameters of poultry which agreed with the trend in this study with the exception of PCV, RBC and heterophils. Packed cell volume was significantly ( $P < 0.05$ ) higher among broiler chickens fed 5, 15 and 20 % SFSC based diets. The PCV values of 21.10 - 31.77 % observed in this study were within normal range values of 22 - 35 % for healthy broiler chickens as reported by Schalm *et al.* (1975). This indicates that the diets were suitable and

**Table 4.7: Haematological Parameters of Broiler Chickens Fed Diets Containing Graded Levels of Sunflower Seed Cake**

Parameters	Graded Levels of SFSC (kg/100kg diet)					SEM	Reference values
	0	5	10	15	20		
PCV (%)	21.10 <sup>c</sup>	31.77 <sup>a</sup>	27.97 <sup>b</sup>	29.96 <sup>a</sup>	31.65 <sup>a</sup>	0.93	22.00-35.00 <sup>1</sup>
Hb conc (g/dl)	10.44	9.13	9.86	10.47	10.54	0.94	7.00-15.00 <sup>2</sup>
RBC (x 10 <sup>12</sup> /L)	2.81 <sup>a</sup>	2.45 <sup>b</sup>	2.65 <sup>a</sup>	2.76 <sup>a</sup>	2.66 <sup>a</sup>	0.16	1.59-4.10 <sup>2</sup>
WBC (x 10 <sup>6</sup> /L)	5.24	5.38	4.72	4.59	5.08	0.50	1.90-9.50 <sup>3</sup>
Heterophils (%)	7.62 <sup>a</sup>	6.27 <sup>b</sup>	6.70 <sup>a</sup>	6.57 <sup>a</sup>	7.70 <sup>a</sup>	0.63	15.00-40.00 <sup>3</sup>
Lymphocytes (%)	65.28	67.50	70.13	66.99	68.87	6.33	40.0-100.00 <sup>4</sup>
Monocytes (%)	2.35	2.99	3.25	2.72	3.53	0.62	1.00-7.00 <sup>5</sup>
Eosinophils (%)	1.75	1.99	1.86	1.84	2.04	0.19	1.50-6.00 <sup>3</sup>
MCV (fl)	118.08	113.87	117.28	117.98	116.87	2.52	90.00-140.00 <sup>3</sup>
MCH (pg)	46.08	46.44	46.30	45.55	45.99	1.48	33.00-47.00 <sup>4</sup>
MCHC (g/dl)	33.92	34.48	34.65	33.75	34.27	1.64	26.00-85.00 <sup>4</sup>

<sup>a,b,c</sup> = means on the same row with different superscripts are significantly different (P<0.05); SEM = Standard Error of the Mean; SFSC = Sunflower Seed Cake; PCV = Packed Cell Volume; HB = Haemoglobin; RBC = Red Blood Cells; WBC = White Blood Cells; MCV = Mean Corpuscular Volume; MCH = Mean Corpuscular Haemoglobin; MCHC = Mean Corpuscular Haemoglobin Concentration; Reference values (<sup>1</sup>Schalm *et al.*, 1975; <sup>2</sup>Mitruka and Rawnsely, 1997; <sup>3</sup>Simrak *et al.*, 2004; <sup>4</sup>Jain, 1986; <sup>5</sup>Jain, 1993).

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adequate for broiler chickens.

The haemoglobin concentration (9.13 - 10.54 g/dl) observed in this study fall within the normal range of 7 - 15 g/dl reported by Mitruka and Rawnsley (1997) for a healthy broiler chicken. This indicates that the birds had sufficient blood pigment for proper transportation of oxygen. The RBC and WBC values of  $2.45 - 2.81 \times 10^{12}/L$  and  $4.59 - 5.38 \times 10^6/L$  fall within the normal range of  $1.59 - 4.10 \times 10^{12}/L$  and  $1.90 - 9.50 \times 10^6/L$  reported by Mitruka and Rawnsley (1997) and Simrak *et al.* (2004) for a healthy bird. The lymphocytes values in this study were between 65.28 - 70.13 % which fall within the normal range of 40 - 100 % reported by Jain (1986). This implies that, all the birds across the treatment groups had adequate immune response status which implied that the inclusion of sunflower seed cake at higher levels reduced the propensity of birds picking infection and the bird's immune system may have produced sufficient cytokines for combating some kind of infection as reported by Adeyemo *et al.* (2007).

Mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration (MCHC) are useful in the diagnosis of anaemia in most animals (Lamb, 1991). The observed MCV, MCH and MCHC values were within normal range values reported by Jain (1986) and Simrak *et al.* (2004) for healthy birds. Ismaila *et al.* (2011) evaluated the mean values of haematological parameters in relation to sex in local and exotic chickens and reported MCV of 135.36 and 134.76fl which were higher than the range (113.87 - 118.08fl) obtained in this study while the MCH were 45.55 - 46.44pg within the normal range of 33.00 - 47.00pg and MCHC of 34.48 and 32.44 % in male and female chickens were higher than the 33.75 - 34.65 % recorded in this study across the treatment groups. This implied that the birds were not anaemic.

#### **4.4.4 Serum biochemical profile of broiler chickens fed diets containing graded levels of sunflower seed cake**

Table 4.8 shows the result of serum biochemical profile of broiler chickens fed diets containing graded levels of sunflower seed cake. Total protein, albumin, globulin, cholesterol, triglycerides, glucose, creatinine, uric acid, HDL and SOD were all significantly ( $P < 0.05$ ) affected by graded levels of sunflower seed cake across the treatment groups. This result agrees with the submissions that some blood components normally vary in concentration depending upon the nature of nutritional intake (Adeyemo *et al.*, 2007). Total protein were significantly ( $P < 0.05$ ) highest in broiler chickens fed the control diet and 20 % SFSC based diets. The values obtained in this study for total protein (4.32 - 4.96 g/dl) fall within the normal range values of 3.60 to 5.50 g/dl reported by Ross *et al.* (1976) for healthy birds. These values indicates good nutritional adequacy of sunflower seed cake as an alternative feedstuff in poultry diets. Lowest level of albumin was observed in birds fed the control diet, though the values were within normal range values reported by Ross *et al.* (1976). Cholesterol and high density lipoprotein values were significantly ( $P < 0.05$ ) reduced in birds fed 20 % SFSC based diet while the highest value for uric acids was observed in birds fed 20 % SFSC based diet. Triglycerides were significantly ( $P < 0.05$ ) higher in birds fed 5 and 10 % SFSC based diets while glucose value was significantly ( $P < 0.05$ ) lowest in birds fed 15 % SFSC based diet. Birds fed the control diet had significantly ( $P < 0.05$ ) the least superoxide dismutase value compared to other birds across the treatment groups. Superoxide dismutase, glutathione peroxidase, malondialdehyde, catalase, globulin and uric acid values showed no definite pattern as the inclusion of sunflower seed cake increased which may be due to the level of fibre and energy values of sunflower seed cake.

**Table 4.8: Serum Biochemical Profile of Broiler Chickens Fed Diets Containing Graded Levels of Sunflower Seed Cake**

Parameters	Graded Levels of SFSC (kg/100kg diet)					SEM	Reference values
	0	5	10	15	20		
Total protein (g/dl)	4.59 <sup>a</sup>	4.33 <sup>b</sup>	4.39 <sup>b</sup>	4.32 <sup>b</sup>	4.96 <sup>a</sup>	0.30	3.60-5.50 <sup>1</sup>
Albumin (g/dl)	1.60 <sup>b</sup>	1.84 <sup>a</sup>	1.86 <sup>a</sup>	1.78 <sup>a</sup>	1.99 <sup>a</sup>	0.17	1.10-2.20 <sup>1</sup>
Globulin (g/dl)	2.99	2.48	2.53	2.55	2.58	0.41	1.2-3.20 <sup>2</sup>
Cholesterol (mg/dl)	183.77 <sup>a</sup>	152.33 <sup>a</sup>	173.44 <sup>a</sup>	146.82 <sup>a</sup>	130.22 <sup>b</sup>	21.20	2.23-5.17
Triglycerides mg/dl	56.97 <sup>b</sup>	61.50 <sup>a</sup>	67.58 <sup>a</sup>	52.11 <sup>b</sup>	60.98 <sup>b</sup>	2.99	<135.00
Glucose (mg/dl)	190.10 <sup>a</sup>	185.33 <sup>a</sup>	181.27 <sup>a</sup>	174.77 <sup>b</sup>	189.57 <sup>a</sup>	5.32	
Creatinine (mmol/l)	0.78 <sup>a</sup>	0.63 <sup>b</sup>	0.81 <sup>a</sup>	0.66 <sup>b</sup>	0.78 <sup>a</sup>	0.08	
Uric acid (mg/dl)	2.23 <sup>b</sup>	2.36 <sup>b</sup>	1.75 <sup>b</sup>	1.76 <sup>b</sup>	4.07 <sup>a</sup>	0.84	
LDL (mg/dl)	19.61	26.81	18.16	24.84	27.05	4.68	<130.00
HDL (mg/dl)	152.78 <sup>a</sup>	113.26 <sup>a</sup>	141.77 <sup>a</sup>	111.56 <sup>a</sup>	90.98 <sup>b</sup>	23.48	>90.00
SOD	15.77 <sup>b</sup>	17.83 <sup>a</sup>	19.89 <sup>a</sup>	20.22 <sup>a</sup>	20.94 <sup>a</sup>	1.39	
GPx	18.22	18.82	17.38	17.75	18.23	1.55	
MDA	22.52	22.52	22.08	22.17	22.97	2.09	
CAT	19.63	19.79	26.75	24.97	26.77	4.46	

<sup>a,b</sup> = means on the same row with different superscripts are significantly different (P<0.05); SEM = Standard Error of the Mean; SFSC = Sunflower Seed Cake; LDL = Low Density Lipoprotein; HDL = High Density Lipoprotein; SOD = Superoxide Dismutase; GPx = Glutathione Peroxidase; MDA = Malondialdehyde; CAT = Catalase; Reference values <sup>1</sup>Ross *et al.*, (1976); <sup>2</sup>LAVC, (2009).

#### **4.4.5 Carcass characteristics and internal organs weights of broiler chickens fed diets containing graded levels of sunflower seed cake**

##### ***4.4.5.1 Carcass characteristics***

Table 4.9 shows the carcass characteristics of broiler chickens fed diets containing graded levels of sunflower seed cake. The live weight and dressed weight of broiler chickens fed 20 % SFSC based diet was significantly ( $P<0.05$ ) higher than birds fed the control diet and other treatment groups. This indicates that the inclusion of SFSC at 20 % in broiler chickens diets significantly improved carcass characteristics of the birds compared to birds fed the control diet and other treatment groups. This result agreed with the findings of Niemiec *et al.* (1996) who observed that slaughter performance of broiler chickens was improved with diet containing sunflower seed cake. Dressing percentage of broiler chickens processed at 9 weeks of age were not significantly ( $P>0.05$ ) affected by graded levels of sunflower seed cake across the treatment groups. This result agreed with the findings of Valdivie, Sardinas and Garcia (1982). They reported that dressing percentage is usually positively correlated with live weight of birds and negatively correlated to gut size. In contrast, Afifi (1972) reported a significant difference among dietary treatments in the dressing percentage of broiler chickens fed up to 18 % sunflower seed cake.

Dietary treatments had significant influence on prime cut parts such as back, neck, breast and drumsticks. This result disagreed with the similarities among dietary treatments reported by Kwari *et al.* (2010). The increased relative percent weights of breast cut, thighs and neck with increments of sunflower seed cake were different from that of other segments of the prime cut parts measured. It is possible that the breast cut, thighs and neck were forced to enlarge to accommodate the "extra bulk" of the diet containing 20 % sunflower seed cake. No significant

( $P > 0.05$ ) differences were observed in thighs and wings among broiler chickens across all the treatment groups.

#### ***4.4.5.2 Internal organs parameters***

Table 4.9 shows the internal organs weights of broiler chickens fed diets containing graded levels of sunflower seed cake. Internal organs weights for heart, empty and full gizzard, spleen, kidney, lungs, intestinal weight and abdominal fat of broiler chickens were significantly ( $P < 0.05$ ) affected by graded levels of sunflower seed cake across treatment groups. The internal organs weights of broiler chickens fed the control diet had significantly ( $P < 0.05$ ) higher values which were similar to those birds on 5 and 15 % SFSC based diets in % heart, liver, full gizzard, empty gizzard, intestinal weight and abdominal fat and 20 % SFSC based diet in % liver and abdominal fat respectively.

The higher percent weight of liver in birds fed the control diet, 5, 15 and 20 % SFSC based diets is possibly as a result of high levels of toxic factors and the attempt by the liver to detoxify them. This result agreed with the findings of Ukachukwu (2000) and Akinmutini (2004) who reported that liver is the organ involved in detoxification and leads to stress on the liver to produce more enzymes to compensate for enzyme inactivation by anti-nutrients present. The significantly lower percent gizzard weight in birds fed 10 and 20 % SFSC based diets may again indicate complete elimination of anti-nutrients in the diets. Higher values for kidney in birds fed the control diet may be linked to the increased activity of kidney enzymes to detoxify the available anti-nutritional factors present in the ingredients.

**Table 4.9: Carcass Characteristics and Internal Organs Weights of Broiler Chickens Fed Diets Containing Graded Levels of Sunflower Seed Cake**

Carcass Parameters	Graded Levels of SFSC (kg/100kg diet)					SEM
	0	5	10	15	20	
Live weight (g/bird)	2233.3 <sup>b</sup>	2000.0 <sup>c</sup>	2366.67 <sup>b</sup>	2266.67 <sup>b</sup>	2533.3 <sup>a</sup>	53.81
Dressed weight g/bird	1600.0 <sup>c</sup>	1433.3 <sup>d</sup>	1666.67 <sup>b</sup>	1600.00 <sup>c</sup>	1800.0 <sup>a</sup>	33.38
Dressing percentage	71.67	71.78	70.41	70.61	71.10	1.35
Prime cut parts weight expressed as percentages of dressed weight						
Back	16.77 <sup>a</sup>	13.90 <sup>b</sup>	14.83 <sup>b</sup>	14.95 <sup>b</sup>	14.80 <sup>b</sup>	0.69
Neck	6.71 <sup>a</sup>	4.92 <sup>c</sup>	6.43 <sup>a</sup>	6.15 <sup>b</sup>	6.17 <sup>b</sup>	0.23
Breast	33.08 <sup>a</sup>	29.74 <sup>b</sup>	33.66 <sup>a</sup>	33.95 <sup>a</sup>	32.53 <sup>a</sup>	1.65
Wings	10.63	10.18	10.61	9.77	10.09	0.52
Thighs	16.69	15.35	15.93	16.51	16.33	0.73
Drumsticks	13.17 <sup>a</sup>	12.35 <sup>a</sup>	13.31 <sup>a</sup>	11.43 <sup>b</sup>	13.70 <sup>a</sup>	0.96
Internal organs weights expressed as percentage of live weight						
Heart	0.55 <sup>a</sup>	0.47 <sup>a</sup>	0.42 <sup>b</sup>	0.55 <sup>a</sup>	0.45 <sup>b</sup>	0.05
Liver	2.34 <sup>a</sup>	1.96 <sup>a</sup>	1.54 <sup>b</sup>	2.14 <sup>a</sup>	1.83 <sup>a</sup>	0.31
Full gizzard	3.42 <sup>a</sup>	2.94 <sup>a</sup>	2.25 <sup>b</sup>	3.21 <sup>a</sup>	2.33 <sup>b</sup>	0.18
Empty gizzard	2.13 <sup>a</sup>	1.83 <sup>a</sup>	1.33 <sup>b</sup>	2.11 <sup>a</sup>	1.50 <sup>b</sup>	0.18
Spleen	0.13 <sup>a</sup>	0.08 <sup>b</sup>	0.06 <sup>b</sup>	0.07 <sup>b</sup>	0.07 <sup>b</sup>	0.01
Kidney	0.87 <sup>a</sup>	0.67 <sup>b</sup>	0.48 <sup>b</sup>	0.61 <sup>b</sup>	0.55 <sup>b</sup>	0.10
Lungs	0.61 <sup>a</sup>	0.48 <sup>a</sup>	0.45 <sup>b</sup>	0.45 <sup>b</sup>	0.37 <sup>c</sup>	0.08
Intestinal weight (g)	5.25 <sup>a</sup>	6.22 <sup>a</sup>	3.82 <sup>b</sup>	5.03 <sup>a</sup>	3.72 <sup>b</sup>	0.84
Abdominal fat	0.51 <sup>a</sup>	0.47 <sup>a</sup>	0.18 <sup>b</sup>	0.56 <sup>a</sup>	0.51 <sup>a</sup>	0.27

<sup>a,b,c,d</sup> = means on the same row with different superscripts are significantly different (P<0.05); SEM = Standard Error of the Mean; SFSC = Sunflower Seed Cake

#### **4.4.6 Economics of production of broiler chickens fed diets containing graded levels of sunflower seed cake (1 - 9 weeks)**

Gross margin and return per naira invested were employed to evaluate the profitability of producing broiler chickens fed diets containing graded levels of sunflower seed cake as shown in Table 4.10. Feed cost (₦/kg) was observed decreasing linearly with increasing graded levels of sunflower seed cake in broiler starter and finisher diets across the treatment groups. This accounts for 11.06% reduction in feed cost. This result agreed with the findings of Mohammed *et al.* (2020) who reported that feed cost (₦/kg) decreases with an increase in the inclusion level of toasted full fat sunflower seed meal in the diets of broiler chickens. High revenue (₦2,072) was generated by birds fed 20 % SFSC based diet followed by birds fed 10 % (₦1,944), 15 % (₦1,864), and 0 % SFSC (₦1,824) while the least revenue (₦1,648) was generated by birds fed 5 % SFSC based diet. The variation in revenue (₦) generated was as a result of the significant differences observed in the average live weight (kg/bird) between treatment groups. Birds fed the control diet gained a gross margin of ₦825.37, while birds fed 20 % SFSC had the best economic gain with a gross margin of ₦994.70 with a higher margin of ₦169.33 above what was obtained for the control group. This result revealed that 20 % inclusion of SFSC accounts for 20.52 % economic gain as a cost effective alternative feed ingredient that can substitute groundnut cake in broiler chickens diets.

Return per Naira invested were highest in birds fed 20 % SFSC based diet with ₦1.92 and lowest in birds fed 5 % SFSC based diet with ₦1.62 while birds fed the control diet, 10 and 15 % SFSC based diets had ₦1.83, ₦1.80 and ₦1.73 return per Naira invested. This result is supported by the findings of Ghadeer *et al.* (2016) who reported that feeding broiler chickens with diets containing sunflower seed cake improved the economic efficiency of broiler chicken production.

**Table 4.10; Economics of Production of Broiler Chickens Fed Diets Containing Graded Levels of Sunflower Seed Cake (1 - 9 weeks)**

Variable costs	Graded Levels of SFSC (kg/100kg diet)				
	0	5	10	15	20
Cost of day-old chick (₦/bird)	300.00	300.00	300.00	300.00	300.00
Maintenance (₦/bird)	33.33	33.33	33.33	33.33	33.33
Wood shavings (₦/bird)	6.67	6.67	6.67	6.67	6.67
Starter feed cost (₦/kg)	127.50	126.10	124.70	123.40	121.90
Starter feed intake (kg/bird)	1.25	1.21	1.42	1.31	1.50
Cost of feeding starter (₦/kg)	159.37	152.58	177.07	161.65	182.85
Finisher feed cost (₦/kg)	118.80	117.40	116.00	114.70	113.40
Finisher feed intake (kg/bird)	3.01	3.24	3.62	3.77	3.64
Cost of feeding finisher (₦/kg)	357.59	380.38	419.92	432.42	412.78
Total cost of feeding (₦/bird)	516.96	532.96	596.99	594.07	595.63
Water (₦/bird)	6.67	6.67	6.67	6.67	6.67
Brooding (₦/bird)	41.67	41.67	41.67	41.67	41.67
Vaccination & medication (₦)	33.33	33.33	33.33	33.33	33.33
Labour (₦/bird)	40.00	40.00	40.00	40.00	40.00
Transportation (₦)	20.00	20.00	20.00	20.00	20.00
Total variable cost (TVC (₦))	998.63	1,014.63	1,078.66	1,075.74	1,077.30
<b>Revenue</b>					
Average live weight (kg/bird)	2.28	2.06	2.43	2.33	2.59
Cost of live chicken (₦/kg)	800	800	800	800	800
Revenue (R (₦/bird))	1,824	1,648	1,944	1,864	2,072
Gross margin (R - TVC (₦))	825.37	633.37	865.34	788.26	994.70
Return per ₦ Invested (R/TVC)	1.83	1.62	1.80	1.73	1.92

SFSC = Sunflower Seed Cake

## **4.5 FEEDING TRIAL 2: Influence of Maxigrain<sup>®</sup> Supplementation on Graded Levels of Sunflower Seed Cake in Broiler Chicken Diets**

### **4.5.1 Growth Performance of Broiler Chickens Fed Diets Supplemented with Maxigrain<sup>®</sup> on Graded Levels of Sunflower Seed Cake**

#### ***4.5.1.1 Starter phase (1 - 4 weeks)***

The result of growth performance of broiler starter chicks fed diets supplemented with maxigrain<sup>®</sup> on graded levels of sunflower seed cake is presented in Table 4.11. The result shows significant ( $P < 0.05$ ) differences in all the growth parameters measured. Final weight and total weight gain were significantly ( $P < 0.05$ ) higher for starter chicks fed 5, 10 and 20 % SFSC based diets with maxigrain<sup>®</sup> supplementation. This could be due to the synergy of the multi-enzyme releasing more protein and energy for tissue synthesis. This result agreed with the findings of Kocher *et al.* (2000) who reported that commercial enzyme products had some effects in diets containing high concentrations of sunflower seed cake. Contrary to this findings, Freitas *et al.* (2011) reported no improvement in final weight and total weight gain when they supplemented protease enzyme in poultry diet.

Total feed intake was significantly ( $P < 0.05$ ) higher in starter chicks fed the control diet, 5, 10 and 15 % SFSC based diets than for starter chicks fed 20 % SFSC based diet supplemented with maxigrain<sup>®</sup>. This implied that maxigrain<sup>®</sup> supplementation improved total feed intake of starter chicks fed diets containing graded levels of sunflower seed cake up to 15 % only and thereafter decreases. This result contradicts the findings of Ranade and Rajmane (1992) and Samarasinghe *et al.* (2000) who reported that enzyme supplementation in poultry diet results in decreased feed intake.

**Table 4.11: Growth Performance of Broiler Starter Chicks Fed Diets Supplemented with Maxigrain<sup>®</sup> on Graded Levels of Sunflower Seed Cake (1 - 4 weeks)**

Growth Parameters	Graded Levels of SFSC (kg/100kg diet)					SEM
	0	5	10	15	20	
Initial Weight (g/bird)	41.15	41.49	41.32	41.35	41.13	0.89
Final Weight (g/bird)	888.49 <sup>b</sup>	923.25 <sup>a</sup>	900.00 <sup>a</sup>	847.12 <sup>c</sup>	898.81 <sup>a</sup>	16.38
T. Weight Gain(g/bird)	847.34 <sup>b</sup>	881.76 <sup>a</sup>	858.68 <sup>a</sup>	805.76 <sup>c</sup>	857.68 <sup>a</sup>	16.33
T. Feed Intake (g/bird)	1554.95 <sup>a</sup>	1578.70 <sup>a</sup>	1567.43 <sup>a</sup>	1555.38 <sup>a</sup>	1500.60 <sup>b</sup>	38.90
Feed Conversion Ratio	1.83 <sup>b</sup>	1.79 <sup>a</sup>	1.82 <sup>b</sup>	1.93 <sup>c</sup>	1.75 <sup>a</sup>	0.03
Feed Cost per kg gain	234.39 <sup>b</sup>	226.76 <sup>b</sup>	228.84 <sup>b</sup>	238.68 <sup>c</sup>	214.34 <sup>a</sup>	4.09
Mortality (%)	0.00 <sup>a</sup>	3.33 <sup>b</sup>	0.00 <sup>a</sup>	3.33 <sup>b</sup>	0.00 <sup>a</sup>	1.06

<sup>a,b,c</sup> = means on the same row with different superscripts are significantly different (P<0.05); SEM = Standard Error of the Mean; T = Total; SFSC = Sunflower Seed Cake

Better feed conversion ratio were observed in birds fed 5 and 20 % SFSC based diets supplemented with maxigrain<sup>®</sup>. This is as a result of better feed utilization due to the disruption of plant cell wall fraction by xylanase and  $\beta$ -glucanase in the enzyme. This disruption liberates locked protein and starch for easier digestion, thus improving feed digestibility and utilization. This result is supported by the findings of Khan *et al.* (2006) who reported that enzyme supplementation improved productive performance of birds fed sunflower-corn based diets. This also agreed with the findings of Scott *et al.* (1997) who reported that feed conversion ratio was improved due to better feed utilization. Exogenous enzyme compliments the digestive enzyme of poultry by hydrolyzing the non-starch polysaccharides (NSPs) in cereals and vegetable proteins, thereby decreasing gut viscosity, and thus improved nutrient absorption (Creswell, 1994).

Feed cost per kg gain was significantly different across the treatment groups with starter chicks fed 20 % SFSC based diet supplemented with maxigrain<sup>®</sup> having better feed cost per kg meat produced which indicates a great benefit for farmers to maximise profit. This result is supported by the reports of kwari *et al.* (2011). Significant ( $P < 0.05$ ) differences were observed for percent mortality across the treatment groups with starter chicks fed 5 and 15 % SFSC based diets supplemented with maxigrain<sup>®</sup> recording higher mortality than other treatment groups. These mortalities were as a result of hot weather temperature during the feeding trial. The findings of Ali (1999) showed no significant ( $P < 0.05$ ) impact due to the inclusion of sunflower seed cake in broiler chickens diets on the mortality rate of chicks during the growing period.

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

The result of growth performance of broiler chickens fed diets supplemented with maxigrain<sup>®</sup> on graded levels of sunflower seed cake is presented in Table 4.12. Significant ( $P < 0.05$ ) differences

**Table 4.12: Growth Performance of Broiler Chickens Fed Diets Supplemented with Maxigrain<sup>®</sup> on Graded Levels of Sunflower Seed Cake (5 - 8 weeks)**

Growth Parameters	Graded Levels of SFSC (kg/100kg diet)					SEM
	0	5	10	15	20	
Initial Weight (g/bird)	888.49	923.25	900.00	847.12	898.81	16.38
Final Weight (g/bird)	2183.07 <sup>a</sup>	1950.27 <sup>b</sup>	2068.97 <sup>b</sup>	2041.86 <sup>b</sup>	2211.33 <sup>a</sup>	67.40
T. Weight Gain (g/bird)	1294.58 <sup>a</sup>	1027.02 <sup>b</sup>	1168.97 <sup>a</sup>	1194.75 <sup>a</sup>	1312.52 <sup>a</sup>	70.43
T. Feed Intake (g/bird)	3054.80 <sup>b</sup>	2863.20 <sup>b</sup>	3273.90 <sup>a</sup>	3153.30 <sup>a</sup>	3329.60 <sup>a</sup>	147.40
Feed Conversion Ratio	2.36 <sup>a</sup>	2.80 <sup>b</sup>	2.79 <sup>b</sup>	2.65 <sup>b</sup>	2.56 <sup>a</sup>	0.12
Feed Cost per kg gain	282.11 <sup>a</sup>	330.32 <sup>b</sup>	326.00 <sup>b</sup>	305.24 <sup>a</sup>	291.49 <sup>a</sup>	13.10
Mortality (%)	10.35	7.01	10.18	7.02	8.34	4.40

<sup>a,b,c</sup> = means on the same row with different superscripts are significantly different (P<0.05); SEM = Standard Error of the Mean; T = Total; SFSC = Sunflower Seed Cake

were observed in final weight, total weight gain, total feed intake, feed conversion ratio and feed cost per kg gain among broiler chickens across the treatment groups.

Final weight and total weight gain were significantly ( $P < 0.05$ ) higher in birds fed the control diet and 20 % SFSC based diet compared to other treatment groups but similar to birds fed 10 and 15 % SFSC based diets in total weight gain. Total feed intake was significantly ( $P < 0.05$ ) higher in birds fed 10, 15 and 20 % SFSC based diets supplemented with maxigrain<sup>®</sup> when compared to other treatment groups. This result is in agreement with the findings of Atteh (2004) who reported that enzyme supplementation improved some of the growth parameters of broiler chickens. Furthermore, Eruvbetine *et al.* (2002) observed that the addition of multi-enzymes like amylases and xylanases enhanced the utilization of non-starch polysaccharide components while proteases enhanced the utilization of proteinous components of feed.

Feed conversion ratio and feed cost per kg gain were significantly ( $P < 0.05$ ) better in birds fed the control diet and 20 % SFSC based diet compared to other treatments but similar to birds fed 15 % SFSC based diet in feed cost per kg gain. The result indicates positive influence of maxigrain<sup>®</sup> supplementation on decreased passage rate of feed in the digestive tract by degrading the cell wall of ingredients which enhanced nutrients availability and thus, improved feed utilization. This translates to a great benefit for farmers to maximise profit which is in line with the reports of kwari *et al.* (2011).

There were no significant ( $P < 0.05$ ) differences for percent mortality across the treatment groups. Though mortalities were recorded as a result of hot weather temperature during the feeding trial. Moreover, Valdivie *et al.* (1982) used sunflower seed cake at 0 and 20 % in broiler chickens diet and reported no significant differences between treatment groups for mortality rate.

#### **4.5.2 Apparent digestibility of nutrients by broiler chickens fed diets supplemented with maxigrain<sup>®</sup> on graded levels of sunflower seed cake**

Maxigrain<sup>®</sup> supplementation of diets containing graded levels of sunflower seed cake significantly ( $P < 0.05$ ) influenced all the apparent nutrients digestibility as shown in Table 4.13. Apparent digestibility was significantly ( $P < 0.05$ ) higher in broiler chickens fed the control diet and 20 % SFSC based diet in all the parameters except NFE digestibility. Dry matter digestibility was higher and similar in birds fed the control diet (84.37 %), 15 (85.01 %) and 20 % (85.58 %) SFSC based diets supplemented with maxigrain<sup>®</sup>. This result indicates that maxigrain<sup>®</sup> supplementation improved nutrients digestibility in broiler chickens. The observed result agreed with the findings of Tavernari *et al.* (2009) who observed that dry matter digestibility coefficients of Ca and P were improved in broiler chickens fed diets containing sunflower seed cake supplemented

with exogenous enzyme. Birds fed the control diet, 15 and 20 % SFSC based diets had higher crude protein digestibility values of 84.28, 80.82 and 84.34 % respectively. The observed trend in this study agreed with the findings of Freitas *et al.* (2011) who used protease enzyme and confirmed improved digestibilities of metabolizable energy and crude protein in broiler chickens. This mechanism might have induced partial reduction in gut viscosity to decreased retention time of digesta in the gut, thus improving feed conversion ratio and growth (Lazaro *et al.*, 2003).

Maxigrain<sup>®</sup> supplementation of diets containing graded levels of sunflower seed cake significantly ( $P < 0.05$ ) influenced crude fibre digestibility in birds fed the control diet (62.20 %), 15 (63.48 %) and 20 % SFSC (64.94 %) based diets respectively. This result agreed with the

**Table 4.13: Apparent Digestibility of Nutrients By Broiler Chickens Fed Diets Supplemented with Maxigrain® on Graded Levels of Sunflower Seed Cake**

Proximate Composition	Graded Levels of SFSC (kg/100kg diet)					SEM
	0	5	10	15	20	
Dry matter	84.37 <sup>a</sup>	75.95 <sup>b</sup>	75.49 <sup>b</sup>	85.01 <sup>a</sup>	85.58 <sup>a</sup>	3.06
Crude protein	84.28 <sup>a</sup>	73.02 <sup>c</sup>	78.32 <sup>b</sup>	80.82 <sup>a</sup>	84.34 <sup>a</sup>	2.08
Crude fibre	62.20 <sup>a</sup>	54.37 <sup>c</sup>	57.62 <sup>b</sup>	63.48 <sup>a</sup>	64.94 <sup>a</sup>	2.70
Ether extract	79.89 <sup>a</sup>	66.40 <sup>b</sup>	80.56 <sup>a</sup>	63.17 <sup>c</sup>	81.93 <sup>a</sup>	2.89
Nitrogen free extract	79.77 <sup>c</sup>	72.75 <sup>d</sup>	85.40 <sup>a</sup>	83.30 <sup>b</sup>	87.53 <sup>a</sup>	1.27

<sup>a,b,c,d</sup> = means on the same row with different superscripts are significantly different (P<0.05); SEM = Standard Error of the Mean; SFSC = Sunflower Seed Cake

findings of Omole *et al.* (2011) who investigated the performance and nutrients digestibility of broiler chickens fed diets containing exogenous Hamecozyme<sup>®</sup> and observed significant improvement in crude protein and crude fibre digestibility as the level of Hamecozyme<sup>®</sup> increased in the diets. On the contrary, Kocher *et al.* (2000) did not observe any influence of enzyme supplementation in diets containing sunflower seed cake. One explanation for this discrepancy in results is that different sunflower seed varieties or cultivars varying in chemical composition were used in the experiments. Ether extract digestibility was significantly ( $P<0.05$ ) higher in birds fed the control diet (79.89 %), 10 (80.56 %) and 20 % SFSC (81.93 %) based diets and nitrogen free extract digestibility differed significantly ( $P<0.05$ ) across the treatment groups with birds fed 10 (83.30 %) and 20 % SFSC (87.53 %) based diets supplemented with maxigrain<sup>®</sup> having higher nitrogen free extract digestibility.

#### **4.5.3 Haematological parameters of broiler chickens fed diets supplemented with maxigrain<sup>®</sup> on graded levels of sunflower seed cake**

There were no significant ( $P>0.05$ ) differences among treatment groups for haematological parameters measured when maxigrain<sup>®</sup> was supplemented in diets containing graded levels of sunflower seed cake as shown in Table 4.14. A similar trend was reported by Selvaraj and Purushothaman (2004) who stated that the inclusion of full-fat sunflower seeds at different levels in broiler chickens diets did not affect haematological parameters of poultry. The non-significant effect of dietary treatments on the haematological values indicates that the haematological parameters did not deviate from normal bench mark values reported for healthy birds which confirmed that the birds were not anaemic (Abu *et al.*, 1999).

PCV with range values of 27.33 - 28.67 % obtained in this study were within normal range

**Table 4.14: Haematological Parameters of Broiler Chickens Fed Diets Supplemented with Maxigrain® on Graded Levels of Sunflower Seed Cake**

Parameters	Graded Levels of SFSC (kg/100kg diet)					SEM	Reference values
	0	5	10	15	20		
PCV (%)	27.33	28.00	27.67	28.00	28.67	2.28	22.00-35.00 <sup>1</sup>
Hb conc (g/dl)	9.20	9.30	9.17	9.30	9.53	0.75	7.00-15.00 <sup>2</sup>
RBC (x 10 <sup>12</sup> /L)	2.77	3.17	3.43	3.03	3.40	0.35	1.59-4.10 <sup>2</sup>
WBC (x 10 <sup>6</sup> /L)	11.27	11.77	10.90	9.30	12.17	1.54	1.90-9.50 <sup>3</sup>
Heterophils (%)	17.33	17.00	14.33	20.67	20.67	3.13	15.00-40.00 <sup>3</sup>
Lymphocytes (%)	82.67	85.33	84.00	78.67	77.67	3.07	40.0-100.00 <sup>4</sup>
MCV (fl)	100.92	91.38	80.11	93.08	89.49	9.56	90.0-140.00 <sup>3</sup>
MCH (pg)	33.59	30.35	26.54	30.92	29.28	3.02	33.00-47.00 <sup>4</sup>
MCHC (g/dl)	33.29	33.21	33.12	34.40	30.52	1.10	26.00-85.00 <sup>4</sup>

SEM = Standard Error of the Mean; SFSC = Sunflower Seed Cake; PCV = Packed Cell Volume; HB = Haemoglobin concentration; RBC = Red Blood Cells; WBC = White Blood Cells; MCV = Mean Corpuscular Volume; MCH = Mean Corpuscular Haemoglobin; MCHC = Mean Corpuscular Haemoglobin Concentration; Reference values (<sup>1</sup>Schalm *et al.*, 1975; <sup>2</sup>Mitruka and Rawnsley, 1997; <sup>3</sup>Simrak *et al.*, 2004; <sup>4</sup>Jain, 1986).

values of 22 - 35 % reported by Schalm *et al.* (1975) for healthy birds. Haemoglobin concentration, white blood cells, red blood cells, heterophils, lymphocytes, mean corpuscular volume, mean corpuscular haemoglobin and mean corpuscular haemoglobin concentration values were all within normal range values reported for healthy birds across the treatment groups. This result may be attributed to the influence of maxigrain<sup>®</sup> supplementation in the diets which helped to improve utilization of nutrients in the feed. The non-significant effect of heterophils and lymphocytes showed the effectiveness of maxigrain<sup>®</sup> in degrading fibre in SFSC based diets.

The blood contains several metabolites which provide useful information on nutritional status and clinical investigation. They are also the readily available and fast means of assessing clinical and nutritional health status of animals in feeding trials because ingestion of dietary components has measurable effects on blood composition (Egbunike and Williams, 2005). Generally, the result showed that blood quality and health of birds were not compromised by feeding graded levels of sunflower seed cake supplemented with maxigrain<sup>®</sup>.

#### **4.5.4 Serum biochemical profile of broiler chickens fed diets supplemented with maxigrain<sup>®</sup> on graded levels of sunflower seed cake**

Maxigrain<sup>®</sup> supplementation of diets containing graded levels of sunflower seed cake significantly ( $P < 0.05$ ) influenced serum biochemical parameters such as total protein, albumin, globulin, cholesterol, creatinine and uric acid across the treatment groups as shown in Table 4.15. Total protein values were significantly ( $P < 0.05$ ) higher in birds fed 20 % SFSC supplemented with maxigrain<sup>®</sup> than those birds fed 0, 5, 10 and 15 % SFSC based diets. The observed total protein values (5.20 - 5.72 g/dl) were within normal range values of 3.60 to 5.50

**Table 4.15: Serum Biochemical Profile of Broiler Chickens Fed Diets Supplemented with Maxigrain® on Graded Levels of Sunflower Seed Cake**

Parameters	Graded Levels of SFSC (kg/100kg diet)					SEM	Reference values
	0	5	10	15	20		
Total protein (g/dl)	5.42 <sup>b</sup>	5.44 <sup>b</sup>	5.37 <sup>b</sup>	5.20 <sup>b</sup>	5.72 <sup>a</sup>	0.04	3.60-5.50 <sup>1</sup>
Albumin (g/dl)	2.27 <sup>a</sup>	2.17 <sup>b</sup>	2.08 <sup>d</sup>	2.12 <sup>c</sup>	2.20 <sup>b</sup>	0.03	1.10-2.20 <sup>1</sup>
Globulin (g/dl)	3.25 <sup>b</sup>	3.27 <sup>b</sup>	3.45 <sup>a</sup>	3.51 <sup>a</sup>	3.25 <sup>b</sup>	0.06	1.20-3.20 <sup>2</sup>
Cholesterol mg/dl	131.23 <sup>c</sup>	136.04 <sup>c</sup>	135.38 <sup>c</sup>	140.82 <sup>b</sup>	147.27 <sup>a</sup>	2.06	2.23-5.17
Triglycerides mg/dl	81.37	80.14	83.58	82.42	79.88	2.42	<135.00
Glucose (g/dl)	68.80	67.07	68.23	65.90	66.10	34.72	
Creatinine mmol/l	0.54 <sup>b</sup>	0.40 <sup>b</sup>	0.57 <sup>b</sup>	0.83 <sup>a</sup>	0.37 <sup>b</sup>	0.40	
Uric acid (mg/dl)	3.02 <sup>b</sup>	2.50 <sup>b</sup>	4.17 <sup>a</sup>	5.82 <sup>a</sup>	3.77 <sup>b</sup>	1.13	
LDL (mg/dl)	81.00	79.40	79.90	82.20	81.80	0.62	<130.00
HDL (mg/dl)	119.04	125.80	112.73	131.16	127.47	9.67	>90.00

<sup>a,b,c</sup> = means on the same row with different superscripts are significantly different (P<0.05); SEM = Standard Error of the Mean; SFSC = Sunflower Seed Cake; LDL = Low Density Lipoprotein; HDL = High Density Lipoprotein; Reference values (<sup>1</sup>Ross *et al.*, 1976; <sup>2</sup>LAVC, 2009; \*\*\*Bounous and Stedman, 2000).

g/dl reported for normal healthy birds reported by Ross *et al.* (1976). These values indicates good nutritional balance which can enhance blood clotting for preventing haemorrhage.

Albumin values recorded were within normal range values and varied significantly ( $P < 0.05$ ) across treatment groups with birds fed the control diet recording the highest value of 2.27 g/dl. Rama Rao *et al.* (2004) however reported that plasma parameters including total protein, albumin, globulin etc. were generally stable in the diets which contained soybean cake replaced progressively by sunflower seed cake at 0, 25, 50 and 75 % throughout the growing period and values of these parameters were within normal bench marks for poultry (Adejumo and Williams, 2006). Cholesterol concentration significantly increased with increased graded levels of sunflower seed cake with maxigrain<sup>®</sup> supplementation. This may have been influenced by physical and nutritional status of the birds (increased metabolizable energy and ether extract in the diets) as opined by Sturkie (2000). Globulin and uric acid were significantly ( $P < 0.05$ ) higher in birds fed 10 and 15 % SFSC based diets. Higher uric acid values were recorded in birds fed 10 (4.17 mg/dl) and 15 % SFSC (5.82 mg/dl) based diets supplemented with maxigrain<sup>®</sup>. This may be as a result of low blood flow to the kidney caused by dehydration.

Birds fed 15 % SFSC based diet with maxigrain<sup>®</sup> supplementation had significantly ( $P < 0.05$ ) higher creatinine value than other birds across the treatment groups. There were no significant ( $P > 0.05$ ) differences in triglycerides, glucose, high and low density lipoprotein values across the treatment groups. A similar trend was reported by Salari *et al.* (2009) who found that alkaline phosphatase activity, phosphorus, calcium, glucose, triglyceride, high and low density lipoprotein concentrations were not significantly affected by inclusion of full-fat sunflower seeds at levels of 70, 140, and 210 g/kg in broiler chicken diets. The observed values recorded for these parameters did not deviate from normal range values reported for healthy birds. Thus, the birds

health status were not compromised by maxigrain<sup>®</sup> supplementation of diets containing graded levels of sunflower seed cake.

#### **4.5.5 Carcass characteristics and internal organs weights of broiler chickens fed diets supplemented with maxigrain<sup>®</sup> on graded levels of sunflower seed cake**

Live weight, dressed weight and dressing percentage were significantly ( $P < 0.05$ ) influenced by maxigrain<sup>®</sup> supplementation of diets containing graded levels of sunflower seed cake as shown in Table 4.16. Broiler chickens fed the control diet and 20 % SFSC based diet with maxigrain<sup>®</sup> supplementation had significantly ( $P < 0.05$ ) higher live weight and dressed weight compared to birds in other treatment groups. Birds fed 0, 5, 10 and 20 % SFSC based diets supplemented with maxigrain<sup>®</sup> were statistically similar and recorded the highest ( $P < 0.05$ ) dressing percentage compared to birds fed 15 % SFSC based diet. This result is attributed to the differences in body weight and gut size as dressing percentage is usually positively correlated with live weight of birds and negatively correlated to gut size (Valdivie, Sardinias and Garcia, 1982). This result agreed with the findings of Afifi (1972) who reported significant differences among dietary treatments in the dressing percentage of broiler chickens fed diets containing up to 18 % sunflower seed cake. Prime cut parts were non-significantly different except drumsticks which differed significantly ( $P < 0.05$ ) in birds fed the control diet, 10 and 20 % SFSC based diets having higher percentages for drumsticks over birds fed 5, and 15 % SFSC based diets. This result may be attributed to the physiological response of birds to different dietary treatments. This result is in agreement with the reports of other researchers, who also did not find any response of broiler chickens to sunflower seed cake diets supplemented with exogenous enzymes on carcass parameters (Tavernari *et al.*, 2008; Mushtaq *et al.*, 2009).

**Table 4.16: Carcass Characteristics and Internal Organs Weights of Broiler Chickens Fed Diets Supplemented with Maxigrain<sup>®</sup> on Graded Levels of Sunflower Seed Cake**

Carcass Parameters	Graded Levels of SFSC (kg/100kg diet)					SEM
	0	5	10	15	20	
Live weight (g/bird)	2133.3 <sup>a</sup>	1966.7 <sup>b</sup>	2033.3 <sup>b</sup>	2000.0 <sup>b</sup>	2133.3 <sup>a</sup>	48.99
Dressed weight g/bird	1579.67 <sup>a</sup>	1366.3 <sup>c</sup>	1483.00 <sup>b</sup>	1334.67 <sup>c</sup>	1591.3 <sup>a</sup>	20.26
Dressing percentage	74.16 <sup>a</sup>	69.55 <sup>a</sup>	72.91 <sup>a</sup>	66.74 <sup>b</sup>	74.59 <sup>a</sup>	2.51
Prime cut parts weights expressed as percentage of dressed weight						
Back	15.07	15.75	14.95	15.02	15.05	0.52
Neck	5.95	5.76	6.46	6.44	6.14	1.17
Breast	28.20	27.74	26.03	26.23	27.73	1.47
Wings	10.76	10.80	11.24	10.78	10.67	0.37
Thighs	17.02	15.58	16.49	16.19	16.13	1.03
Drumsticks	12.59 <sup>a</sup>	12.12 <sup>b</sup>	12.44 <sup>a</sup>	12.28 <sup>b</sup>	13.45 <sup>a</sup>	0.36
Internal organs weights expressed as percentage of live weight						
Heart	0.39	0.36	0.39	0.35	0.41	0.03
Liver	1.82 <sup>a</sup>	1.54 <sup>b</sup>	1.51 <sup>b</sup>	1.63 <sup>a</sup>	1.45 <sup>b</sup>	0.13
Full gizzard	2.72 <sup>b</sup>	2.69 <sup>b</sup>	2.68 <sup>b</sup>	2.56 <sup>b</sup>	2.87 <sup>a</sup>	0.04
Empty gizzard	1.68	1.69	1.76	1.59	1.54	0.38
Kidney	0.49	0.46	0.52	0.48	0.52	0.06
Lungs	0.46 <sup>a</sup>	0.48 <sup>a</sup>	0.43 <sup>b</sup>	0.50 <sup>a</sup>	0.47 <sup>a</sup>	0.03
Intestinal weight (g)	4.25	3.64	3.77	3.80	4.02	0.44
Abdominal fat	0.86 <sup>b</sup>	1.03 <sup>a</sup>	1.17 <sup>a</sup>	1.52 <sup>a</sup>	1.59 <sup>a</sup>	0.36

<sup>a,b,c</sup> = means on the same row with different superscripts are significantly different (P<0.05); SEM = Standard Error of the Mean; SFSC = Sunflower Seed Cake.

Internal organs weights were significantly ( $P<0.05$ ) different across treatment groups for liver, gizzard, lungs and abdominal fat. Percent liver weight were significantly ( $P<0.05$ ) higher in birds fed the control diet (1.82 %) and 15 % SFSC (1.63 %) based diet supplemented with maxigrain<sup>®</sup> while others were comparable ( $P>0.05$ ). The observed variations between treatment groups agreed with the observations of Brenes *et al.* (1993) who reported that enzyme supplementation affects the relative size of some organs with relative reduction in the weights of such organs. In the work of Saleh *et al.* (2005), supplementation of cellulase to corn-soya diets of broiler chickens significantly reduced abdominal fat. However, some results suggested that enzyme supplementation improved carcass yield (Omojola and Adesehinwa, 2007). The use of exogenous enzymes in poultry diets with high sunflower seed cake inclusion resulted in better carcass percentage (Khan *et al.*, 2006).

#### **4.5.6 Economics of production of broiler chickens fed diets supplemented with maxigrain<sup>®</sup> on graded levels of sunflower cake (1 - 8 weeks)**

The cost benefit of producing broiler chickens fed diets supplemented with maxigrain<sup>®</sup> on graded levels of sunflower seed cake was evaluated at the end of the 8 weeks feeding trial using gross margin and return per Naira invested as shown in Table 4.17. Feed cost decreased with an increase in graded levels of sunflower seed cake in the diets for both starter and finisher phases across the treatment groups and this account for 11% reduction in feed cost. A similar trend was observed by Mohammed *et al.* (2020) who reported that feed cost (₦/kg) decreases with an increase in the inclusion level of toasted full fat sunflower seed meal in the diets of broiler chickens.

Revenue generated was high in birds fed 20 % SFSC (₦1,768) based diet with maxigrain<sup>®</sup>

**Table 4.17: Economics of Production of Broiler Chickens Fed Diets Supplemented with Maxigrain® on Graded Levels of Sunflower Seed Cake (1 - 8 weeks)**

Variable costs	Dietary Levels of SFSC (kg/100kg diet)				
	0	5	10	15	20
Cost of day-old chicks (₦/bird)	310.00	310.00	310.00	310.00	310.00
Maintenance (₦/bird)	33.33	33.33	33.33	33.33	33.33
Wood shavings (₦/bird)	6.67	6.67	6.67	6.67	6.67
Starter feed cost (₦/kg)	128.10	126.70	125.30	123.90	122.50
Starter feed intake (kg/bird)	1.55	1.58	1.57	1.56	1.50
Cost of feeding starter (₦/kg)	198.56	200.19	196.72	193.28	183.75
Finisher feed cost (₦/kg)	119.37	117.97	116.57	115.33	114.01
Finisher feed intake (kg/bird)	3.05	2.86	3.27	3.15	3.33
Cost of feeding finisher (₦/kg)	364.08	337.39	381.18	363.29	379.65
Total cost of feeding (₦/bird)	562.64	537.58	577.90	556.57	563.40
Water (₦/bird)	6.67	6.67	6.67	6.67	6.67
Brooding (₦/bird)	41.67	41.67	41.67	41.67	41.67
Vaccination & medication (₦)	33.33	33.33	33.33	33.33	33.33
Labour (₦/bird)	40.00	40.00	40.00	40.00	40.00
Transportation (₦)	20.00	20.00	20.00	20.00	20.00
Total variable cost (TVC (₦))	1,054.31	1,029.25	1,069.57	1,048.24	1,055.07
<b>Revenue</b>					
Average live weight (kg/bird)	2.18	1.95	2.07	2.04	2.21
Cost of live chicken (₦/kg)	800	800	800	800	800
Revenue (R (₦/bird))	1,744	1,560	1,656	1,632	1,768
Gross margin (R - TVC (₦))	689.69	530.75	586.43	583.76	712.93
Return per ₦ Invested (R/TVC)	1.65	1.52	1.55	1.56	1.68

SFSC = Sunflower Seed Cake

supplementation which is closely followed by birds fed the control diet with ₦1,744 while birds fed 5 % SFSC based diet supplemented with maxigrain<sup>®</sup> generated the lowest revenue of ₦1,560. This is attributed to the significant differences in average live weight (kg/bird) observed across the treatment groups. Birds fed 20 % SFSC based diet supplemented with maxigrain<sup>®</sup> gained a superior gross margin of ₦712.93 followed by birds fed the control diet (₦689.69), 10 (₦586.43) and 15 % SFSC (₦583.76) based diets while birds fed 5 % SFSC based diet gained the least gross margin of ₦530.75. Return per Naira invested were higher in birds fed 20 % SFSC (₦1.68) based diet and the control diet (₦1.65) while birds fed 15 (₦1.56), 10 (₦1.55), and 5 % SFSC (₦1.52) based diets descended simultaneously in return per Naira invested. This result revealed that 20 % inclusion of sunflower seed cake as a substitute for groundnut cake in broiler chickens diets reduced feed cost by 11% and improved economic viability of broiler chickens production as supported by the reports of Ghadeer *et al.* (2016) and Mohammed *et al.* (2020).

## CHAPTER FIVE

### 5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

#### 5.1 Summary

A laboratory study and two feeding trials were conducted to evaluate the effect of feeding diets containing graded levels of sunflower seed cake (SFSC) with and without maxigrain<sup>®</sup> supplementation on the growth performance, nutrients digestibility, haematological and serum biochemical parameters, carcass characteristics and cost benefit of producing broiler chickens. In each of the two feeding trials, 300 unsexed Cobb 500 day-old broiler chicks were randomly assigned to 5 dietary treatment groups with 60 birds per treatment and replicated 3 times with 20 birds per replicate in a completely randomized design. Five treatment diets were formulated with graded levels of sunflower seed cake incorporated as a substitute for groundnut cake in broiler starter and finisher diets at 0, 5, 10, 15, and 20 kg/100kg diet. The laboratory study revealed proximate composition of sunflower seed cake to contain 90.22 % dry matter, 37.19 % crude protein, 10.10 % crude fibre, 19.55 % ether extract, 6.07 % ash while nitrogen free extract was calculated as 27.09 %. The levels of the four commonly limiting essential amino acids were 1.63, 2.24, 3.00, and 1.29 g/100g for lysine, methionine, threonine and tryptophan respectively.

Result of the 1<sup>st</sup> feeding trial showed that birds fed 20 % SFSC based diet performed significantly ( $P < 0.05$ ) better in all growth parameters measured at the starter phase. Total feed intake ranged from 1251.17 to 1503.29 g/bird which increased with graded levels of sunflower seed cake from 0 to 20 kg/100kg diet. Birds fed diets with 10 and 20 % SFSC based diets had significantly ( $P < 0.05$ ) better values for feed conversion ratio while birds fed diets with 10, 15

and 20 % SFSC had better feed cost per kg gain. At the finisher phase, birds fed 20 % SFSC based diet had significantly ( $P<0.05$ ) higher final weight (2594.66 g/bird) and total weight gain (1509.54 g/bird) which accounts for 13.81 % improvement in final weight and 19.86 % for total weight gain. Birds fed the control diet, 10 and 20 % SFSC based diets had the best values of 2.39, 2.67 and 2.33 for feed conversion ratio and ₦284.26, ₦307.72 and ₦264.62 for feed cost per kg gain.

Significant ( $P<0.05$ ) differences were observed for % DM, % CP, % CF and % NFE apparent digestibilities. Haematological and serum biochemical parameters were significantly ( $P<0.05$ ) influenced by graded levels of sunflower seed cake but were within normal range values reported for healthy birds. Carcass traits and internal organs weight were significantly ( $P<0.05$ ) influenced by graded levels of sunflower seed cake. Birds fed 20 % SFSC based diet gained ₦994.70 gross margin with a return per Naira invested of ₦1.92. This accounts for 11.06 % reduction in feed cost and 20.52 % economic gain.

In the 2<sup>nd</sup> feeding trial, Maxigrain<sup>®</sup> was supplemented at 0.01 kg/100kg diet as recommended by the manufacturer on graded levels of sunflower seed cake. The starter phase result showed starter chicks fed 5, 10 and 20 % SFSC based diets with maxigrain<sup>®</sup> supplementation were significantly ( $P<0.05$ ) higher in final weight and total weight gain than birds fed the control diet. Total feed intake was significantly ( $P<0.05$ ) higher in starter chicks fed the control diet, 5, 10 and 15 % SFSC based diets than those starter chicks fed 20 % SFSC based diet supplemented with maxigrain<sup>®</sup>. Feed conversion ratio was better in starter chicks fed 5 and 20 % SFSC based diets while starter chicks fed 20 % SFSC based diet supplemented with maxigrain<sup>®</sup> had the best feed cost per kg gain. At the finisher phase, final weight and total weight gain were significantly ( $P<0.05$ ) higher in birds fed the control diet and 20 % SFSC based diet supplemented with

maxigrain<sup>®</sup> compared to other treatment groups but similar to birds fed 10 and 15 % SFSC based diet in total weight gain. Total feed intake was significantly ( $P<0.05$ ) higher in birds fed 10, 15 and 20 % SFSC based diets supplemented with maxigrain<sup>®</sup> compared to the other treatment groups. Feed conversion ratio and feed cost per kg gain were significantly ( $P<0.05$ ) better in birds fed control and 20 % SFSC based diet supplemented with maxigrain<sup>®</sup> compared to other treatment groups but similar to birds fed 15 % SFSC based diet for feed cost per kg gain.

Maxigrain<sup>®</sup> supplementation of diets containing graded levels of sunflower seed cake significantly ( $P<0.05$ ) influenced apparent digestibilities of % DM, % CP, % CF, % EE and % NFE with birds fed the control diet and 20 % SFSC based diet having higher apparent digestibilities for all the parameters except NFE. No significant ( $P>0.05$ ) difference were observed across treatment groups for haematological parameters when maxigrain<sup>®</sup> was supplemented. Live weight, dressed weight and dressing percentage were significantly ( $P<0.05$ ) influenced by maxigrain<sup>®</sup> supplementation of diets containing graded levels of sunflower seed cake. Prime cut parts were not significantly different except for drumsticks which differed significantly ( $P<0.05$ ) with birds fed the control diet, 10, and 20 % SFSC based diets having higher percentages for drumsticks over birds fed 5 and 15 % SFSC based diets. Internal organs weights were significantly ( $P<0.05$ ) different across treatment groups for liver, full gizzard, lungs and abdominal fat. Birds fed 20 % SFSC based diet gained ₦712.93 gross margin while birds fed the control diet gained ₦689.69 gross margin with a return per Naira invested of ₦1.68 and ₦1.65 respectively.

## **5.2 Conclusion**

Based on the findings of these research study, the following conclusions were drawn:

- i. Sunflower seed cake provides a rich source of crude protein (37.19 %) and essential amino acids in broiler chickens diets. This highlights the nutritive value of sunflower seed cake and its use as a dietary protein source in broiler chickens diets.
- ii. Sunflower seed cake incorporated up to 20 % as a substitute for groundnut cake in broiler starter and finisher diets improved growth performance by 19.86 % without detrimental effect on nutrients digestibility, haematological and serum biochemical parameters and carcass characteristics of broiler chickens.
- iii. Maxigrain<sup>®</sup> supplementation of diets containing sunflower seed cake significantly improved growth performance, nutrient digestibility, haematological parameters, serum biochemistry and carcass traits of broiler chickens.
- iv. The performance of the birds revealed that sunflower seed cake has favourable impacts on productivity and profitability compared with the control, with 20 % inclusion of sunflower seed cake as a substitute for groundnut cake in broiler chickens diets significantly reduced feed cost by 11.06 % and increased economic gain by 20.52 %.

### **5.3 Recommendations**

- i. Poultry farmers and feed millers can incorporate up to 20 % sunflower seed cake as a cost effective substitute for groundnut cake in broiler starter and finisher diets for improved performance and economic gain without adverse effect on the nutrient quality of the feed and profitability of the enterprise.
- ii. Further research should be conducted with sunflower seed cake on other poultry species

#### **5.4 Contribution to Knowledge**

The findings of this research study established that;

- i. Sunflower seed cake incorporated up to 20 % as a substitute for groundnut cake in broiler chickens diets improved final weight and total weight gain by 13.81 and 19.86 % compared with the control without detrimental effects on growth performance, nutrients digestibility, blood parameters and carcass characteristics of broiler chickens.
- ii. 20 kg/100kg diet inclusion of sunflower seed cake reduced feed cost by 11.06 % in broiler chickens diets without compromising feed quality and increased economic gain by 20.52 % compared with the control.

## REFERENCES

- Abbas, T. E. E., and Yagoub, Y. M. (2008). Sunflower cake as a substitute for groundnut cake in commercial broiler chicks' diets. *Pakistan Journal of Nutrition*, 7(6): 782-784. <http://dx.doi.org/10.3923/pjn.2008.782.784>
- Abdel-Malaak, N. Y. (1989). Physiological responses of some nutritional treatments in relation to productive traits in broiler chicks. Ph.D. Thesis, Faculty of Agriculture, Zagazig University, Egypt.
- Abdelrahman, M. M., and Saleh, F. H. (2007). Performance of broiler chickens fed on corn-sunflower meal diets with  $\beta$ -glucanase enzyme. *Jordan Journal of Agricultural Science*. 3(3): 272-280.
- Abeke, F. O. (2008). *Fibre in poultry diets concerns and options*. In: Proceeding of the 33<sup>rd</sup> Annual conference of the Nigerian Society for Animal Production held at the College of Agricultural Sciences, Olabisi Onabanjo University, Ayetoro, Ogun State, Nigeria, p 409.
- Abeke, F. O., Ogundipe, S. O., Sekoni, A. A., Dafwang, I. I. and Oladele, S. B. (2003). *Effect of Duration of Cooking Lablab Beans on Organ Weight and Blood Parameters of Pullet Chicks*. Proceedings of the 28th Annual Conference of the Nigerian Society for Animal Production, Ibadan. 28: 240-242.
- Abid, A. R., Iqbal, Z., Rassol, S., Babar, M. E., and Aslam, A. (1990). Effect of amino acid supplementation on the nutritive value of sunflower meal in broilers feeds. *Sarhad Journal of Agriculture*. 6(2): 143-146.
- Abu, O. A., Tewe, O. O., and Bakare, J. (1999). Performance, nutrient digestibility and carcass characteristics of rabbit fed sweet potato based diets. *International Journal of Animal Science*. 14(2): 197-201.
- Adams, E. A., and Pough, R. (1993). Non-starch polysaccharides and their digestion in poultry. *Feed Compounder*, 13: 19-21.
- Adebayo, O. O., and Adeola, R. G. (2005). Socio-economic Factors Affecting Poultry Farmers in Ejigbo Local Government Area of Osun State. *Journal of Human Ecology*, 18: 39-41
- Adejumo, D. O., and Williams, A. O. (2006). Effects of partial replacement of soyabean meal or groundnut cake with sunflower seed meal in broiler chicken diets on performance and plasma metabolites. *Global Journal of Pure Applied Science*. 12(2): 159-164. <http://dx.doi.org/10.4314/gjpas.v12i2.16584>
- Adeyemo, G. O., Longe, O. G., and Lawal, H. A. (2007). Proximate composition of locust meal. In *Tropentag* (pp. 1-4).

- Adeyeye, E. I. (2004). The chemical composition of liquid and solid endosperm of ripe coconut. *Oriental Journal of Chemistry*, 20(3):471-476.
- Aduku, A. O. (2012). *Tropical Feedstuffs Analysis Table*. Department of Animal Science, Ahmadu Bello University, Zaria, Nigeria.
- Afifi, M. A. (1972). Sunflower seed meal as a substitute for soybean meal in broilers ration. *Arch. Geflugelkund.* 36: 129-136.
- Aftab, U. (2009). Utilization of alternative protein meals with or without multiple enzyme supplementation in broilers fed low-energy diets. *Journal of Applied Poultry Research*. 18(2): 292-296. <http://dx.doi.org/10.3382/japr.2008-00103>
- Akande, K. E., Doma, U. D., Agu, H. O., and Adamu, H. M. (2010). Major antinutrients found in plant protein sources: their effect on nutrition. *Pakistan Journal of Nutrition*, 9(8): 827-832.
- Akinmutimi, A. H. (2004). Effect of processing on metabolisability of energy content of sword beans (*Canavalia gladiata*) using broiler chicks (starter phase). *Proceedings of 28th Annual Nigerian Society of Animal Production conference* Ibadan, Nigeria, p. 194-196.
- Alagawany, M., Farag, M. R., Abd El-Hack, M. E., and Dhama, K. (2015). The practical application of sunflower meal in poultry nutrition. *Advances in Animal and Veterinary Sciences*. 3(12): 634-648. <http://dx.doi.org/10.14737/journal.aavs/2015/3.12.634.648I>
- Alaku, S. O. (2010). Introduction to Animal Science. First Edition, Jee Communications, Enugu-Nigeria, p. 13-16, 236
- Ali, M. E. (1999). *Effect of some Agricultural industrial by products in the performance of broiler chicks*. (Ph.D. Thesis), Animal Production Department, Faculty of Agriculture, Zagazig University, Egypt.
- Ali, S. A. M., Hyder, O., and Abdalla Abasaid, M. A. (2011). Sunflower meal as an alternative protein source to groundnut meal in laying hens' ration. *Egyptian Journal of Poultry Science*, 31(4): 745-753.
- Allen, C. M., Bedford, M. R., and McCracken, K. J. (1995). *A synergistic response to enzyme and antibiotic supplementation of wheat-based diets for broilers*. Proceedings, 10th European Symposium on Poultry Nutrition, 15–19 October, Antalya, Turkey. World's Poultry Science Association. p. 369–370.
- Almirall, M., Francesch, M., Perez-Vendrell, A. M., Brufau, J., and Esteve García, E. (1995). The differences in intestinal viscosity produced by barley and  $\beta$ -glucanase alter digesta enzyme activities and ileal nutrient digestibilities more in broilers chicks than in cocks. *Journal of Nutrition*. 125(4): 947–955.
- Annison, G. (1993). The role of wheat non-starch polysaccharides in broiler nutrition. *Australian Journal of Agricultural Research*, 44(3): 405-422.

- Annison, G., and Choct, M. (1993). Enzymes in poultry diets. In: *Enzymes in Animal Nutrition Proceedings*, 1st Symposium, Switzerland. October 13-16. pp: 61-63.
- Araújo, L. F., Araújo, C. S. S., Petrolí, N. B., Laurentiz, A. C., Albuquerque, R., and Neto, M. A. T. (2011). Sunflower meal for broilers of 22 to 42 days of age. *Revista Brasileira de Zootecnia*. 40(10): 2142-2146. <http://dx.doi.org/10.1590/S1516-35982011001000011>
- Araújo, W. A. G., Albino, L. F. T., Rostagno, H. S., Hannas, M. I., Pessoa, G. B. S., Messias, R. K. G., Lelis, G. R., and Ribeiro Jr., V. (2014). Sunflower meal and enzyme supplementation of the diet of 21- to 42 day-old broilers. *Brazilian Journal of Poultry Science*. 16(2): 17-24.
- Are, L. A., Igbokwe, E. M., Asadu, C. L. A., and Bawa, G. S. (2010). Comprehensive Certificate of Agricultural Science for Senior Secondary Schools. 1st Edition, University Press Plc Ibadan, Nigeria, p. 421-423
- Arija, I., Brenes, A., Viveros, A., and Elices, R. (1998). Effects of inclusion of full-fat sunflower kernels and hulls in diets for growing broiler chickens. *Animal Feed Science Technology*. 70(1-2): 137–149. [http://dx.doi.org/10.1016/S0377-8401\(97\)00077-1](http://dx.doi.org/10.1016/S0377-8401(97)00077-1)
- Association of Official Analytical Chemists, AOAC. (2006). *Official Methods of Analysis* (W. Horwitz), 8th Ed, Washington DC. p. 423-858.
- Atteh, J. O. (2004). Response of broiler chicks to dietary fungal or bacterial enzyme additives. Paper presented at the Bio–ingredients Nigeria Ltd Seminar, Lagos
- Attia, Y. A., El-Deek, A. A., and Osman, M. (1998). Evaluation of sunflower meal as a feedstuff in diets for ducks. *Arch Geflugelkud*,62(6): 273-282.
- Ayivor, V. F., and Hellins, C. E. K. (1982). *Poultry Keeping in the Tropics*. 3rd Edition University press, Ibadan
- Bawa, G. S., Tegbe, T. S. B., Ogundipe, S. O., Dafwang, I. I. and Abu, E. A. (2003). *The effect of feeding graded dietary levels of lablab seed as a replacement for soyabean on the performance characteristics of young pigs*. Proceedings of the 28<sup>th</sup> Annual conference of the Nigerian Society for Animal Production, p. 230-232.
- Bedford, M. R. (1995). Mechanism of action and potential environmental benefits from the use of feed enzymes. *Animal Feed Science and Technology*. 53: 145–155.
- Bedford, M. R., and Schulze, H. (1998). Exogenous enzymes of pigs and poultry. *Nutrition Research Review*. 11: 91-114.
- Benitez, L. V. (1989). *Amino Acid and fatty acid profiles in aquaculture nutrition studies*. In S. S. De Silva (Ed.), *Fish Nutrition Research in Asia*. Proceedings of the Third Asian Fish Nutrition Network Meeting p. 23- 35. Asian Fish Society Special Publication. 4, 166 p. Asian Fisheries Society, Manila Philippines.

- Biesiada-Drzazga, B., Ewska, A. G., Janocha, A., and Markowska, M. (2010). Analysis of application of concentrated mixtures containing soybean extracted meal and sunflower meal in goose broiler feeding. *Arch Geflügelkd*, 74(2): 109–115.
- Boros, D., Marquardt, R. R., and Guenter, W. (1998). Site of exoenzyme action in gastrointestinal tract of broiler chicks. *Canadian Journal of Animal Science*. 78(4): 599-602. <http://dx.doi.org/10.4141/A97-092>
- Brenes, A., Rotter, B.A., Marquardt, R.R. and Guenter, W. (1993). The nutritional value of raw, autoclaved and dehulled peas (*Pisum sativum*) in chicken diets as effected by enzyme supplementation, *Canadian Journal of Animal Science*, 73: 605-614.
- Brenes, A., Centeno, C., Viveros, A., and Arija, I. (2008). Effect of enzyme addition on the nutritive value of high oleic acid sunflower seeds in chicken diets. *Poultry Science*, 87(11): 2300–2310. <http://dx.doi.org/10.3382/ps.2008-00130>
- Campbell, E. J. (1983). Sunflower oil. *J. Am. Oil Chemistry Society*, 60(2): 339A
- Campbell, G. L., Classen, H. E., and Salmon, R. (1989). Enzyme supplementation of barley diets for broilers. *Feedstuffs*. 56: 26-27.
- Carré, P. (2009). Review and evaluation major and most promising processing technologies for oil seed pretreatment and extraction. Sustoil. D2.1: Report about dehulling, the first step of oilseeds biorefining. Sustoil: Developing advanced Biorefinery schemes for integration into existing oil production/transesterification plants. WP 2: Optimisation of primary processing (e.g. oil extraction and refinery). Creol
- CETIOM. (2003). Sunflower meal: quality protein and fibre. Fiches Techniques October 2003. Edition CETIOM
- Cheva-Isarakul, B., and Tangtaweewipat, S. (1991). Effect of different levels of sunflower seed in broiler rations. *Poultry Science*. 70(11): 2284-2294.
- Choct, M. and Annison, G. (1990). Anti-nutritive activity of wheat pentosans in broiler diets. *British Poultry Science*, 30: 811–821.
- Chrappa, V., Peter, V., and Bod, A. K. (1987). Administration of sunflower meal to broiler chickens. *Zivocisma-Vyroba*. 32: 163-172.
- Clandinin, D. R., and Robblee, A. R. (1950). The effect of methods of processing on the nutritive value of sunflower meal. *Poultry Science*. 29(5): 746-789.
- Classen, H. L. (1996). Successful application of enzymes relies on knowledge of the chemical reaction to be affected and conditions under which the reaction will occur. *Feed Mix*, 4: 22-28.

- Classen, H. L., and Bedford, M. R. (1991). The use of enzymes to improve the nutritive value of poultry feeds. In: *Recent Advances in Animal Nutrition*. W. Haresign, and Cole D. J. A., U.K. p. 95-116.
- Clifford, M. N. (2000). Chlorogenic acids and other cinnamates – nature, occurrence, dietary burden, absorption and metabolism. *Journal of Science in Food Agriculture*. 80(7): 1033–1043.
- Colin, G. S., George, B., and Ensminge, M. E. (2004). Poultry Science by Pearson education incorporated upper saddle river New Jersey 07458.
- Cowan, W. D., Pettersson, D. R., and Rasmussen, P. B. (1999). The influence of multi-component pectinase enzymes on energy and amino acid availability in vegetable proteins. *Proceedings of Australian Poultry Science*. (Symposium), Vol. 11. University of Sydney, Australia.
- Creswell, D. C. (1994). Upgrading the nutritional value of grains with the use of enzymes. Technical bulletin, American Soybean Association, 341 Orchard Road No.11-03 Liat Towers, Singapore.
- Daghir, N. J., Raz, M. A., and Uwayjon, M. (1980). Studies on the utilization of full-fat sunflower seed in broilers rations. *Poultry Science*. 59(10): 2273-2278. <http://dx.doi.org/10.3382/ps.0592273>.
- Dass, S. (1994). Poultry Production. 1st Ed., CBS Publishers and Distributions, New Delhi Bangalore, India, p. 98-100
- De Leonardis, A., Albanese, T., and Macciola, V. (2006). Biodegradation in vivo and in vitro of chlorogenic acid by a sunflower seedling (*Helianthus annuus L.*) like-polyphenoloxidase enzyme. *European Food Research and Technology*. 223(3): 295–301.
- De Leonardis, A., Macciola, V., and Di Domenico, N. (2005). A first pilot study to produce a food antioxidant from sunflower seed shells (*Helianthus annuus L.*). *European Journal of Lipid Science Technology*. 107(4): 220–227.
- Delic, I., Levic, J., and Sredanovic, S. (1992). Standard and improved sunflower meal containing 44% crude protein-production, chemical composition, nutritive value. 33rd *Meeting of Production and Manufacturing of Oilcrops*, Budva. p. 268-287.
- Dessouky, M. S. (1996). *Nutritional studies on rapeseeds and sunflower seeds as feedstuffs in broiler rations*. (Ph.D. Thesis), Faculty of Agriculture, Al-Azhar University., Egypt.
- Devendra, C. (1988). General approaches to animal nutrition research and their relevance to fish production in the Asian region. In: Desilva, S. S., (Ed.), *Finfish nutrition research in Asia*. Heinemann Asia Singapore, Singapore. p. 724.
- Dilger, R. N., Onyango, E. M., Sands, J. S., and Adeola, O. (2004). Evaluation of microbial phytase in broiler diets. *Poultry Science*. 83: 962–970.

- Dublecz, K. (2003). Poultry nutrition without animal protein sources. *Allattenyesztes es Takarmanyozas*, 52(5): 479-489.
- Duru, S., and Dafwang, I. I. (2010). Effect of Maxigrain Supplementation of Diets with or Without Rice Offal on the Performance of Broiler Chicks. *International Journal of Poultry Science* 9(8): 761-764
- Earp, C. F., Akinghala, J. O., Ring, S. H. and Rooney, L. W. (1981). Evaluation of several methods to determine tannin in sorghum with varying kernel characteristics. *Cereal chemistry* 58: 234-238.
- Egbunike, G. N., and Williams, J. T. (2005). Utilization of crude testis extracts to enhance broiler production in the humid tropics. ASSET (Inpress).
- El-Barbary, A. (1997). *Effect of sunflower seed meal (Helianthus annuus) as feed replacement for layer ration on some physiological parameters and reproductive performance*. (M. Sc. Thesis), Faculty of Agriculture, Alexandria University.
- El-Deek, A. A., Abaza, M. A., Mona, O., Attia, Y. A., and Khalaf, A. M. (1999b). Inclusion of sunflower meal and commercial enzyme to egg type strain ration during growth period 2- Effects on sexual maturity, laying performance, internal egg and shell qualities and economic returns. *Egyptian Journal of Poultry Science*, 19(3): 549-567.
- El-Sherif, K., Gippert, T., and Gerendai, D. (1995). Effect of different levels of expeller sunflower seed meal in broiler diets. *Animal Breed Feed*, 44(5): 427-435.
- El-Sherif, K., Gippert, T., and Gerendai, D. (1997). Effect of feeding sunflower meal supplemented with energy and amino acids on laying hen performance. *Animal Breed Feed*, 46(1): 87-94.
- El-Zubeir, E. A., and Ibrahim, M. A. (1991). Effect of dietary full fat raw sunflower seed on performance and carcass skin colour of broilers. *Journal of Science in Food Agriculture*. 55(3): 479-481.
- Eruvbetine, D., Dipeolu, M. A. and Oguntona, E. B. (2002). Composition of enzyme and antibiotic inclusion in diets for laying hens. *Proceedings of the 27<sup>th</sup> Conference, Nigeria Society for Animal Production (NSAP) March 17-21, 2002*, held at the Federal University of Technology, Akure, Nigeria. p. 101- 104.
- European Commission (2007). Council Regulation (EC) No 834/2007 of 28 June 2007 on organic production and labelling of organic products and repealing Regulation (EEC) No 2092/91. Official Journal of European Union, L 189, 20.7.2007, p. 1-23
- F.A.O. (1997). Food and Agricultural Organization, year book report, Rome, Italy, pp 100-110.
- FAS (2011). *Sunflower seed and Products World Supply and Distribution*. Foreign Agricultural Service - USDA

- Fasuyi, A. O. and Aletor, V. A. (2005). Varietal and functional properties of cassava leaf meal and leaf protein concentrates. *Pakistan Journal of Nutrition*, 4(1), 43-49.
- FEDIOL (2010). *Risk assessment of the chain of sunflower seed meal and oil products*. FEDIOL
- Fengler, A. I., and Marquardt, R. R. (1988). Water-soluble pentosans from rye. II. Effects on the rate of dialysis and on the retention of nutrients by the chick. *Cereal Chemistry* 65: 298–302.
- Freitas, D. M., Viera, S. L., Angel, C. R., Favero, A. and Maiorka, A. (2011). Performance and nutrient utilization of broiler fed diet supplemented with a novel monocomponent protease. *Journal of Applied Poultry Resources*. 20: 322 -334.
- Furlan, A. C., Mantovani, C., Murakami, A. E., Moreira, I., Claudio, S., and Nunes, M. E. (2001). Utilização do farelo de girasol na alimentação de frangos de corte. *R. Bras. Zootec.* 30(1): 158-164.
- Gama, E. N. (2002). *Response of broilers to graded levels of cassava as compared to maize*. (B,Tech Agric Proiect), Federal University of Technology, Yola, Adamawa State, 'Nigeria.
- Geron, L. J. V. (2007). Utilization of agro-industrial waste in livestock feed. *Pubvet*, 1: 110-25.
- Ghadeer, A., Elsayed, H., Wafaa, E. and Mahmoud, E. (2016). Effect of dietary inclusion of sunflower meal on performance, carcass traits, litter moisture and economic efficiency of broiler chickens. *Zagazig Veterinary Journal*, 44(3): 234-243.
- Gheyasuddin, S., Carter, C. M., and Mattil, K. F. (1970). Effect of several variables on the extractability of sunflower seed proteins. *Journal of Food Science*,35(4): 453-456. <http://dx.doi.org/10.1111/j.1365-2621.1970.tb00955.x>.
- Golob, P., Farrell, G., and Orchard, J. E. (2002). Crop Post-harvest: Principles and practice, volume 1. In: Golob, P., Farell, G., and Orchard, J. E. *Crop Post-harvest: Science and Technology*. John Wiley & Sons.
- González-Pérez, S., Merck, K. B., Vereijken, J. M., Van Koningsveld, G. A., Gruppen, H., and Voragen, A. G. J. (2002). Isolation and characterization of undenatured chlorogenic acid free sunflower (*Helianthus annuus*) proteins. *Journal of Agriculture and Food Chemistry*. 50(6): 1713-1719.
- Green, S., Bertrand, S. L., Duron, M. J. C., and Maillard, R. (1987). Digestibilities of amino acids in soyabean, sunflower and groundnut meals, determined with intact and caeectomised cockerels. *British Poultry Science*. 28(4): 643-652.
- Grompone, M. A. (2005). Sunflower oil. In: *Bailey's Industrial Oil and Fat Products*, Sixth Edition, John Wiley and Sons, Inc.

- Horvatovic, M. P., Glamocic, D., Zikic, D., and Hadnadjev, T. D. (2015). Performance and some intestinal functions of broilers fed diets with different inclusion levels of sunflower meal and supplemented or not with enzymes. *Brazilian Journal of Poultry Science*. 17(1): 25-30.
- Hossain, M. A., Islam, M. M., Islam, A. F., and Iji, P. A. (2011). Constraints to use of all-vegetable feed ingredients and strategies to improve such diets for poultry birds. A review. *Bangladesh Research Publications Journal*, 6(1): 120-135.
- Huisman, J., and Tolman, G. H. (1992). Anti-nutritional factors in the plant proteins of diets for non-ruminants. In: P. C. Garnsworthy, W. Haresign and D. J. A Cole (Eds.) *Recent Advances in Animal Nutrition*. U.K: Butter-worth Heinemann Ltd., Oxford, p. 3-31.
- IARMS (2019). Metrological Data from Institute for Agricultural Research Metrological Station, Ahmadu Bello University, Samaru, Zaria, Nigeria.
- Ibrahim, M. A., and El-Zubeir, E. A. (1991). Higher fiber sunflower seed meal in broiler chick diets. *Animal Feed Science and Technology*. 33(3-4): 343-347. [http://dx.doi.org/10.1016/0377-8401\(91\)90072-Z](http://dx.doi.org/10.1016/0377-8401(91)90072-Z).
- Institute National of the Recherche Agronomique, INRA. (2004). *Tables of composition and nutritional value of raw materials for animals of livestock interest: pigs, poultry, cattle, sheep, goats, rabbits, horses, fish*. Madrid: Ediciones Mundi Press, p. 194-197.
- Ismaila, Y. S., Denban, M. K., Emmanuel, K. M., and Augustine, C. (2011). Nutritional and phytochemical screening of *Senna obtusifolia* indigenous to Mubi. *Advances in Applied Science Research*, 22: 432-437.
- Jackson, D., and Dalibard, P. (1995). The measurement and validation of the technique of using digestible amino acids for diet formulation in poultry and swine. In: simpósio latino americano de nutrição de suínos e aves, Campinas. Anais. Campinas: CBNA, 47-72.
- Jain, N. C. (1986). Scholm Veterinary Haematology 4<sup>th</sup> edition Philadelphia, Lea and Ferbinger. *Journal of Applied Poultry Research*. 5: 203-209
- Jain, N. C. (1993). *Essentials of Veterinary Hematology*. Philadelphia: Lea Fabiger.
- Jakmola, R. C. (2005). *Evaluation of locally available feed and fodder to improve the quality and formulate the complete economic rations with high roughage diet*. Final Reports (1999-2005) National Agricultural Technology Project, CSWRI, Avikanagar. p. 67.
- Jordan, F. T. W and Pattison, M. (1999) .*PoulDisee*, 4th Edition, Saunders Company Ltd, United Kingdom, p. 546
- Kakade, M. L., Rachis, J. J., Meghee, J. E. and Puski, C. (1974). Determination of Typsin Inhibitor Activity of Soy Products: A collaboration Analysis of Improved procedure. *Cercals Chemistry*, 51: 376-379.

- Kalmendal, R., Elwlinger, K., Holm, L., and Auson, R. (2011). High fiber sunflower cace affects small intestine digestion and health in broiler chickens. *British Poultry Science*. 52(1): 86–96.
- Kartika, I. A. (2005). Nouveau procédé de fractionnement des graines de tournesol: expression et extraction en extrudeur bi-vis, purification par ultrafiltration de l’huile de tournesol. Thèse de doctorat. Institut national polytechnique de Toulouse, spécialité: Sciences des Agroressources.
- Khan, R. U., Chand, N., and Ali, A. (2013). Effect of organic acids on the performance of Japanese quails. *Pakistan Journal of Zoology*. 48: 1799-1803.
- Khan, S. H., Sardar, R., and Siddique, B. (2006). Influence of enzymes on performance of broilers fed sunflower-corn based diets. *Pakistan Veterinary Journal*. 26(3): 109-114.
- Khusheeba, M., and Sajid, M. (2013). A review on role of exogenous enzyme supplementation in poultry production. *Emirates Journal of Food Agriculture*. 25(1): 66-80, doi: 10.9755/ejfa.v25i1.9138
- Kidd, M. J. (2000). Successful Broiler Production Depends on a Sound Feeding Programme. Information Sheet 1609, Mississippi State University.
- Klasing, K. C. (1998). Comparative Avian Nutrition. CAB International, Wallingford, UK.
- Kocher, A., Chret, M., Porter, M. D., and Broz, J. (2000). The effects of enzyme addition to broiler diets containing high concentrations of canola or sunflower meal. *Poultry Science*,79(12): 1767–1774.
- Kwari, I. D., Igwebuikie J. U., and Diarra, S. S. (2010). Growth performance and carcass measurements of broiler chickens fed different levels of raw sorrel (*Hibiscus sabdariffa*) seed meal. *Journal of Environmental Issues and Agriculture in Developing Countries*. p. 162 – 168.
- Kwari, I. D., Igwebuikie, J. U., and Dierra, S. S. (2011). Growth, haematology and serum chemistry of broiler chicks fed raw or differently processed roselle (*Hibiscus sabdariffa*) seed meal in a semi-arid environment, *International Journal of Science and Nature*, 2(1): 22-27.
- Lairon, D., Lafont, K., Vigne, J. L., Nalbone, G., Leonardi, J., and Hanton, J. C. (1985). Effect of dietary fibers and cholestyramine on the activity of pancreatic lipase in vitro. *Am. Journal of Clinical Nutrition*. 42: 629–638.
- Lamb, G. N. (1991). Manual of veterinary laboratory technique. ciba-geigy, Kenya. Pp.92-109.
- LAVC (2009). Clinical Pathology in Avian Species. Latin America Veterinary Congress (LAVC), Lima, Peru.
- Lazaro, R. M., Garcia, P., Medel, S., and Mateos, G. G. (2003). Influence of enzyme and

- performance and digestive parameters of broilers fed rye-based diets. *Poultry Science*, 82:132-140.
- Lee, K. H., and Lee, M. C. (1982). Effect of feeding locally produced sunflower oil as protein supplement on the performance of the broiler chicks. *Journal of Taiwan livestock Research*. 15: 9-24.
- Leeson, S., and Summers, J. D. (2001). Nutrition of the Chicken, 4<sup>th</sup> Edition. University Books, Guelph, Canada.
- Lesson, S. (2000). Introduction to Poultry Nutrition. Department of Animal and Poultry Science, University of Guelph.
- Leung, J., Fenton, T. W., and Clandinin, D. R. (1981). Phenolic components of sunflower flour. *Journal of Food Science*. 46: 1386–1393. <http://dx.doi.org/10.1111/j.1365-2621.1981.tb04180.x>
- Levic, J., Radoicic, D., Sredanovic, S., and Levic, L. J. (1998). Technological procedures for enhancing the production of high protein content sunflower meal. In: Koseoglu, S. S., Rhee, K. C., Wilson, R. F, editor. *Advances in oils and fats, antioxidants and oilseed by-products*. American Oil Chemists' Society Press. 104-107.
- Liu, J. D., Li, Q. Y., Zeng, Z. K., Li, P., Xu, X., Wang, H. L., Zhang, S. and Piao, X. S. (2015). Determination and prediction of the amino acid digestibility of sunflower seed meals in growing pigs. *Asian Australasian Journal of Animal Science*, 28(1): 86-94. <http://dx.doi.org/10.5713/ajas.14.0109>
- Loosli, J. K., Oyenuga, V. A., and Babatunde, G. M. (1999). Animal Production in the Tropics, 6th Edition Heiman Educational Books Publishers, Ibadan, Nigeria, p. 402
- Luckett, S., Garcia, R. S., Barker, J. J., Konarev, A. V., Shewry, P. R., Clarke, A. R., and Brady, R. L. (1999). High resolution structure of a potent cyclic proteinase inhibitor from sunflowers. *Journal of Molecular Biology*. 290(2): 525–533.
- Lusas, E. W. (1985). Sunflower seed protein in new protein foods. Academic press public, Inc., New York. 5: 393. (C. F. Salem, 1990). <http://dx.doi.org/10.1016/B978-0-12-054805-7.50019-1>.
- Maheri-Sis, N., Baradaran-Hasanzadeh, A. R., Salamatdoust, R., Khosravifar, O., Agajanzadeh-Golshani, A., and Dolg, J. (2011). Effect of microwave irradiation on nutritive value of sunflower meal for ruminants using in vitro gas production technique. *Journal of Animal and Plant Sciences*. 21(2): 126-131.
- Mandal, A. B., Elangovan, A. V., Tyagi, P. K., Kaur, S., and Johri, A. K. (2006). Compatibility of using rapeseed and sunflower seed meal in maize-sorghum-soy based diets for broiler chickens. *Indian Journal of Animal Science*. 76(9): 737-741.

- Mandal, A. B., Tyagi, P. K., Elangovan, A. V., Kaur, S., and Johri, A. K. (2003). Utilizing sunflower seed meal along with maize or maize and pearl millet in the diets of broilers. *Indian Journal of Poultry Science*. 38(3): 243-248.
- Mandibaya, W., Mutisi, C., and Hamudikuwanda, H. (1999). The nutritive value, intake, digestibility and nitrogen balance of farm-grown and prepared sunflower-based dairy calf meals. *Tropical Animal Health Production*, 31(5): 321-331.
- Maria, M. Y., Justo, P., Julio, G., Javier, V., Francisco, M., and Manuel, A. (2004). Determination of tryptophan by high performance liquid chromatography of alkaline hydrolysates with spectrophotometric detection. *Food Chemistry*, 85(2): 317-320.
- Marinov, B., Angelova, L., and Mandov, I. (1973). Sources of protein in mixed feeds for chickens. 1-Sunflower seed oil meal. *Zhivotnovodni Nauki*, 10: 81– 85.
- Marquardt, R. R. (1997). Enzyme enhancement of the nutritional value of cereals: role of viscous, water-soluble, non-starch polysaccharides in chick performance. In: *Enzymes in Poultry and Swine Nutrition*, edited by Marquardt, R. R. and Han, Z. The International Development Research Center: 5-18.
- Marquardt, R. R., Brenes, A., Zhang, Z., and Boros, D. (1996). Use of enzymes to improve nutrient availability in poultry feedstuffs. *Animal Feed Science and Technology*. 60: 321-330.
- McDonald. P., Edwards, R. A., Greenhalgh, J. F. D and Morgan; C. A. (1998). *Animal Nutrition*, Fifth Edition, Longman Educational Books Publishers, United Kingdom, p. 450
- McNab, J. M. (2002). *Poultry Feedstuffs: Supply, Composition and Nutritive Value*. CABI Publishing.
- Mitruka, B. M., and Rawnsley, H. M. (1997). *Clinical, biochemical and hematological reference value in normal experimental animals*. Mason publishing company, New York. p. 35-50.
- Mohammed, A. B., Doma, U. D., Bello, K. M., Yusuf, S. Z., and Alhassan, N. M. (2020). Performance and Economics of Production of Broiler Chickens Fed Dietary Levels of Toasted Full Fat Sunflower Seed Meal (*Helianthus annuus*). *Nigerian Journal of Animal Science and Technology*, 3(2): 197 - 205
- Morgan, A. J. and Bedford, M. R. (1995). Advances in the development and application of feed enzymes. *Journal of Australian Poultry Science*, 7: 109–115.
- Morrison, A. B., Clandinin, D. K., and Robblee, A. R. (1953). The effects of processing variables on the nutritive value of sunflower seed oil meal. *Poultry Science*. 32(3): 492-496.

- Musharaf, N. A. (1991). Effect of graded levels of sunflower seed meal in broiler diets. *Animal Feed Science and Technology*. 33(1-2): 129-137. [http://dx.doi.org/10.1016/0377-8401\(91\)90051-S](http://dx.doi.org/10.1016/0377-8401(91)90051-S)
- Mushtaq, T. M., Sarwar, G., Nisa, M. U., and Jamil, A. (2006). The influence of exogenous multi enzyme preparation and graded levels of digestible lysine in sunflower meal-based diets on the performance of young broiler chicks two weeks post hatching. *Poultry Science*. 85(12): 2180–2185. <http://dx.doi.org/10.1093/ps/85.12.2180>
- Mushtaq, T., Sarwar, M., Ahmad, G., Mirza, M. A., Ahmad, T., Noreen, U., Mushtaq, M. M. H., and Kamran, Z. (2009). Influence of sunflower meal based diets supplemented with exogenous enzyme and digestible lysine on performance, digestibility and carcass response of broiler chickens. *Animal Feed Science and Technology*. 149(3-4): 275-286.
- Naidu, S. (2008). *Irrigation management*, Volume 5. In: Sethuraman, G., International Encyclopaedia of Agricultural Science and Technology, Mittal Publications.
- Narahari, D., and Rajini, R. A. (2003). Chemical composition and nutritive value of kapok seed meal for broiler chickens. *Journal of British Poultry Science* 44(3): 505-509.
- Nassiri, M. H., Salari, S., Arshami, J., Golian, A., and Maleki, M. (2012). Evaluation of the nutritional value of sunflower meal and its effect on performance, digestive enzyme activity, organ weight, and histological alterations of the intestinal villi of broiler chickens. *Journal of Applied Poultry Research*. 21(2): 293–304. <http://dx.doi.org/10.3382/japr.2011-00396>
- National Research Council (NRC) (1994). Nutrient Requirement of Domestic Animal. Nutreints Requirements of Poultry, 4th edition. Washington D.C: National Academic Press. 100-120.
- National Veterinary Research Institute. (2000) . A Guide to the Use of Vaccines, Vom, Plateau State, Nigeria, p. 1-2
- NCPA (2008). *Trading rules of the national cottonseed products association, Inc*. Adopted at the 112th Annual Session of the Association Held at Destin, Florida, May 3 - 6, 2008 with Charter and By-Laws, Lists of Committees and Members and Other Information. National Cottonseed Products Association, Florida.
- Niemiec, J., Wierczewska, E., St Pi Ska, M., and Riedel, J. (1996). Wp yw ró nego rodzaju t uszczu w paszy na wyniki produkcyjne kurcz t brojlerów. *Zesz. Nauk. Prz. Hod.* 24: 137-142.
- Ogundipe, S. O., Abeke, F. O., Sekoni, A. A., Dafwang, I. I. and Adeyinka, I. A. (2003). Effects of duration of cooking on the utilization of Lablab purpureus beans by pullet chickens. *Proceeding of 28th Conference of the Nigerian Society for Animal Production*, pp 233-235.
- Oil World (2011). Major meals world summary balances. *Oil World Weekly*, 54(8): 95-104.

- Ojo, S. O. (2003). Productivity and technical efficiency of poultry egg production in Nigeria. *International Journal of Poultry Science*, 2:6
- Okonkwo, W. I., and Akubuo, C. O. (2001). Thermal analysis and evaluation of heat requirement of a passive solar energy poultry chick brooder in Nigeria. *Journal of Renewable Energy*, 9:1
- Oliveira, D. D., Pinheiro, J. W., Fonseca, N. A. N., and Oba, A. (2012). Performance of broiler chickens fed with sunflower cake. *Semina Ciênc Agrár*, 33:1979-1990.
- Ologhobo, A. D. (1991). Substitution of sunflower seed meal for soybean meal and groundnut meal in practical broiler diets. *Archives of Animal Nutrition*. 41(3): 513-520.
- Olomu, J. M. (1995). Optimum protein and energy levels for finishing broiler chickens in tropical environment. *Nigerian Journal of Animal Production*, 4: 239-253
- Olukosi, J. O., and Erahbor, P. O. (1988). Introduction to Farm Management Economics: Principles and Applications, Agitab Publishers, Zaria. p. 114
- Oluyemi, J. A., and Roberts, F. A. (2000). Poultry Production in Warm Wet Climates. Revised edition. Spectrum Books Limited, Ibadan, Nigeria, p. 244
- Omojola, A. B., and Adesehinwa, A. O. K. (2007). Performance and carcass characteristics of broiler chickens fed diets supplemented with graded levels of Roxazyme G. *International Journal of Poultry Science*. 6(5): 335-339. <http://dx.doi.org/10.3923/ijps.2007.335.339>
- Omole, A. J., Obi, O. O., Ogunleke, O. O., Odejide, J. O., Awe, O. A., and Popoola, Y. A. (2011). Performance and nutrient digestibility of broiler finishers fed diets containing exogenous Hamecozyme. Proceedings of the 16th Annual Conference, Animal Science Association of Nigeria (ASAN). Sept. 12th-15th 2011 Kogi State University, Anyigba, Nigeria. Pp 399-401.
- Oshodi, A. A., Esuoso, K. O., and Akintayo, E. T. (1998). Proximate and amino acid composition of some underutilized Nigerian legume flour and protein concentrates. *La Rivista Italiana delle Sostanze grasse*, 75:409-412.
- Ozen, N., and Erdem, H. (1992). Replacement of soybean meal by sunflower meal in broiler diets supplemented with synthetic lysine and methionine. Ondo Kus Mayis University. Ziraat Fakultesi, Zootekni Bolumu, Samsun, Turkey. *Cited in Poultry Science*. 79: 77-79 (2000).
- Pariza, M. W., and Cook, M. (2010). Determining the safety of enzymes used in animal feed. *Regional Toxicology Pharmacology*. 56: 332-342.
- Parkhurst, C. R., and Mountney, G. J. (1997). Poultry Meat and Egg Production. CBS Publishers and Distributions, New Dethi, India, p. 110-190
- Pauzenga, U. (1985). *Feeding parent Stock*. Zootechnician International, pp. 22-24.

- Pedrosa, M. M., Muzquiz, M., Garcia-Vallejo, C., Burbano, C., Cuadrado, C., Ayet, G., and Robredo, L. M. (2000). Determination of caffeic and chlorogenic acids and their derivatives in different sunflower seeds. *Journal of Science in Food Agriculture*. 80(4): 459–464. [http://dx.doi.org/10.1002/\(SICI\)1097-0010\(200003\)80:4<459::AID-JSFA549>3.0.CO;2-O](http://dx.doi.org/10.1002/(SICI)1097-0010(200003)80:4<459::AID-JSFA549>3.0.CO;2-O)
- Peric, L., Milic, D., and Bjedov, S. (2010). The effect of sunflower meal on growth performance of broiler chicks. *Proceedings of the 13th European Poultry Conference; Tours. France*.
- Pettersson, D., and Aman, P. (2007). Enzyme supplementation of a poultry diet containing rye and wheat. *Brazilian Journal of Nutrition*. 62: 139-149.
- Pinheiro, J. W., Fonseca, N. A. N., Silva, C. A., Cabrera, L., Bruneli, F. A. T., and Takahashi, S. E. (2002). Farelo de girassol na alimentação de frangos de corte em diferentes fases de desenvolvimento. *R. Bras. Zootec*. 31(3): 1418-1425. <http://dx.doi.org/10.1590/S1516-35982002000600013>
- Poncet, C., Rémond, D., Lepage, E., and Doreau, M. (2003). Comment mieux valoriser les protéagineux et oléagineux en alimentation des ruminants. *Fourrages*, 174: 205-229.
- Rad, F. H., and Keshavarz, K. (1976). Evaluation of the nutritional value of sunflower meal and the possibility of using sunflower meal for soybean meal in poultry diets. *Poultry Science*. 55(5): 1757-1765. <http://dx.doi.org/10.3382/ps.0551757>
- Rajesh, M. M., Sudhakara, P., and Reddy, P. V. V. S. N. (2006). Effect of sunflower meal with or without enzyme supplementation on the performance of broilers. *Indian Journal of Veterinary and Animal Science Research*. 2(2): 200-204.
- Rama Rao, S. V., Raju, M. V. L. N., Panda, A. K., and Redely, M. R. (2006). Sunflower seed meal as a substitute for soybean meal in commercial broiler chicken diets. *British Poultry Science*. 47(5): 592-598. <http://dx.doi.org/10.1080/00071660600963511>
- Rama Rao, S. V., Raju, M. V. L. N., Reddy, M. R., and Panda, A. K. (2004). Replacement of yellow maize with pearl millet (*Pennisetum typhoides*), foxtail millet (*Setaria italica*) or finger millet (*Eleusine coracana*) in broiler chicken diets containing supplemental enzymes. *Asian-Australian Journal of Animal Science*. 17(6): 836-842.
- Ranade, A. S., and Rajmane, B. V. (1992). Effect of feed supplement on commercial broilers. In: *Proceedings of the 19<sup>th</sup> World's Poultry Congress*, Amsterdam, Netherlands, 2:485-487.
- Randall, C. J. (1998). Diseases and Disorders of Domestic Fowl and Turkey, 2nd Edition, Mosby International Ltd, London, p. 178
- Ravindran, A., and Blair, R. (1992). Feed resources for poultry production in Asia and Pacific. II. Plant protein sources. *World Poultry Science Journal*. 48(3): 205-231.

- Raza, S., Ashraf, M., Pasha, T. N., Latif, F., Babar, M. E., and Hashmi, A. S. (2009). Effect of enzyme supplemented high fibre sunflower meal on performance of broilers. *Pakistan Journal of Zoology*, 41(1): 57-60.
- Rosen, G. (2006). Exogenous enzymes as pro-nutrients in broiler diets. In J. Wiseman and P. C. Garnsworthy, eds, *Recent developments in non-ruminant nutrition*, Nottingham, UK: Nottingham University Press, p. 163-191.
- Ross, J. G., Christie, G., Halliday, W. G., and Jones, R. M. (1976). Determination of Haematology and blood chemistry values in healthy six-week old broiler hybrids. *Avian Pathology*. 5(4): 273-281
- Rostagno, H. S., Albino, L. F. T., and Donzele, J. L. (2005). Tabelas brasileiras para aves e suínos : composição de alimentos e exigências nutricionais. 2.ed. Viçosa, MG: UFV, Departamento de Zootecnia, 186p.
- Sabir, M. A., Sosulski, F. W., and Finlayson, A. J. (1974). Chlorogenic acid-protein interactions in sunflower. *Journal of Agriculture and Food Chemistry*. 22(4): 575-578. <http://dx.doi.org/10.1021/jf60194a052>
- Salari, S., Nassiri, M. H., Arshami, J., and Golian, A. (2009). Nutritional evaluation of full-fat sunflower seed for broiler chickens. *Asian-Australian Journal of Animal Science*. 22(4): 557–564.
- Saleh, F., Ohtsuka, A., and Hayashi, K. (2005). Effect of dietary enzymes on the ileal digestibility and abdominal fat content in broilers. *Animal Science Journal*. 76(5): 475–478. <http://dx.doi.org/10.1111/j.1740-0929.2005.00293.x>
- Salem, M. S. (1990). *Chemical and technological studies on proteins of some oil seeds*. (Ph. D. Thesis), Faculty of Agriculture, Al-Azhar University, Egypt.
- Salih, F. I. M., and Taha, S. H. (1989). Sunflower seed meal as a protein concentrate in diets for broiler chicks. *Sudan Journal of Animal Production*. 2: 27-33.
- Samarasinghe, K., Wenk, C., Silva, K. F. S. T., and Gunasekera, J. M. (2000). Turmeric (*Curcuma longa*) root powder and mannanoligosaccharides as alternatives to antibiotic in broiler chicken diets. *Asian-Australasian Journal of Animal Science*, 16: 1495–1500.
- Samy, M. S. M. (1979). Nutritive values of some Egyptian Feedstuffs with poultry. *Pakistan Journal of Animal Science Research*, 31(1-2): 9-12.
- San Juan, L. D., and Villamide, M. J. (2000). Nutritional evaluation of sunflower seed and products derived from them. Effect of oil extraction. *British Poultry Science*. 41(2): 182–192. <http://dx.doi.org/10.1080/713654913>
- SAS (2008). *Statistical Analysis System User Guide for Statistics Version 10*. Carolina, U.S.A.: SAS Institute Inc,

- Schalm, O. W., Jain, N. C. and Carroll, E. J. (1975). *Veterinary haematology*. 3rd ed. Lea and Fabiger, Philadelphia.
- Schneeman, B. O. (1978). Effect of plant fiber on lipase, trypsin, and chymotrypsin activity. *Journal of Food Science*. 43(2): 634–635. <http://dx.doi.org/10.1111/j.1365-2621.1978.tb02372.x>
- Scott, M. L., Nesheim, M. C., and Young, R. J. (1997). *Essential inorganic elements: nutrition of the chicken*. 3rd ed. New York (NY): M. L Scott Associates. p. 287-304
- Selvaraj, R. K., and Purushothaman, M. R. (2004). Nutritive value of full-fat sunflower seeds in broiler diets. *Poultry Science*. 83(3): 441-446.
- Senkoylu, N., and Dale, N. (2006). Nutritional evaluation of a high-oil sunflower meal in broiler starter diets. *Journal of Applied Poultry Research*. 15(1): 40–47.
- Sheppy, C. (2003). The current feed enzyme market and likely trends. In: M. R. Bedford and G. G. Partridge (Eds.). pp.1-10. *Enzymes in Farm Animal Nutrition* CABI Publishing Wallingford, Oxon, UK.
- Shu'aibu, M. T. (2014). Effects of Processing Methods of African Locust Bean Seed Meal on Nutrient Composition and Utilisation by Broiler Chickens. A Ph.D Thesis, Department of Animal Science, Faculty of Agriculture, Ahmadu Bello University, Zaria.
- Simrak, S., Chinrasari, O., and Aegwanich, W. (2004). Haematological, electrolyte and serum Biochemical value of the thai indigenous chicken. *Journal of Science and Technology*. 26(5): 425-430
- Sing, K. S., and Panda, B. (1992). *Poultry Nutrition*. New-Delhi, India: Kalyani Publishers.
- Singh, K. S., and Prasad, C. M. (1979). Feeding value of sunflower and groundnut cakes for broilers. *Animal Feed Science and Technology*. 4(2): 143-159.
- Singh, R. A. (2005). Poultry Production, In: Sastry, N. S. R and Thomas, C. K (Eds), *Livestock Production Management*. Fourth Revised and Enlarged Edition, Kalyani Publishers, New Delhi, India, p. 393-447
- Slavica, S., Jovanka, L., and Olivera, D. (2006). Enhancing nutritional quality of sunflower meal in broiler feeding. *Archives of Zootech*, 9(1): 65-72.
- Smith, K. J. (1968). A review of the nutritional value of sunflower meal. *Feedstuffs (USA)*, 40: 20-22.
- Soliman, A. A. (1997). *Evaluation of the productivity and performance of broiler breeder hens fed practical or vegetable diets containing high levels of barley and sunflower meal with multi-enzymes supplement during the pre-laying and laying periods*. (Ph.D. Thesis), Faculty of Agriculture, Alexandria University, Egypt.

- Sosulski, F. W., McCleary, C. W., and Sliman, F. S. (1972). Diffusion extraction of chlorogenic acid from sunflower kernels. *Journal of Food Science*. 37(2): 253-255. <http://dx.doi.org/10.1111/j.1365-2621.1972.tb05829.x>
- Sredanovic, S. A., Levića, J. D., Jovanovic, R. D., and Đuragić, O. M. (2012). The nutritive value of poultry diets containing sunflower meal supplemented by enzymes. *Apteff*, 43(1-342): 79-91.
- Sredanovic, S., Levic, J., and Djuragic, O. (2005). Enzyme enhancement of the nutritional value of sunflower meal. *Biotechnology in Animal Husbandry*. 21(5-6-2): 197-202.
- Steen, R. W. J. (1989). A comparison of soya-bean, sunflower and fish meals as protein supplements for yearling cattle offered grass silage-based diets. *Animal Production*. 48(1): 81-89.
- Sturkie, P. D. (2000). *Avian Physiology*. 5<sup>th</sup> edition. Academic press. San Diego, California, U.S.A. p. 1-10
- Sutardi, I. and Buckle, K. A. (1985). Reduction in phytic acid levels in soya bean during production, storage and frying. *Journal of Food Science*, 50: 260-263.
- Swain, B. K., Johri, T. S., Shrivastav, A. K., and Majumdar, S. (1996). Performance of broilers fed on high or low fibre diets supplemented with digestive enzymes. *Journal of Applied Animal Research*. 10(1): 95–102. <http://dx.doi.org/10.1080/09712119.1996.9706134>
- Swick, R. A. (1999). Considerations in using protein meals for poultry and swine. St Louis: American Soybean Association. (Technical Bulletin, AN21).
- Tavernari, F. C., Albino, L. F. T., Morata, R. L., Dutra Júnior, W. M., Rostagno, H. S., and Viana, M. T. S. (2008). Inclusion of sunflower meal, with or without enzyme supplementation, in broiler diets. *Brazilian Journal of Poultry Science*. 10(4): 233–238. <http://dx.doi.org/10.1590/s1516-635x2008000400007>
- Tavernari, F. C., Dutra Junior, W. M., Albino, L. F. T., Rostagno, H. S., Vieira, R. A., and da Silva, C. R. (2009). Effect of different levels of sunflower meal in diets on the performance of broiler chickens. *R Bras Zootec*. 38(9): 1745-1750.
- Thomas, O. P., Martin, R. S., Wessels, J. P. H., and Human, J. B. B. (1965). Sunflower meal as a source of protein for chickens rations. *South African Journal of Agricultural Science*. 8: 1061-1064.
- Treviño, J., Rebole, A., Rodriguez, M.L., Ortiz, L. T., Centeno, C., and Alzueta, C. (1998). Nutritional effect of chlorogenic acid fed to growing broiler chickens. *Journal of Science in Food Agriculture*. 76(2): 156–160. [http://dx.doi.org/10.1002/\(SICI\)1097-0010\(199802\)76:2<156::AID-JSFA912>3.0.CO;2-M](http://dx.doi.org/10.1002/(SICI)1097-0010(199802)76:2<156::AID-JSFA912>3.0.CO;2-M)
- Turaki, I. S. (2005). *Effect of Varying Levels of Benniseed as a Source of Methionine on the Performance and Carcass Characteristics of Broiler*. (M.Sc Thesis), Faculty of

Agriculture, Abubakar Tafawa Balewa University, Bauchi, Nigeria

- Udensi, E. A., Arisa, N. U. and Maduka, M. (2008). Effect of time duration of thermal treatments on the nutritive value of *Mucuna flagellipes*. *Nigerian Food Journal*, 26(2): 53-59.
- Ukachukwu, S. N. (2000). *Chemical and nutritional evaluation of Mucuna cochinchinesis (Iyon beans) as an alternative protein ingredient in broiler diets* (Ph.D Thesis), Faculty of Agriculture, University of Nigeria, Nsukka.
- Umar, H. A., Adamu, R., Dahiru, D., and Nadro, M. S. (2007). Levels of anti-nutritional factors in some wild edible fruits of Northern Nigeria. *African Journal of Biotechnology*, 6(16): 1935-1938.
- Valdivie, M., Sardinias, O., and Garcia, J. A. (1982). The utilization of 20% sunflower seed meal in broiler diets. *Cuban Journal of Agricultural Science*, 16: 167-171.
- Velmurugu, R. (1990). *Poultry development review*. Palmerston North, New Zealand: Monogastric Research Centre, Institute of Food, Nutrition and Human Health, Massey University.
- Viera, S. L., Lima, I. L., Borges, C. A. Q., Fernandes, L. M., and Quadros, V. R. (2003). Broiler utilization of vegetarian diets. *Journal of Poultry Science*, 82: 38-39.
- Villamide, M. S., and San Juan, L. D. (1998). Effect of chemical composition of sunflower seed meal on its true metabolizable energy and amino acid digestibility. *Poultry Science*. 77(12): 1884-1892. <http://dx.doi.org/10.1093/ps/77.12.1884>
- Waldroup, P. W., Hillard, C. M., and Mitchell, R. J. (1970). Sunflower meal as a protein supplement for broiler diets. *Feedstuffs*, 42-43.
- Warenham, C. N., Wiseman, J., and Cole, D. J. A. (1994). In: *Principles of Pig Science*, Eds. D. J. A. Cole, J. Wiseman and M. A. Varley, Nottingham: Nottingham press, 141-167.
- Zatari, I. M., and Sell, J. L. (1990). Sunflower meal as a component of fat supplemented diets for broiler chickens. *Poultry Science*, 69(9): 1503-1507.
- Zhang, Y., and Parsons, C. M. (1994). Effects of over processing on the nutritional quality of sunflower meal. *Poultry Science*. 73(3): 436-442. <http://dx.doi.org/10.3382/ps.0730436>
- Žilić, S., Maksimović Dragišić J., Maksimović, V., Maksimović, M., Basić, Z., Crevar, M., and Stanković, G. (2010). The content of antioxidants in sunflower seed and kernel. *Helia*. 33(52): 75-84.