PERFORMANCE OF BROILER CHICKENS FED DIETS CONTAINING VARYING LEVELS OF MOLASSES-FLAVOURED SORGHUM DISTILLER WASTES

BY

ZARMA, Adamu Garba
MTech/SAAT/2018/8174

DEPARTMENT OF ANIMAL PRODUCTION,
SCHOOL OF AGRICULTURE AND AGRICULTURAL TECHNOLOGY,
FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

AUGUST, 2023

PERFORMANCE OF BROILER CHICKENS FED DIETS CONTAINING VARYING LEVELS OF MOLASSES-FLAVOURED SORGHUM DISTILLER WASTES

BY

ZARMA, Adamu Garba
MTech/SAAT/2018/8174

**A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL,
FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF TECHNOLOGY IN ANIMAL PRODUCTION**

AUGUST, 2023

DECLARATION

I hereby declare that this thesis titled: **"Performance of broiler chickens fed diets containing varying levels of molasses-flavoured sorghum distiller wastes"** is a collection of my original research work, and it has not been presented for any other qualification anywhere. Information from other sources (published or unpublished) has been duly acknowledged.

ZARMA, Adamu Garba
MTech/SAAT/2018/8174
Federal University of Technology,
Minna, Nigeria

SIGNATURE & DATE

CERTIFICATION

The thesis titled: **"Performance of broiler chickens fed diets containing varying levels of molasses-flavoured sorghum distiller wastes"** by ZARMA, Adamu Garba (MTech/SAAT/2018/8174) meets the regulations governing the award of the degree of Master of Technology of the Federal University of Technology, Minna, and it is approved for its contribution to scientific knowledge and for its literary presentation.

DR. A. A. MALIK MAJOR SUPERVISOR	------------------------------- SIGNATURE & DATE
DR. (MRS) K. E. AKANDE CO-SUPERVISOR	----------------------------- SIGNATURE&DATE
PROF. D. N. TSADO HEAD OF DEPARTMENT	------------------------------ SIGNATURE & DATE
PROF. J.H. TSADO DEAN, SCHOOL OF AGRICULTURE AND AGRICULTURAL TECHNOLOGY	------------------------------ SIGNATURE & DATE
ENGR. PROF. O. K. ABUBAKRE DEAN OF POSTGRADUATE SCHOOL	------------------------------ SIGNATURE & DATE

DEDICATION

This research work is specially dedicated to my late wife, Mrs Hauwa Zarma.

ACKNOWLEDGEMENTS

My sincere appreciation goes to the Head of Department of Animal Production, Prof. D.N. Tsado. My special thanks goes to my major supervisor, Dr. A. A. Malik, without whose quality and friendly supervision this work would not have been completed. I would also like to sincerely thank my co-supervisor, Dr (Mrs). K. E. Akande, for her input, guidance, kindness and encouragement to move forward, despite all odds. I am also thankful to Prof. O. J. Alabi and the entire staff of the Department of Animal Production, for the various roles they played in ensuring my success as a student of the Department. Also, many thanks go to the Federal College of Education, Kontagora, for the study leave granted to me, to enable me undergo this postgraduate programme.

Special thanks also go to my lovely children, Dinah, Dorcas (late), Deborah and David, for their support and encouragement. Many thanks also go to my course mates; and especially Mr. Mubarak Ibrahim, for the role they played to ensure that the work is completed within record time. Special thanks go to Mr Mgbonu Kelechi, for the role he played to see to the success of this work.

I also thank Miss Rebecca Ibrahim of First Bank Plc., Kontagora, and Dr.Solomon Adekojo for their encouragement and support towards the success of this research work.

Finally, my gratitude go to all those who contributed one way or the other towards the successful completion of this research work. You are too numerous to mention here. But I pray that God Almighty will reward you all, and continue to bless you all! Thank you!!

ABSTRACT

This study was conducted to determine the performance of broiler chickens fed diets containing varying levels of molasses-flavoured sorghum distiller wastes. A total of 180 one-day-old broiler birds were used in this study. The birds were randomly allotted to four treatments using a completely randomized design model. Each treatment had three replicates with 15 birds per replicate. Treatment 1 served as the control which had 0 % of molasses-flavoured sorghum distiller wastes. Treatments 2, 3 and 4 had 10, 20, and 30 % inclusion levels of molasses-flavoured sorghum distiller wastes (MFSDW) respectively. The birds were fed the experimental diets *ad libitum* for seven weeks (after adjustment for one week) during which data on growth performance, apparent nutrient digestibility, economy of feed conversion, carcass characteristics and sensory properties were collected. The data were analyzed using a one-way analysis of variance, and means separated using Duncan Multiple Range Test, where significant. Results of the study showed that the addition of dietary MFSDW at 30 % significantly ($P<0.05$) improved the total body weight gain (TBWG) 1734.22 g and feed conversion ratio (FCR) 4.37 compared to the control 1643.12 g and 4.63 respectively. Addition of 30 % inclusion level of MFSDW influenced ($P<0.05$) the total cost of feed intake (₦35.55) compared to the control group (₦47.00) while the feed cost per kg WG at 10 % inclusion level (504.05) was significantly different ($P<0.05$) from those fed the basal diet (664.52) at the starter phase. At the finisher phase, chickens fed 30 % inclusion level had better ($P<0.05$) total cost of feed intake, FI (₦ 416.20) and feed cost per kg WG (₦1241.68) compared to the basal group (₦596.93 and ₦1753.30 respectively). The addition of dietary MFSDW at 10 % had better ($P<0.05$) dressing percentage (88.81 %) compared to the control (83.54 %). Furthermore, the addition of MFSDW to the diets of broiler birds at 30 % inclusion level positively influenced ($P<0.05$) the juiciness of their meat (8.45) compared to those fed the basal diet (7.90). It can therefore, be concluded that the addition of MFSDW at 30 % inclusion level in the diets of broiler birds improved their growth performance, apparent nutrient digestibility, economy of feed conversion, carcass characteristics and sensory properties of the meat.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

In Nigeria, broiler chicken has a very high potential for meeting the daily animal protein requirements for the populace, which has for a long time been below standard requirements (Food and Agricultural Organisation, FAO, 2004). Broiler chicken has higher feed conversion efficiency than most other species of domestic animals (Daryll and Harwood, 2013). Considering its high quality protein, readily available fat with low cholesterol, and low fibre content, chicken meat is rated higher than those of other species of domestic animals; and can be conveniently used to substitute for red meat, thereby reducing the dangers associated with the consumption of red meat.

Animal feed is the largest cost item in livestock production, especially poultry, accounting for between 60-70 % of the total cost of production. Due to high cost of conventional feed ingredients, there is the need to identify and use locally available feed resources to compound feeds that are nutritionally balanced, with the aim of reducing the total cost of production and maximize profit (Leeson and Summers, 2005). The rapid expansion of local breweries has stimulated interest in feeding the major by-product of ethanol production process, distillers' wastes (DW), to livestock (Dinneen, 2007). Reports from the International Starch Institute, (ISI) suggested that sorghum is the 5th most important grain in terms of production (ISI, 2008). Utilization of sorghum, in place of maize, for ethanol production has kept increasing over the years. Processing sorghum produce different by-products such as sorghum bran, sorghum brewers' grains, sorghum distillers' dried grains, sorghum wine residue and sorghum gluten feed (National Resource Institute, NRI, 1999; INTSORMIL, 2008; Tokach *et al*., 2010).

The problem associated with feeding distillers' wastes to livestock is the high concentration of sulphur found in it (Pritchard, 2007) which could potentially result in health problems and decrease in performance (Gould, 1998). In order to effectively utilize these by-products for non-ruminants, they have to be subjected to treatments that will improve and facilitate nutrients release as well as enhance their palatability and rate of consumption by broilers. One way of enhancing the palatability of distillers' wastes in broiler diet is through the addition of molasses as a flavouring agent and supplement. The concentration of sulphur in distillers' wastes makes it to have bitter or sour taste, which may eventually reduce its palatability and consumption (Dinneen, 2007). Flavouring distillers' wastes with molasses is an attempt to enhance its consumption by broilers. Utilization of sorghum distillers' wastes to feed broiler chickens is geared towards reducing the cost of production, and thereby maximizing profit.

1.2 Statement of the Research Problem

Cereal grains like maize and guinea corn, which forms the bulk of energy source in poultry feed, are limited in supply because they are used both as industrial raw materials and as food for humans. Hence, there is competition between humans and poultry for these limited available resources (Adejinmi *et al.*, 2007). Feed is the largest cost item in poultry production accounting for between 60-70 % of the total cost of production. Due to the high cost of conventional feed ingredients like maize and guinea corn, there is the need to identify and use alternative feed resources to compound diets that are nutritionally balanced at a lower cost (Leeson and Summers, 2005). Sorghum distillers' wastes have the potential, as an alternative feed resource, to replace certain percentage of maize or guinea corn in broiler diets.

Fasuyi (2005) reported that growth rate of broiler chicken was not affected when sorghum brewers’ grains were included up to 20 % in their diets; however, feed conversion ratio was lowered due to high feed intake. Adama *et al*. (2007) concluded that the inclusion of 10 % sorghum brewers’ grains to the feed of broiler chicken decreased digestibility and growth non-significantly. Heuzé *et al*. (2015) opined that dried brewers' grains should not exceed 10 % of the diet unless its price can compensate for the decreased feed efficiency.

Molasses is generally added to poultry feed as an energy supplement, a nutritive additive and a binder. According to Shymaa (2017), molasses can be a source of quick energy and an excellent source of minerals for farm animals. There are limited research works on the use of molasses as a flavouring agent for sorghum distiller’s wastes and their effects on the performance of broiler chickens. Therefore, this study is designed to evaluate the effectiveness of molasses-flavoured sorghum brewers’ wastes as a cheaper non-conventional feed ingredient for broiler chicken.

1.3 Justification for the Study

The population of Nigeria is on the increase. Nigeria is the seventh most populated country of the world (National Bureau of Statistics, 2015). The animal protein production is far less than the average demand. Meaningful improvement on the supply of animal protein is needed in order to bridge the gap between animal protein intake and its supply. The use of by-products as feedsstuffs for livestock does not only benefit the animals by providing nutrients, it also helps in getting rid of rubbish heaps and waste dumps in the environment (Grasser, *et al*., 1995; Oltjen and Beckett, 1996; Mirzael–Aghazaghali and Maherisis, 2008).

By-products can be a source of environmental pollution as dumping or burning creates potential water and air pollution (Mirzael – Aghazaghali and Maherisis, 2008). Feeding of these by-products to livestock not only serves as a means of utilizing them but also allow these by-products to be part of sustainable agriculture, turning potential wastes into milk, meat and eggs for human consumption (Oltjen and Beckett, 1996).

Distillers’ grains are rich in energy and contain approximately 36 % fibre, making them a valuable potential energy source for ruminant animals (Stock *et al*., 2000). Utilizing them as cheaper non-conventional feedstuffs for broiler chicken would considerably reduce cost of production and increase animal protein supply in Nigeria.

1.4 Aim and Objectives of the Study

The aim of this research study is to evaluate the performance of broiler chicken fed diets containing varying levels of molasses-flavoured sorghum distillers' wastes.

The objectives are to:

i. determine the growth performance and apparent nutrient digestibility of broiler chickens fed diets containing varying levels of molasses-flavoured sorghum distillers' wastes;

ii. evaluate the carcass characteristics of broiler chickens fed diets containing varying levels of molasses-flavoured sorghum distillers' wastes;

iii. assess the sensory properties of the meat of broiler chickens fed diets containing varying levels of molasses-flavoured sorghum distillers' wastes; and

iv. determine the economy of feed conversion of broiler chickens feed diets containing molasses-flavoured sorghum distillers' wastes.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Molasses: Its Chemical and Nutritional Composition

Molasses (or treacle in the UK consumer market) is a general term for concentrated juice from sugarcane or sugarbeet, or raw cane sugar in concentrated solution, after varying amounts of sucrose have been removed (Clarke, 2003). Sugarcane molasses is the major food molasses. Molasses are the residue left after the crystallization of sucrose. It is relatively little used in confectionery apart from in the manufacture of liquorice, which is its largest use, and in making treacle toffee. In this product, the treacle adds colour and flavour (Edwards, 2009). Several variants of molasses are defined and recognized based on their composition and production techniques. These include cane molasses, beet molasses, citrus molasses, hemicelluloses molasses, starch molasses, high test molasses, black strap integral molasses, condensed molasses, sulphured molasses and unsulphured molasses (Clarke, 2003; Edwards, 2009; Chaouachi, 2009; Eric, 2012).

The calcium content of sugar cane molasses is high (up to one percent), whereas the phosphorus content is low (Abdelgader *et al*. 2019). Cane molasses is also high in sodium, potassium, magnesium and sulphur. Beet molasses is higher in potassium and sodium but lower in calcium. Habibu *et al*. (2014) stated that some of the mineral contents in molasses are iron, zinc, copper, manganese, potassium, sodium and calcium. The vitamins present belong to vitamin B complex including: thiamine, riboflavin, niacin, panthothenic acid, biotin and choline but molasses lacks vitamin C.

2.2 Utilization of Molasses in Animal Production

Sugar cane molasses is capable of yielding greater quantities of soluble carbohydrates which can be used as a source of energy in poultry diets (Hajer, 2007). Cane molasses is a cheap source of energy compared to other energy rich feeds, especially sorghum and other cereal grains. Eisa (1996) reported that obtaining energy from molasses is far much cheaper than obtaining it from cereal grains, because molasses has a relatively high content of soluble carbohydrates in the form of sugars. According to Shymaa (2017), molasses can be a source of quick energy and an excellent source of minerals for farm animals and even humans.

Molasses can be a key ingredient for cost effective management of feeds and pastures (Shymaa, 2017). The use of molasses had no significant effect on feed cost and cost per kilogram feed, however; revenue and gross margin were positively influenced by 60 g per litre and no significant effect was recorded at lower levels in comparison with the control. Thus, molasses utilization in feeds of poultry is a means of effective management of cost (Ndelekwute *et al*., 2015; Abdelgader *et al*., 2019). It could be concluded that 60 g of molasses per litre of drinking water could be fed to broiler chickens at finishing phase for improved growth, dressing percentage and economic maximization (Ndelekwute *et al*., 2015).

Sugarcane molasses has several important roles in livestock feeding, due to the nutritive, appetizing and physical properties of its sugar content. However, toxicity of molasses has been reported when given in large dose (Pérez, 1995). In poultry, molasses is commonly used as a binder in dry poultry diets and as an energy source but can as well be administered to chickens through drinking water (Ndelekwute *et al*., 2011). Molasses have also been extensively used in diets to feed both pigs and chickens (Ndelekwute *et al*., 2011). The problem of feeding molasses through diet is that it easily forms cake with feed. The caking problem is better solved by feed pelleting which farmers cannot afford (Ndelekwute *et al*., 2011). The authors proffered a solution by feeding molasses through drinking water, and reported improved performance.

Sugarcane juice can make up to 25 percent of the poultry ration and molasses up to 30 percent, but it should be noted that over ten percent molasses results in watery faeces (FAO, 2004). Raw sugar however can be fed at up to 50 percent of the ration without watery faeces. Combining one part molasses with three parts sugar gives good production without the digestive problems. Molasses is often added to rations at low levels of inclusion to make it more palatable, although there may be problems with evenly mixing the liquid, and with fungal toxins in the stored feed, encouraged by the sugar levels. Even, for human consumption, the supplementation of sorghum dry distillers' grains (DDG) with molasses up to 50 % inclusion level is shown to have received 50 % acceptance (Rosentrater and Krishnan, 2006). Table 2.1 summarizes inclusion levels for different feedstuffs in poultry rations.

Table 2.1 Optimum levels of inclusion in poultry rations of some ingredients

Feedstuff	Optimum level in the diet (%)
Banana meal	5-10
Citrus molasses	5-10
Citrus pulp	1-2
Cocoa bean residue	2-7
Cocoa husk	6-15
Cocoa shell	5-15
Coconut meal/cake	5-15
Coffee grounds	3-5
Coffee pulp	3-5
Kapok seed cake	5-10
Leucaena leaf meal	2-5
Oil-palm sludge, dried	10-30
Oil palm sludge, fermented	20-40
Palm kernel meal	10-40
Palm oil	2-8
Rubber seed meal	10-30
Sugar cane molasses	10-30
Raw sugar	40-50
Sugar cane juice	10-25

Source: Hutagalung (1981)

2.3 Growth Performance of Broiler Chickens Fed Molasses

Feeding of 60 g per litre molasses solution to broiler chicken resulted in significantly higher dressing percentage and abdominal fat compared to the control and other levels (20 and 40 g) of molasses (Ndelekwute *et al*., 2015). However, there were no significant (P>0.05) differences between the other levels of molasses and the control. Ndelekwute *et al*. (2015) indicated that 60 g/litre of molasses improved feed consumption rate and produced higher feed intake. This is an indication that higher levels of molasses in water are required to improve carcass yield in broiler chickens (Ndelekwute *et al*., 2015). Similarly, Shymaa (2017) reported that giving molasses in the drinking water of broiler chickens resulted in increased feed intake. Meanwhile, he stated that the highest feed consumption level was attained by the birds given 2 ml of molasses per litre of drinking water; whereas the lowest levels of feed consumption was attained by the control group that did not have molasses. According to Abdelgader *et al*. (2019), poultry, particularly geese and ducks, can be fattened on liquid diets containing up to 60 % DM of molasses. On the other hand, Khalid *et al*. (2007) reported contradicting results, that incorporation of cane molasses in broiler diets above 4 % decreased feed intake. It can be adduced that increased feed intake might be due to the fact that, molasses increases the palatability of feed. The palatability of molasses makes it an excellent carrier for other feeds especially unpalatable feedstuffs. Molasses was shown to have no significant effect on weight gain, feed gain ratio, protein efficiency ratio and water intake (Ndelekwute *et al*., 2015), which was contrary to the findings of Ndelekwute *et al*. (2011) who reported that broiler chicken fed with molasses supplement had significantly better body weight, conformation parameters (breast width, keel length) at both starter and finisher phases as well as consuming lesser feed at the finisher phase. They stated that there was no mortality and recommended that molasses can be fed as a supplement to broilers through drinking water. Feeding of molasses did not have any significant effect on the weight of internal organs except small intestine and caeca (Ndelekwute *et al*., 2015). Both the small intestine and the caeca were enlarged and this was attributed to increased fermentation in the two segments, as molasses have been reported to cause fermentation in the gut.

2.4 Sorghum Production

Sorghum is the 5th most important cereal grain in terms of production (ISI, 2008) and part of the grain production goes into processing. In 2006, about 1.2-2.3 million tons of sorghum were used for ethanol production in the world (Taylor *et al*., 2006). Assuming that ethanol production yields 35 % distillery by-products, sorghum distillers' dried grains (DDGS) at that time was about 0.4 - 0.8 million tons. In the USA, roughly 29 % of the sorghum produced is being utilized for ethanol production (Jessen, 2010). Sorghum brewer's grains are available in regions that produce sorghum beer (clear or opaque beer), notably in Africa. The main producers of sorghum beer are South Africa (150,000 tonnes/year sorghum grains are used for malting), Nigeria, and Zimbabwe. Total opaque beer production in industrial breweries of Southern and Eastern Africa is around 1700 million litres per year but it is assumed that twice this volume is home-brewed (Taylor, 2003). Sorghum is not widely used in the starch industry and the production of sorghum gluten feed and gluten meal is limited (Taylor *et al*., 2006).

Recent expansion in ethanol production in North America and other parts of the world has caused an increase in the availability of distillers' grains plus solubles as a feedstuff for livestock production. This has resulted in the need for additional research on the efficacy of using ethanol by-products in livestock diets as compared to traditional feeds such as feed grains, oil-seed meals and forages. With a large proportion of corn (*Zea mays*) being used for ethanol production, there is a need to further investigate other non-corn alternatives that are both suitable for the production of ethanol, and are easily grown in Nigeria and their by-products suitable as livestock feedstuffs. Dried distillers grains plus solubles (DDGS) are an excellent and potentially lower cost feedstuff than other more traditional feed sources to the cattle feeding industry.

Much research has shown an improvement in growth by including either wet or dry corn distiller's grains plus solubles in the diet over traditional high grain feedlot diets (Van der Pol *et al*., 2009). Grain sorghum (*Sorghum bicolor*) has been shown to be a viable alternative to corn for ethanol production, and although sorghum is a major crop produced in Nigeria, it is currently not utilized as extensively as corn in biofuel production (Wang *et al*., 2008). Efficacy of sorghum dried distiller's grains plus solubles in the feed lot has been researched much less than corn distillers' grains plus solubles. There is also a high degree of variability of results in the literature; some research has shown a favourable response with feeding the sorghum by-product (Al-Suwaiegh *et al*., 2002), while others have shown that the feeding value of sorghum distillers grains (wet or dry) is lower than traditional feeds or corn distillers grains (Vasconcelos *et al*., 2007; May *et al*., 2010).

2.5 By-products of Grains Processing (Milling and Brewing)

Braver (2014) stated that a by-product is a secondary product resulting from the harvesting or processing of a principal commodity. They have little direct value as a human edible food; however, many by-products have substantial value as animal feedstuffs. The feeding of by-products in the form of crop residues has been practiced for hundreds of years. The feeding of by-products such as distillers' grains have become more common recently, due to factors such as changing regulatory pressures, economic considerations, and waste technology (Grasser *et al*., 1995).

Sorghum grain (*Sorghum bicolor L. Moench*) is used by various food industries, including milling, starch production, brewing and distilling, resulting in the following numerous by-products:

i. Sorghum bran (sorghum offal, sorghum milling waste, sorghum mill feed) is a mixture of grain pericarp (bran) and of variable amounts of grain fragments (endosperm, germ). It is usually a by-product of the dry milling in sorghum flour manufacturing, but the manufacture of other sorghum-based food products may also require a dehulling step. This is because the pericarp contains tannins that decrease food value and organoleptic qualities (Lazaro and Favier, 2000). The removal of hulls and bran is done manually by pounding in a mortar and pestle, or mechanically through the adaptation of barley pearling machines (NRI, 1999).

ii. Sorghum brewer's grains (sorghum brewers' grain, sorghum brewers' spent grain, sorghum spent grain, draft, sorghum beer residues) are the by-products of brewing based on sorghum grains (other grains such as barley, maize and rice are sometimes included). They can be used fresh or dried (artificially or sun-dried). Sorghum has been the basis of traditional African beers, such as the clear beers of West Africa (*dolo* and *pito*) and the opaque beers of Southern Africa. Though the diastatic power of sorghum malt is very low, certain stout and lager beers are now produced in Africa using malted sorghum rather than the imported and more expensive barley. Chinese beer is normally made of malted rice and barley, but sorghum is also used (INTSORMIL, 2008). Sorghum brewers' grains originate from industrial facilities or from small scale units (INTSORMIL, 2008).

iii. Malted sorghum sprouts are another brewery by-product, similar to barley culms (sprouts and rootlets).

iv. Sorghum distillers' dried grains and soluble (sorghum DDGS) are the dried by-product of the manufacture of alcohol (beverage or fuel) from sorghum grains or from grain mixtures in which sorghum grain predominates. Starch content and ethanol yield from sorghum grain are comparable to those obtained with maize, and the use of sorghum grain alone, or blended with other grains for ethanol production, has been increasing since 2000s (Tokach *et al*., 2010).

v. Sorghum wine residue is the by-product of the manufacture of traditional sorghum liquor ("sorghum wine" or kaoliang) in China.

vi. Sorghum gluten feed is a by-product of the manufacture of sorghum starch or syrup by wet milling. It is the sorghum equivalent of the corn gluten feed and consists of a mixture of bran, steep liquor and other residues.

vii. Sorghum gluten meal is another by-product of sorghum starch extraction. Like corn gluten meal, sorghum gluten meal consists of the gluten (protein) fraction of the grain that remains after separation of fibre and starch.

viii. Sorghum germ meal (sorghum oil germ cake) is another by-product of sorghum starch extraction, consisting of the germ of sorghum grains from which part of the oil has been pressed.

By-products of grain milling have become increasingly important to the livestock industry over the past ten years because their production has increased dramatically (MacDonald, 2011). According to the Renewable Fuels Association (RFA, 2014), by-products of the ethanol industry have quickly become one of the largest contributors to the U.S. livestock feed supply. Roughly one-third of every bushel of grain that enters the ethanol process is returned to the livestock feed supply, most often in the form of distiller's grains, but also as gluten feed and gluten meal. In the 2013 marketing year, the ethanol industry produced million metric tons (mmt) of high quality feed which is expected to rise to 37.8 mmt in the 2014 marketing year (RFA, 2014).

Other industries that produce by-products that can be used as animal feedstuffs include the food and fiber industries (Grasser *et al*, 1995). A few noteworthy by-products from these industries include almond hulls, dried beet pulp, wet brewer's grains, wet citrus pulp, pressed citrus pulp, whole cottonseed, and rice bran. All are by-products of the food industry except for whole cottonseed, a by-product of the fiber industry. In 1992, these by-products accounted for 27 % of the total feed concentrate moved within the state of California (Grasser *et al*., 1995). Current research has the primary focus to improve utilization of by-products as an animal feed resource to coincide with an environmental focus in the livestock industry today.

Within the grain milling industry are the wet and dry milling industries; which produce different primary products and by-products. The by-products, wet and dry gluten feed (WGF and DGF, respectively) are derived from the wet milling process of grain, primarily corn (Stock *et al*., 2000). By-products of the dry milling of grains, primarily corn and sorghum, to produce ethanol are generally referred to as distiller's grains (DG) or condensed distiller's solubles (CDS). Distiller's grains can be further categorized as dry distiller's grains (DDG), dry distiller's grains with solubles (DDGS), wet distiller's grains (WDG), wet distiller's grains with solubles (WDGS), and modified wet distiller's grains with solubles (MWDGS), based on amount of drying and addition of CDS (Stock *et al*., 2000; Lardy, 2007; MacDonald, 2011). Briefly, the differing processes of wet and dry grain milling will be described.

2.5.1 Wet versus dry milling

The wet milling process of grain involves removal of crop residue, fines, and broken kernels through screening (Stock *et al*., 2000). The grain is then steeped for 40 to 48 hours before going through a series of grinds, differential separations, and centrifuges to separate the kernel fractions. Liquid recovered from the steeping process contains some transferred nutrients and has value as a feedstuff; it is concentrated down and sold as steep liquor. The primary component to be isolated is starch, sold as it is or converted to a wide variety of products such as corn syrup or high-fructose corn sweetener; the corn germ is also separated and processed to extract corn oil. The remaining portion of the kernel is termed bran and can be dried down to form DGF or mixed back with the steep liquor to form WGF (Stock *et al*., 2000; MacDonald, 2011).

The dry milling process of grain (primarily corn and sorghum) for ethanol production involves conversion of starch to ethanol (Stock *et al*., 2000; MacDonald, 2011). The grain source is ground and added yeasts ferment starch, producing ethanol. The fermented mash is distilled, removing the ethanol, and leaving behind what is called whole stillage. The whole stillage is either centrifuged or screened to separate out the coarse grain particles or WDG. Wet DG can be sold as it is or dried and sold as DDG. The remaining liquid fraction, called thin stillage, can either be sold as it is or partially evaporated to produce CDS. A portion of CDS can be added back to WDG or DDG to produce WDGS or DDGS (Stock *et al*., 2000; MacDonald, 2011). Nutrient composition of the various dry milling by-products varies widely, with CP ranging from 20-35 %, and NEg (Mcal/kg) from 1.47-2.05 on a DM basis (Lardy, 2007).

2.6 Importance of By-product Utilization

Ruminants have the unique capacity to utilize fibre, compared to monogastrics. The rumen provides an environment in which microbes, some of which produce the enzyme cellulase, can thrive. Cellulase breaks down cellulose, the most abundant plant constituent, comprising 20-40 % of the dry matter of all plants. This ability makes a large number of by-products, such as distiller’s grains (DG), particularly suitable for ruminant diets (Grasser *et al*., 1995). Furthermore, on a DM basis, distiller’s grains contain approximately 36 % fibre, making them a valuable potential energy source for ruminant animals (Stock *et al*., 2000). The usage of by-products as feedstuffs in ruminant diets not only benefits the animals by potentially providing vital nutrients, it also serves an important environmental purpose (Mirzaei-Aghsaghali and Maherisis, 2008).

Demand for food and fibre increases as the human population increases, resulting in increased generation of by-products. Assuming that global production of by-products parallels the projected growth rate of cereal grains, there will be increase in the generation of by-products by up to 40 % by 2020. Based on this projection, by-products would become an increasing waste problem if not fed to livestock. Disposal of by-products can present an environmental issue as dumping or burning creates potential water and air pollution problems (Mirzaei-Aghsaghali and Maherisis, 2008). Feeding by-products to livestock not only serves as a means to utilize them, but has also allowed by-products to become a vital part of sustainable agriculture, turning a potential waste product into milk and meat for human consumption. Furthermore, feeding by-products reduces the livestock industry's dependence on cereal grains that can be used directly as human edible food (Mirzaei-Aghsaghali and Maherisis, 2008; Wilkinson, 2011). Although it is not necessary to use cereal grains in livestock feeding, in systems that do not, productivity and efficiency can be decreased (Wilkinson, 2011). Furthermore, by maximizing utilization of nutrients, pollution problems associated with nutrient excretion can be minimized. While multiple research studies have been performed in these areas regarding distiller's grains, composition can vary greatly (Buckner *et al*., 2011). Therefore, further research is warranted to better characterize the value of distiller's grains in livestock feeding, and possibly improve their utilization.

2.7 Nutrient Composition of Wet Distiller's Grains

Corn and sorghum grain consist of two-thirds starch on a dry matter basis (DMB) after fermentation and removal of starch, approximately one-third of the original grain is recovered in the whole stillage (Stock *et al.*, 2000; Klopfenstein, 2008). Removal of starch therefore causes an approximate three-fold concentration in the remaining nutrients: protein, fat, fibre, and minerals. In corn and sorghum DG (CDG and SDG, respectively) CP increases from approximately 10 to 30 %, fat from 4 to 12 % and NDF from 12 to 36 % (Stock *et al*., 2000; Klopfenstein, 2008).

2.7.1 Corn versus sorghum distillers' grains

Although similar in nutrient composition, reviews by Klopfenstein, (2008) and Owens (2008) suggest that corn WDG (CWDG) is superior to sorghum WDG (SWDG) as a feedstuff. However, several studies have found no significant differences between the two types of DG in terms of animal performance and carcass characteristics, and digestibility of nutrients (Al-Suwaiegh *et al*., 2002; Vasconcelos *et al.*, 2007; Depenbusch *et al*., 2009; May *et al*., 2010). Al-Suwaiegh *et al*. (2002) evaluated the nutritional value of DG from the fermentation of corn or sorghum. 60 steers were individually fed three dry-rolled corn (DRC) based finishing diets for 127 days containing no WDG (control), or 30 % CWDG or 30 % SWDG, replacing DRC. The steers fed CWDG and SWDG had similar ADG and G:F ($P = 0.19$ and $P = 0.25$, respectively). Standard carcass measurements did not differ ($P \geq 0.37$) between DG source, with the exception of fat thickness which tended ($P= 0.08$) to be higher for SWDG fed steers compared to CWDG fed steers (Al-Suwaiegh *et al*., 2002). Similarly, Depenbusch *et al*. (2009) used diets containing 15 % CDG or SDG. 299 crossbred yearling steers were fed for approximately 114 days comparing seven dietary treatments using steam-flaked corn (SFC) based finishing diets. Treatments included a control ration containing no WDGS, 15 % sorghum WDGS (SWDGS) with 0 or 6 % alfalfa hay, 15 % sorghum DDGS (SDDGS) with 0 or 6 % alfalfa hay, 15 % corn WDGS (CWDGS) with 6 % alfalfa hay, and 15 % corn DDGS (CDDGS) with 6 % alfalfa hay. Performance and digestibility results were similar ($P\geq 0.09$) for DMI, ADG, G:F, carcass characteristics and apparent total tract digestibility of DM and OM between the two types of DG (Depenbusch *et al*., 2009).

Vasconcelos *et al*. (2007) compared SWDGS and CWDGS fed at 10 % of dietary DM. Beef steers (n=200) were fed increasing levels of SWDGS (0, 5, 10, 15 % of DM) and one level of CWDGS (10 % of DM). The WDGS replaced SFC in a high concentrate diet. Neither ADG or G:F differed (P= 0.63 and P= 0.42, respectively) between the diets containing 10 % SWDGS and 10 % CWDGS during the 133 days feeding period (Vasconcelos *et al*., 2007). It should be noted however, that the SWDGS used was not 100 % sorghum based as it contained 34.5 % corn DDG (CDDG) as a means for the plant to extend supplies and reach target moisture content of the final product. Often times, ethanol plants can offer a CDG and SDG combination, this allows them to meet supply quotas and maintain moisture content. However, this adds to the variability of the product received by livestock facilities. May *et al*. (2010) conducted two experiments using beef steers to evaluate the effects of DG source on feedlot cattle performance, carcass characteristics, and total tract nutrient digestibility. In experiment 1, 224 Angus and Angus crossbred steers were used and seven dietary treatments were applied in SFC-based diets. Treatments were: no WDG (control), or diets containing 15 % CWDG, 15 % SWDG, 15 % Blend (50:50 CWDG and SWDG), 30 % CWDG, 30 % SWDG, and 30 % Blend. No differences on final BW (P =0.13), ADG (P> 0.10), and G:F (P> 0.10) were observed. Marbling score, HCW, LM area, and YG did not differ (P> 0.10) among treatments. In Experiment 2, 36 steers were used to evaluate total tract digestibility of nutrients for the control, 15 % CWDG and 15 % SWDG treatments from Experiment 1. Apparent total tract digestion of DM, OM, CP, NDF, and starch did not differ (P≥ 0.25) among treatments (May *et al*., 2010).

In contrast to Depenbusch *et al*. (2009) and May *et al*. (2010), Lodge *et al*. (1997) had reported apparent OM digestibility to be lower for SWDG compared to CWDG when fed to sheep at 80 % of dietary dry matter, completely replacing DRC. Conflicting results may be partially explained by DG completely replacing corn grain, and DG fed at a higher level (80 % versus 15 % of dietary DM). In a review of DG research with beef cattle, Owens (2008) reported the NEg of SDG remained below that of the grain it replaced, which contrasts his findings with CDG. Higher lignin content in NDF of SDG compared to corn may explain the lower NEg values (Owens, 2008). Al-Suwaiegh *et al*. (2002) and May *et al*. (2010) supported this theory by reporting the ADF content of CWDGS to be lower (25.3 and 15.7 %, respectively) than SWDGS (28.3 and 25.3 %, respectively). Al-Suwaiegh *et al*. (2002) calculated the NEg of the two types of distiller's to be 2.00 Mcal/kg and 1.87 Mcal/kg, respectively. However, this difference was diluted out in the total mixed ration (TMR) as calculated NEg of the TMR was not different ($P = 0.15$) for the CWDGS (1.43 Mcal/kg) and SWDGS (1.39 Mcal/kg) diets when DG were included at 15 % of dietary DM (Al-Suwaiegh *et al*., 2002). Conversely, May *et al*. (2010) found a significant difference ($P \leq 0.05$) in the calculated NEg between diets containing CWDG versus SWDG at inclusion levels of 15 and 30 % (DM basis).

Another factor potentially explaining observed differences in NE between corn and sorghum WDG is lipid content. Lipids are an important energy source providing 2.25 times more calories than carbohydrates (starch and fibre). Nutrient content analysis of CWDG and SWDG in studies comparing the two showed that CWDG was higher in lipid content than SWDG; averaging the results of four of the studies mentioned previously; lipid content of CWDG was approximately 13.8 % on a DMB while the lipid content of SWDG was approximately 11.7 % (Al-Suwaiegh *et al*., 2002; Depenbusch *et al*., 2009; May *et al*., 2010). While previous studies have shown no differences in performance or digestibility when comparing CWDG to SWDG at a low inclusion rate (≤ 15 % DMB), some researchers suggest SWDG is inferior to CWDG as a feedstuff. Factors that could potentially cause a discrepancy between the two types of DG include digestible fibre and lipid content of SWDG compared to CWDG. Level of inclusion and corn processing method (DRC vs. SFC) could also play a role.

2.8 Distiller's Grains: Nutrient Variability

Inclusion of ethanol co-products in beef diets can be a major concern because of variability of nutrients in both WDG and DDG. The basic process of producing ethanol is the same across plants, but the DG produced can vary considerably among plants. During the fermentation process, starch, which is approximately 2/3 of the kernel, is removed, resulting in nearly three-fold greater concentration of protein, fat, fibre and P in DG (Stock *et al*., 2000). The amount of solubles added to DG can significantly alter the energy density and feeding value of the co-product. Corrigan *et al*. (2008) reported an average increase of 6 % ether extract (EE) content with the addition of solubles. Lin and Chase (1996) indicated that the major factors affecting variability are the type of grain, milling processes, grain quality, fermentation processes, drying temperatures, and proportion of solubles added back to DG. Grain variation in the original grain used for fermentation is amplified in the resulting co-product, and Holt and Pritchard (2004) recommended diet formulation based on chemical rather than calculated values.

Lardy *et al*. (2003) used three sources (Tjardes and Wright, 2002) to evaluate the nutrient content of ethanol co-products. The approximate range of values for WDG was reported on a DM basis and were as follows: DM = 25 to 35 %; total digestible nutrients (TDN) = 70 to 110 %; CP = 30 to 35 %; undegradable intake protein = 47 to 57 % of CP; degradable intake protein (DIP) = 45 to 53 % of total CP; fat = 8 to 12 %; K = 0.50 to 1.00 %; Ca = 0.02 to 0.03 %; P = 0.50 to 0.80 %; and S =0.46 to 0.70 %. Guiroy *et al*. (2007) evaluated the nutrient content of WDGS and DDGS, as well as variability of corn compared to the final co-product. Their results showed that WDGS samples were more variable than DDGS samples. They also reported more variation in the final co-product than in the original grain source, particularly variation in DM and fat content of DG compared to the original grain.

Variation of nutrient content occurs from plant to plant, but it also occurs within plants during different production cycles. A survey of 10 plants in Minnesota and South Dakota was conducted by Spiehs *et al*. (2002). Samples were taken in selected plants (less than 5 years old) every two months between 1997 and 1999. Mean and coefficient of variation for DM, CP, crude fat, crude fiber, ash, ADF, NDF, Ca, and P; values were as follows: 88.9 and 1.7; 30.2 and 6.4; 10.9 and 7.8; 8.8 and 8.7; 5.8 and 14.7; 16.2 and 28.4; 42.1 and 14.3; 0.06 and 57.2; and 0.89 and 11.7 %, respectively. These calculated coefficients of variation illustrate the sizeable variation in DDGS within and among plants. Buckner *et al*. (2008) sampled WDGS from 6 ethanol plants in Nebraska to study variation both within and across plants. During two periods, plants were sampled 10 times daily for five consecutive days. Considerable variation was reported for fat and S, whereas CP and P variation was not notable. The greatest variation was for S (% of DM) concentration, which varied within plants from 0.44 to 1.72 % and among plants from 0.65 to 90 %. The CV for S ranged from 3.5 to 36.3 %, with the CV for most plants at 5 to 7 %. The variation of S among plants and within loads from the same plant underscores the need for using chemical nutrient analysis determined on stocks of DG for successful diet formulation. Across the sampling periods, fat (% of DM) averages did not vary significantly within plants, and among plants, the average fat content was 11.8 % with a range of 10.7 to 13.1 %. This finding suggests changes in fat content from plant to plant can be attributed to processing methods, possibly related to the amount of solubles added to WDG (Buckner *et al*., 2008).

Belyea *et al*. (2004) studied factors affecting variation in co-products and the relationship between corn grain and DDGS nutrient concentration. Samples were taken from a

Minnesota ethanol plant for five consecutive years. Ground corn samples were obtained from the storage bins before fermentation, whereas DDGS samples were collected at a sampling port. Matching ground corn samples and DDGS samples (from the same fermentation batch) was deemed highly difficult, and therefore not attempted; however, both ground corn and DDGS samples were taken at steady-state processing conditions. Belyea *et al*. (2004) reported no correlation between the composition of corn and DDGS. This suggests that variation in DDGS is independent of composition of corn. Their data also validated the idea that disappearance of starch during the ethanol production process concentrates residual nutrients in DG, as significant correlations were observed among most nutrients in DDGS (Belyea *et al*., 2004). Al-Suwaiegh *et al*. (2002) conducted beef and dairy experiments to analyze both corn and sorghum DG in wet and dry forms. The DM content was 35.4 and 92.2 % for wet and dry DG, respectively. The nutrient composition obtained from chemical assays did not differ greatly between the co-products. The CP of corn DG was 29.7 % (DM basis; average between wet corn DG and dry corn DG), whereas the CP content for sorghum DG (average between wet sorghum DG and dry sorghum DG) was 32.1 % (DM basis). The EE content for corn DG was 14.3 % (DM basis), whereas sorghum DG had a value of 13.2 % (DM basis). The NDF content for corn DG was 42.5 % (DM basis) and 43.6 % (DM basis) for sorghum DG. The ADF values differed between corn and sorghum DG at 25.4 and 28.5 % (DM basis), respectively (Al-Suwaiegh *et al*., 2002).

2.9 Use of Wet Distiller's Grains (WDG) in Livestock Feeding

Several factors make WDG an attractive ingredient in beef cattle diets. The nutrient profile of WDG makes it a valuable source of both protein and energy (from fiber and fat). In addition, replacement of grain with a fibrous feedstuff such as WDG can potentially mitigate certain metabolic disorders. Furthermore, its physical attributes aid in improving diet palatability. However, availability and composition of the by-product can vary from region to region.

High CP concentrations in DG may allow for replacement of a portion of or the entire supplemental CP source, decreasing the overall cost of the diet (May *et al*., 2010). An important consideration when utilizing WDG as a protein source (< 15 % inclusion) is that undegradable intake protein (UIP) content approaches 60 % which is high compared to other feedstuffs (Lardy, 2007; Vasconcelos *et al*., 2007). Maximum efficiency of microbial protein synthesis is achieved with an appropriate balance of degradable intake protein (DIP) and UIP and is directly related to rumen efficiency. Incorporating urea to correct DIP deficiencies in diets containing WDG has yielded varied results and may not generate any positive effects on animal performance (Vasconcelos *et al*., 2007). The absence of performance improvements in response to supplemental DIP in diets containing WDG reflects the ruminant's natural ability to recycle nitrogen in the form of urea back to the rumen (Church, 1988).

At levels of inclusion > 15 %, WDG serves not only as a protein source, but an energy source as well, replacing dietary grain (Klopfenstein, 2008). When WDG are being added to the diet at inclusion levels where grain is being replaced, starch content of the diet decreases while fibre content increases. Starch is the predominant driving factor in the metabolic disorder known as acidosis. It is therefore theorized that inclusion of WDG as an energy source in place of starch could mitigate the occurrence of acidosis (Klopfenstein, 2008). In addition to its contributions as an energy and CP source, the moisture content and physical characteristics of WDG make it an effective "conditioning agent" when preparing a TMR (Total Mixed Ration). These characteristics aid in palatability, reduced sorting of less palatable ingredients, and allow for the replacement of molasses or other liquid feed products (Klopfenstein, 2008; May *et al*., 2010).

With the relatively high fibre content of DGS, it is plausible that DGS could serve as a replacement for roughages in finishing diets. Depenbusch *et al*. (2009) investigated this theory by evaluating the performance of cattle fed diets containing DGS with and without added roughage. While the complete removal of alfalfa hay improved digestibility (P= 0.01), it resulted in reduced DMI, ADG, and HCW (P= 0.01). Consequently, complete removal of hay in diets containing DGS may not result in maximum feedlot performance (Depenbusch *et al*., 2009). Another factor in the use of WDG in cattle diets is availability and transportation costs. High costs associated with moving water limit the transport of high moisture by-products to within an approximately 100-mile radius from the processing plant (Grasser *et al*., 1995; Klopfenstein, 2008).

2.10 Performance of Livestock Fed Distillers' Grains

Research evaluating inclusion levels of DDGS in the diet of young broilers are sparse and some have suggested that up to 25 % DDGS may be included in the diet with no negative effects on body weight gain (BWG), feed conversion (FCR) or feed intake (Min *et al*., 2009). Previous studies suggest that depending on the concentration in the diet, inclusion of both wet and dry DG in SFC-based diets can decrease both gain:feed (G:F) ratio and average daily gain (ADG; Corrigan *et al*., 2008; May *et al*., 2010; Vasconcelos *et al*., 2007) by finishing beef cattle. Another concern with feeding DG is the high concentrations of sulfur (S) found in the co-product (Pritchard, 2007), which could potentially result in health problems and decrease feedlot performance and gain efficiency (Gould, 1998).

Loar *et al*. (2010) reported that with one exception of feed consumption, the results indicate that the different DDGS levels fed during the starter phase did not affect how birds performed from 14 to 28 d of age. At 28 d of age, increasing dietary DDGS linearly decreased BW gain ($P < 0.001$) and liver relative weight ($P < 0.001$). There was also a linear trend (P = 0.05) suggesting an increase in feed conversion with incremental DDGS levels to the grower phase diet. Mortality and viscosity were unaffected by DDGS grower phase level. The only pre- grower DDGS × grower DDGS interaction (P<0.05) observed during the study was for feed consumption, in which birds that consumed no DDGS during the starter phase had a decrease in feed consumption at 22.5 and 30 % DDGS levels during the grower phase when compared with birds that did consume DDGS in the starter phase.

Jung *et al*. (2008) reported that the addition of three per cent DDG to commercial layer diet significantly (P>0.05) improved egg production and egg mass over the positive control (0 percent DDG). The research however found that there was no difference in egg production between the diets with six, nine and twelve per cent DDG as compared to the positive control or the diet with three per cent DDG. It was further reported that there was no significant difference in specific gravity, Haugh units, yolk colour, body weight, or feed efficiency during the first five weeks (21 to 26 weeks of age) due to the addition of up to 12 per cent DDG. The addition of three per cent DDG to the diet significantly improved (P > 0.05) weight gain as compared to the broilers fed the diet with 0, 6, 9, 12 and 16 per cent DDG. Increasing the level of DDG in the diets to 16 per cent significantly (P > 0.05) depressed weight gain, feed intake, and feed efficiency as compared to the 0 or 3 per cent DDG diets (Masa'deh *et al*., 2008).

Shim *et al*. (2008) also reported that DDGS was evaluated as an alternative ingredient to estimate growth performance, carcass quality and pellet durability. Body weight gain at the end of the starter phase (day 18) was increased when birds were fed DDGS (avg. = 0.717 kg) compared to all corn (0.688 kg). They also reported that body weight gain (2.496, 2.487, 2.469 and 2.494 kg) and feed use were similar at 42 days (1.686, 1.715, 1.715 and 1.711 kg/kg) for birds fed 0, 8, 16 and 24 per cent DDGS, respectively. They therefore concluded that DDGS can be a good alternative ingredient for broiler chickens, provided diets are formulated and balanced based on digestible amino acids.

2.11 Combination of Molasses with Other Feedstuffs in Poultry Feeds

The use of molasses to sweeten cassava meal in order to minimize the bitterness associated with cyanide content and thus improve palatability of cassava meal had been recommended for broilers. The use of cassava meal is noted to result in good performance of broilers (Sonaiya and Swan, 2004). According to Hajer (2007), there was significant increase in feed consumption, body weight gain and feed conversion ratio with increased incorporation of dietary molasses. Abdominal fat was similarly increased, but other carcass parameters and blood glucose level were not affected. However, it implied that the replacement of grain sorghum by molasses up to 15 % in broiler diets improved performance. Molasses supplementation of indomie waste at 1.0, 1.5 and 2.0 % inclusion levels has been reported as effective feed in African catfish with no negative effect on growth and health of the fish (Aderolu *et al*., 2013).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Site

This study was carried out at the Poultry Section of the Department of Agricultural Education, Federal College of Education, Kontagora, Niger State. Kontagora is geographically located between latitude 10.40^0N and longitude 5.47^0E. The climate is characterized by mono peak rainfall regime with long dry season and short rainfall that lasts for three to four months. The vegetation is typical Southern Guinea Savanna Zone (Ayinde *et al*., 2013).

3.2 Source of Experimental Birds

A total of 180 day old CHI broiler chicks of Arbor Acre strain were obtained from Courage Farm, along Lagos - Ibadan Express way, Ibadan, Oyo State.

3.3 Sources of Feed Ingredients

The sorghum distillers' wastes were obtained from the local brewers (*burkutu* makers) in the Mammy Market at the Army Barracks in Kontagora, Niger State, The molasses were obtained from the Savannah Sugar Company in Numan, Adamawa State. The maize and soya beans (full-fat) were obtained from the Kontagora Market while the soya bean cake, limestone, bone meal, lysine, methonine, premix and salt were obtained from Hajia Hauwa Feed Mill, behind the Federal University of Technology, Bosso Campus, Minna.

3.4 Preparation of Molasses-Flavoured Sorghum Distillers' Wastes (MFSDW)

The sorghum distillers' wastes were collected from some local breweries in Kontagora, and sun-dried for three days. Ninety four parts (94 %) of the dried sorghum distillers' wastes were mixed with 6 parts (6 %) molasses until a homogenous mixture was achieved. This was achieved by first mixing a small quantity of the sorghum distillers waste with the 6 % molasses after gently warming it over a low heat to obtain a homogenous mixture, before finally mixing it with the bulk. This was labeled molasses-flavoured sorghum distillers' waste (MFSDW). It was used in the preparation of the broiler chicken diets at various levels of inclusion.

3.5 Experimental Diets and Experimental Design

The experimental diets were formulated in accordance with the nutrient requirements of broiler chickens as recommended by Aduku (1993) and Olomu (2011), as shown in Table 3.1 and Table 3.2 (for both the starter and finisher phases respectively).

The rations contained the following ingredients: molasses-flavoured sorghum distillers' wastes (MFSDW), maize, soybean (full fat), soya bean cake, maize offal, palm oil, bone meal, lysine, methonine, common salt, and vitamins and minerals premix.

The composition of the experimental diets is shown below:-

Diet 1 (T_1) = 0 % inclusion of MFSDW

Diet 2 (T_2) = 10 % inclusion of MFSDW

Diet 3 (T_3) = 20 % inclusion of MFSDW

Diet 4 (T_4) = 30 % inclusion of MFSDW

The experimental design was a Completely Randomized Design Model.

Table 3.1: Composition of the experimental diets at the starter phase

Ingredients	T_1	T_2	T_3	T_4
Maize	43.00	35.00	25.50	24.00
Maize offal	3.75	5.75	8.25	6.25
Soybean cake	15.00	13.00	10.00	11.00
Full fat soya	32.00	30.00	30.00	22.50
Bone meal	3.50	3.50	3.50	3.50
Limestone	1.00	1.00	1.00	1.00
Palm oil	0.25	0.25	0.25	0.25
Salt	0.25	0.25	0.25	0.25
*Premix	0.25	0.25	0.25	0.25
Lysine	0.50	0.50	0.50	0.50
Methionine	0.50	0.50	0.50	0.50
MFSDW	0.00	10.00	20.00	30.00
TOTAL	100.00	100.00	100.00	100.00
		Calculated Analysis		
Crude Protein (%)	23.00	23.10	23.40	22.90
ME (kcal/kg)	3118	3061	3009	2955
Ether Extract (%)	10.31	9.79	9.52	8.27
Crude Fibre (%)	4.26	5.10	6.00	6.44
Calcium (%)	1.39	1.40	1.41	1.41
Available Phosphorus %	0.59	0.59	0.59	0.59
Lysine (%)	1.53	1.50	1.48	1.41
Methionine + Cystine (%)	0.92	0.86	0.85	0.82

ME = Metabolizable energy
MFSDW = Molasses-flavoured sorghum distillers' wastes
T_1 = 0 % inclusion of MFSDW T_2 = 10 % inclusion of MFSDW
T_3 = 20 % inclusion of MFSDW T_4 = 30 % inclusion of MFSDW
*Premix per kg supplied: vitamin A 12,500,000.00I.U, vitamin D_3 2,500,000.00I.U, vitamin E 40,000.00mg, vitamin K_3 2,000.00mg, vitamin B_1 3,000.0 mg, vitamin B_2 5,500.00mg, Niacin 55,000.00mg, pantothenate 11,500.00mg, vitamin B_6 5,000.00mg, vitamin B_{12} 25.00mg, chlorine chloride 500,000.00mg, folic acid 1,000.00mg, biotin 80.00mg, manganese 120,000.00mg, iron 100,000.00mg, zinc 80,000.00mg, copper 8,500.00mg, iodine 1,500.00mg, cobalt 300.00mg, selenium 120.00mg, anti-oxidant 120,000.00mg

Table 3.2: Composition of the experimental diets at the finisher phase

Ingredients	T_1	T_2	T_3	T_4
Maize	44.50	40.50	35.50	31.50
Maize offal	11.75	9.75	9.25	7.75
Soybean cake	12.00	10.00	10.00	8.00
Full-fat soybean	25.00	23.00	19.00	16.00
Bone meal	3.50	3.50	3.50	3.50
Limestone	2.00	2.00	2.00	2.00
Palm oil	0.25	0.25	0.25	0.25
Salt	0.25	0.25	0.25	0.25
*Premix	0.25	0.25	0.25	0.25
Lysine	0.25	0.25	0.25	0.25
Methionine	0.25	0.25	0.25	0.25
MFSDW	0.00	10.00	20.00	30.00
TOTAL	100.00	100.00	100.00	100.00
Calculated Analysis				
Crude Protein (%)	20.20	20.30	20.06	20.09
ME (kcal/kg)	3104	3073	3022	2983
Ether Extract (%)	9.30	8.74	7.94	7.27
Crude Fibre (%)	4.70	5.14	5.78	6.24
Calcium (%)	1.36	1.37	1.38	1.31
Avail P %	0.50	0.57	0.57	0.58
Lysine (%)	1.28	1.26	1.21	1.19
Methionine + Cystine (%)	0.80	0.78	0.75	0.73

ME = Metabolizable energy
MFSDW = Molasses-flavoured sorghum distillers' wastes
T_1 = 0 % inclusion of MFSDW　　T_2 = 10 % inclusion of MFSDW
T_3 = 20 % inclusion of MFSDW　　T_4 = 30 % inclusion of MFSDW

*Premix per kg supplied: vitamin A 12,500,000.00I.U, vitamin D_3 2,500,000.00I.U, vitamin E 40,000.00mg, vitamin K_3 2,000.00mg, vitamin B_1 3,000.0 mg, vitamin B_2 5,500.00mg, Niacin 55,000.00mg, pantothenate 11,500.00mg, vitamin B_6 5,000.00mg, vitamin B_{12} 25.00mg, chlorine chloride 500,000.00mg, folic acid 1,000.00mg, biotin 80.00mg, manganese 120,000.00mg, iron 100,000.00mg, zinc 80,000.00mg, copper 8,500.00mg, iodine 1,500.00mg, cobalt 300.00mg, selenium 120.00mg, anti-oxidant 120,000.00mg

3.6 Management of the Experimental Birds

3.6.1 Cleaning and disinfection of the pens

Prior to the arrival of the birds, the pens were cleaned and washed with water and detergents. The pens, feeders and drinkers were disinfected with Izal ® solution in order to get rid of harmful organisms that might affect the birds.

3.6.2 Brooding of the experimental birds

One hundred and eighty (180) CHI day-old broiler chicken of the Arbor Acre strain were obtained from Courage Farm, along Lagos – Ibadan expressway. On arrival, the birds were carefully unboxed and glucose was administered to them for vitality and recovery from the stress of transportation. Broad spectrum antibiotics (Oxytetracycline®) together with multivitamins and coccidiostat were also administered to the chicks for the first five days for prophylaxis in their clean drinking water. They were then reared in a single pen together for one week, during which time they were fed the control diet for acclimatization. After the acclimatization period, the birds were randomly divided into four treatments, each containing forty five birds; and each treatment further divided into three replicates (with each replicate containing 15 birds) in a completely randomized design (CRD) model.

After the adjustment period, the experimental diets and fresh clean drinking water were supplied to the birds *ad libitum* for a period of seven weeks. During cold weather, heat was provided to the birds with the use of charcoal stoves. Light was provided for twenty-four hours throughout the periods of the experiment.

3.6.3 Rearing of the birds

The birds were raised on deep litter system, with wood shavings spread on the floor as litter material. Feed and water were provided to the birds *ad libitum*. Foot dip containing disinfectant solution was placed at the entrance of the poultry house. Other routine management practices like cleaning of the pens, changing of litter materials, washing of the feeders and drinkers, feeding and providing water to the birds were carried out promptly.

3.6.4 Vaccination and administration of medications

The first dose of Gumboro disease (infectious bursal disease) vaccine was administered orally on the 7th day; on the 14th day first dose of Lasota was administered to the birds. From 16th to 20th day, coccidiostat was administered to the birds. On the 21st day, the second dose of Gumboro vaccine was administered, while on the 28th day, the second dose of Lasota was administered.

3.7 Data Collection

Data for the following parameters were collected: growth performance, apparent nutrient digestibility, carcass characteristics, sensory properties and economy of feed conversion, as follows.

3.7.1 Feed intake

The feed were weighed daily before administering it to the birds. The following morning, the left-over feed that was not consumed by the birds were collected and measured. The difference between the quantity of feed supplied and the quantity of left over feed gives the quantity of feed consumed. This was done per replicate and recorded as the daily feed intake, which when added at the end of each week gives the weekly feed intake. The weekly feed intake was further divided by the number of birds per replicate to obtain the average weekly feed intake per bird in each replicate.

$$\text{Average F.I (g)} = \frac{\text{Amount of feed offered to the animal (g) – feed left over (g)}}{\text{Number of birds}}$$

Eq. 3.1

3.7.2 Body weight gain

The body weight was determined by weighing the birds collectively per replicate. This was carried out by the use of a 50 kg weighing scale.

The initial weight of the birds was recorded at the beginning of the research work and at the end of every week. The body weight of the previous week was subtracted from that of the present week to obtain the weekly weight gain. This was then divided by the number of birds in each replicate in order to obtain the average weight gain per bird per week.

$$\text{Body weight of birds (g)} = \frac{\text{Final weight gain} - \text{initial weight of birds}}{\text{Number of birds per replicate}} \qquad \textit{Eq. 3.2}$$

3.7.3 Feed conversion ratio (FCR)

The feed conversion ratio (FCR) was obtained by dividing the quantity of feed consumed per week by the weekly body weight gain of the birds in each replicate (Egbewande, 2009).

$$FCR = \frac{Total\ feed\ intake}{total\ weight\ gain} \qquad \textit{Eq. 3.3}$$

3.7.4 Apparent nutrient digestibility

A nutrient digestibility trial was carried out at the 3rd and 7th week of the experiment. Two birds were randomly selected from each replicate and kept in specially-constructed metabolism cages to adjust them to the conditions in the cages for a period of three days. Feed and water were supplied to the birds *ad libitum*. After the adjustment period, the total faeces voided were collected separately for each replicate for four days. The faeces were weighed and preserved with boric acid in aluminum foil paper and oven dried at a temperature of 80 ^{0}C for 24 hours.

The dry matter, crude protein, crude fibre, ether extract, nitrogen free extract and ash contents of the faeces were determined using the procedures recommended by the Association of Official Analytical Chemists, AOAC (2000). Thereafter, the procedure adopted by Aduku and Olukosi (1990) was used to determine the apparent nutrient digestibility as follows;

$$\text{Apparent Nutrient Digestibility} = \frac{\text{Nutrient in feeds consumed} - \text{Nutrients in faeces voided}}{\text{Nutrient in feeds consumed}} \times 100\ \%$$

Eq. 3.4

3.7.5 Economy of feed conversion

Parameters that were determined included: feed cost per kg, total cost of feed intake and feed cost per kg weight gain.

3.7.6 Carcass characteristics

At the end of the feeding trial, 12 birds (one bird from each replicate) were randomly selected for the determination of the carcass characteristics. Feed was withheld overnight before slaughter in order to ensure that the gut contents were cleared. However, water was provided *ad libitum*. The birds were then slaughtered by severing the jugular veins with a sharp knife and allowed to bleed for about 15 minutes. They were then scalded and eviscerated. The carcass and weights of the breast, thighs, drumsticks and wings were evaluated based on the dressing percentage. While the weights of the abdominal fat, gizzard, proventriculus, heart, liver, kidney, spleen, pancreas, gall bladder, intestine and lungs were weighed and expressed as % of live weight.

Dressing percentage (DP) was calculated by dividing the dressed weight by the live weight multiplied by 100. Intestinal length was measured in centimeters from the start of the duodenal loop to the ileo-caecal junction (Mushtaq *et al*., 2014)

3.7.7 Sensory properties

A 20-member semi-trained panelist was constituted to examine the sensory attributes (colour, aroma, taste, juiciness, tenderness, and overall acceptability) of freshly prepared but slightly spiced parts (breast and thigh meat) of the chickens from each treatment. The assessment was done based on a nine - point hedonic scale ranked thus: 9= like extremely, 8= like very much, 7= like moderately, 6= like slightly, 5= neither like nor dislike, 4= dislike slightly, 3= dislike moderately, 2= dislike very much, 1= dislike extremely (Damazia *et al.*, 2019). The panel was made up of twenty (20) randomly selected students and members of staff of the Department of Agricultural Education, Federal College of Education, Kontagora, Nigeria.

3.8 Chemical Analysis

The proximate composition of the sorghum distillers' wastes, molasses, the experimental diets as well as the faecal droppings collected during the apparent nutrient digestibility trial were analyzed based on the standard procedures of the Association of Official Analytical Chemists, AOAC (2000).

3.9 Data Analysis

Data collected on various parameters were analyzed using the Statistical Package for the Social Sciences, (SPSS) 2015 version 16. Differences between treatment means where significant were separated using Duncan Multiple Range Tests as contained in the package.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Results

4.1.1 Proximate composition of the test ingredients

The proximate composition of the test ingredients (Table 4.1.1) show that UFSDW and MFSDW had greater dry matter content of 92.8 % than that of the pure molasses which was 89.61 %. MFSDW had the highest crude protein content of 21.70 % while UFSDW and pure molasses had 19.70 and 1.40 % respectively. MFSDW had the highest crude fibre content of 10.50 % while UFSDW had a crude fibre content of 10.00 %. Molasses had the highest ash content of 10.08 % while MFSDW and UFSDW had 7.40 and 5.50 % respectively. Molasses had the highest NFE of 7.70 % while the UFSDW and molasses had NFE contents of 56.5 and 51.40 % respectively.

4.1.2 Proximate composition of the experimental diets

The proximate composition of the experimental diets is presented in Table 4.1.2 and it shows that at the starter phase, T_4 contains the highest dry matter content of 92.00 %, T_1 had 90.80 % dry matter content, while T_2 and T_3 had the same dry matter content of 90.40 % each. At the finisher phase, there was an increase in the dry matter content of all the treatments.

The crude fibre content of the experimental feeds for T_1, T_2, T_3 and T_4 were 4.08, 4.38, 4.19 and 4.38 % respectively while at the finisher phase, the crude fibre contents were 4.00, 3.80, 3.50 and 4.62 % respectively. The crude protein contents of the experimental feeds at the starter phase for T_1, T_2, T_3 and T_4 respectively were 21.65, 21.25, 20.85 and 21.94 % while those of the finisher phase were 20.50, 25.25, 19.50 and 19.35 %.

The ash contents of the experimental diets for the various treatments (T_1, T_2, T_3 and T_4) at the starter phase were 12.50, 12.50, 16.50 and 18.50 % respectively while those of the finisher phase were 17.50, 17.50, 16.00 and 11.00 % respectively.

The fat content of the experimental diets at the starter phase for the various treatments were 6.32, 6.81, 6.85 and 5.52 % respectively while fat content of the finisher phase were 4.72, 5.32, 5.68 and 5.48 % respectively for T_1, T_2, T_3 and T_4.

The NFE content of the experimental diets at the starter phase were 41.25, 40.28, 42.01 and 41.70 % respectively while the NFE content of the finisher phase were 47.28, 46.43, 49.70 and 53.14 % respectively for T_1, T_2, T_3 and T_4.

Table 4.1.1: Proximate composition of the test ingredients

Parameters (%)	Molasses	MFSDW	UFSDW
Moisture	10.39	7.20	7.20
Dry matter	89.61	92.80	92.80
Crude protein	1.40	21.70	19.15
Crude fibre	-	10.50	10.00
Ash	10.00	7.40	5.50
Fat	1.20	1.80	1.60
NFE	77.07	51.40	56.55

NFE = Nitrogen free extracts
MFSDW = Molasses flavoured sorghum distillers' wastes
UFSDW = Unflavoured sorghum distillers' wastes

Table 4.1.2: Proximate composition of the experimental diets

Parameters (%)	T_1	T_2	T_3	T_4
Starter phase				
Moisture	9.20	9.60	9.60	8.00
Dry matter	90.80	90.40	90.40	92.00
Crude fibre	4.08	4.36	4.19	4.38
Crude protein	21.65	21.25	20.85	21.94
Ash	12.50	12.50	16.50	18.50
Fat	6.32	6.81	6.85	5.52
NFE	46.25	45.48	42.01	41.66
Finisher phase				
Moisture	6.00	6.70	6.70	6.90
Dry matter	94.00	93.30	93.30	93.10
Crude fibre	4.00	3.80	3.50	4.62
Crude protein	20.50	20.25	19.50	19.35
Ash	17.50	17.50	16.00	11.00
Fat	4.72	5.32	5.60	5.48
NFE	47.28	46.43	48.70	52.65

NFE = Nitrogen free extracts

4.1.3 Growth performance of broiler chicken fed diets containing varying levels of molasses-flavoured sorghum distillers' wastes

The results of the effects of feeding varying levels of sorghum distillers' wastes flavoured with molasses on the growth performance of broiler chickens is presented in Table 4.1.3. The results showed that feeding varying dietary levels of sorghum distillers' wastes flavoured with molasses had positive effect ($P<0.05$) on all the growth performance parameters measured except the initial body weight and mortality (%).

Broiler chickens fed T_1, T_3 and T_4 diets had similar ($P > 0.05$) final body weight (FBW) and total body weight gain (TBWG) which were significantly higher than the values recorded for birds fed the T_2 diet (containing 10 % MFSDW). Furthermore, the total feed intake of birds fed the T_2, T_3 and T_4 diets had similar ($P > 0.05$) values which were significantly lower than those recorded for birds fed the control diet.

The FBW and the TBWG of birds fed diet containing 10 % MFSDW were significantly ($P < 0.05$) lower than the values obtained for birds fed the control diet. However, as the dietary inclusion of MFSDW increased, the FBW and TBWG of the birds increased until they were not significantly different ($P>0.05$) from or even better than those of the control diet.

Similarly, TFI of birds fed the control diet were significantly ($P<0.05$) higher than those of the birds fed the 10 %, 20 % and 30 % MFSDW diets. Also, the FCR of birds fed the 10 % MFSDW diet was significantly ($P<0.05$) higher than that of the birds fed the control diet. However, at 20 % and 30 % dietary inclusion of MFSDW, the FCR were not significantly ($P>0.05$) different from that of the control diet.

Table 4.1.3: Growth performance of broiler chicken fed diets containing varying levels of molasses-flavoured sorghum distillers' wastes

Parameters	T_1	T_2	T_3	T_4	SEM	P - value
Initial BW (g)	121.88	122.44	123.81	124.88	0.419	0.116
FBW (g)	1765.00 ^{a}	1666.67 ^{b}	1818.33 ^{a}	1858.33 ^{a}	25.162	0.010
Total BWG (g)	1643.12 ^{a}	1544.53 ^{b}	1694.52 ^{a}	1734.22 ^{a}	24.870	0.010
Total FI (g)	7602.19 ^{a}	7578.00 ^{b}	7588.13 ^{b}	7579.41 ^{b}	33.83	0.011
FCR	4.63 ^{a}	4.91 ^{b}	4.48 ^{a}	4.37 ^{a}	0.071	0.009
Mortality (%)	2.00	2.33	2.33	2.00	2.170	0.916

^{a,b}Means on the same row with different superscripts were significantly different ($P<0.05$)
BW = Body weight, FI = Feed intake, FBW= Final Body Weight, BWG= Body Weight Gain, FCR= Feed Conversion Ratio
T_1 = 0 % inclusion of MFSDW
T_2 = 10 % inclusion of MFSDW
T_3 = 20 % inclusion of MFSDW
T_4 = 30 % inclusion of MFSDW
SEM = Standard error of the means
P-value = Probability value

4.1.4 Apparent nutrient digestibility of broiler chicken fed diets containing varying levels of MFSDW

The results of feeding varying levels of sorghum distillers' wastes flavoured with molasses on the apparent nutrient digestibility of broiler chicken is presented in Table 4.1.4. The results showed that varying levels of dietary MFSDW influenced ($P < 0.05$) only the ash content during the starter phase of the experiment while other parameters like dry matter, crude protein, crude fibre, ether extract and nitrogen free extract were not significantly influenced ($P > 0.05$) upon feeding MFSDW to broiler chickens. Chickens fed 0, 10 and 20 % MFSDW had similar ether extract digestibility which was significantly higher ($P < 0.05$) than those chickens fed 30 % MFSDW diet.

At the finisher phase of the study, both the crude fibre and ash contents digestibility were influenced ($P <0.05$) when broiler chickens were fed MFSDW diets while the dry matter, crude protein, ether extract and nitrogen free extracts digestibility were not affected ($P > 0.05$) by the feeding MFSDW to broiler chickens.

Chickens fed 0 and 10 % MFSDW diet had similar ($P<0.05$) crude fibre value. Similarly, chickens fed 0, 10, 20 and 30 % MFSDW also had similar ($P< 0.05$) crude fibre digestibility value. Furthermore, the ash digestibility of birds fed 0 and 10 % dietary MFSDW were similar ($P<0.05$). Chickens fed 30 % MFSDW diet had a significantly lower ($P < 0.05$) ash digestibility compared to those birds fed 0, 10 and 20 % MFSDW diets.

Table 4.1.4: Apparent nutrient digestibility of broiler chicken fed diets containing varying levels of MFSDW

Parameter (%)	T_1	T_2	T_3	T_4	SEM	P-value
Starter phase						
Dry matter	91.46	91.26	87.70	87.50	0.84	0.156
Crude protein	92.51	92.12	88.39	90.03	0.71	0.121
Crude fibre	58.13	58.89	40.82	46.81	3.74	0.255
Ether extract	95.44	94.53	94.24	90.57	0.66	0.012
Ash	19.50[a]	19.50[a]	13.51[a]	17.83[b]	1.02	0.099
NFE	92.59	92.54	90.14	88.61	0.74	0.139
TDN	65.55	65.30	61.74	61.43	6.18	0.192
Finisher phase						
Dry matter	90.97	90.67	90.44	93.56	0.71	0.411
Crude protein	92.19	91.50	90.99	94.09	0.65	0.386
Crude fibre	67.02[ab]	61.41[ab]	44.54[b]	82.35[b]	5.08	0.033
Ether extract	92.13	92.19	93.40	95.76	0.72	0.257
Ash	36.23[a]	36.47[a]	31.16[b]	18.98[c]	2.21	0.000
NFE	91.74	92.18	92.11	94.78	0.62	0.298
TDN	65.58	64.77	62.66	69.65	7.47	0.108

[a,b,c] Means on the same row with different superscripts were significantly different ($P < 0.05$). TDN= Total digestible nutrient
NFE = Nitrogen Free Extract, SEM = Standard Error of the Mean,
T_1 = 0 % inclusion of MFSDW T_2 = 10 % inclusion of MFSDW
T_3 = 20 % inclusion of MFSDW T_4 = 30 % inclusion of MFSDW
SEM = Standard error of the means   P-value = Probability value

4.1.5 Economy of feed conversion of broiler chicken fed diets containing varying levels of MFSDW

The result of the economy of feed conversion of broiler chicken fed diets containing varying levels of molasses-flavoured sorghum distillers' wastes is presented in Table 4.1.5. The result showed that the economy of feed conversion was influenced ($P < 0.05$) across the various treatment groups.

Birds fed varying inclusion levels of the test ingredient had their cost of feed per kg and total cost of feed intake to be significantly different ($P<0.05$) from each other. However, birds fed the basal diet had a higher cost of feed per kilogram and total cost of feed intake compared to birds fed 20 and 30 % inclusion levels of dietary MFSDW.

Furthermore, there were significant differences ($P<0.05$) in the cost of feed per kilogram weight gain between broiler chickens fed the experimental diets. Values for chickens fed the basal diet and 30 % inclusion levels of MFSDW diet were similar ($P > 0.05$). Chickens in treatments T_3 and T_4 also had their cost of feed per kilogram weight gain to be similar ($P >0.05$). Furthermore, broiler chickens fed 10 and 20 % inclusion levels of the test ingredients had their cost of feed per kilogram weight gain to be similar ($P > 0.05$). However, birds fed the basal diet and 30 % MFSDW inclusion levels had higher ($P < 0.05$) cost of feed per kilogram weight gain than those chickens fed 10 % inclusion level of the test ingredient.

At the finisher phase, similar trend was observed in the economy of feed conversion as seen in the starter phase. Both cost of feed per kilogram and total cost of feed intake were significantly different ($P < 0.05$) across the treatments. However, chickens fed the basal diet had higher ($P < 0.05$) cost of feed per kilogram and total cost of feed intake compared to chickens fed the 10 %, 20 % and 30 % MFSDW diets.

Similarly, broiler chickens fed the basal diet, 20 and 30 % inclusion levels of the test ingredient had similar values ($P > 0.05$) of cost of feed per kilogram weight gain which was significantly lower ($P < 0.05$) than that obtained for birds fed 10 % inclusion level of dietary MFSDW.

Table 4.1.5: Economy of feed conversion of broiler chicken fed diets containing varying levels of MFSDW

Parameters	T_1	T_2	T_3	T_4	SEM	P-value
Starter phase						
Cost of feed/kg (₦)	261.34^{c}	272.03^{d}	225.08^{b}	204.93^{a}	8.16	0.000
Total cost of FI (₦)	47.00^{c}	48.00^{d}	39.80^{b}	35.55^{a}	1.56	0.000
Feed cost/kg WG (₦)	664.52^{a}	504.05^{c}	537.68^{bc}	605.73^{ab}	22.51	0.020
Finisher phase						
Cost of feed/kg (₦)	295.79^{d}	272.28^{c}	250.70^{b}	226.73^{a}	7.71	0.000
Total cost of FI (₦)	596.93^{d}	519.95^{c}	484.63^{b}	416.20^{a}	20.08	0.000
Feed cost/kg WG (₦)	1753.30^{b}	3039.74^{a}	1696.08^{b}	1241.68^{b}	213.39	0.000

^{a,b,c,d} Means on the same row with different superscripts were significantly different ($P < 0.05$)
T_1 = 0 % inclusion of MFSDW
T_2 = 10 % inclusion of MFSDW
T_3 = 20 % inclusion of MFSDW
T_4 = 30 % inclusion of MFSDW
SEM = Standard Error of the Means
P-value = Probability value
FI = Feed intake
WG = Weight gain

4.1.6 Carcass characteristics of broiler chicken fed diets containing varying levels of MFSDW

Table 4.1.6 shows the result of feeding varying levels of molasses-flavoured sorghum distillers' wastes on the carcass characteristics of broiler chicken. It showed that feeding varying levels of the treatment had effect ($P > 0.05$) on all the parameters measured except dressed weight and the weights of drumsticks, heart and lungs.

Broiler chickens in T_1, T_3 and T_4 had similar ($P > 0.05$) live weight values which were significantly higher ($P < 0.05$) than birds in T_2. Similarly, birds fed T_3 and T_4 diets also had similar ($P > 0.05$) slaughter weight values. However, the slaughter weights of birds in T_4 were significantly higher ($P < 0.05$) than birds in T_1 and T_2 respectively.

Furthermore, the breast weight of birds in T_2, T_3 and T_4 were similar ($P > 0.05$) which were also higher ($P < 0.05$) than that recorded for birds in T_1. The weight of the thigh of birds in T_2 and T_3 were similar ($P > 0.05$). Similarly, there were no effects ($P > 0.05$) in the weights of the thighs of chickens in T_1 and T_3. The weights of the thigh of birds in T_1 and T_4 diets were also similar ($P > 0.05$). However, chickens fed T_2 diet had a significant higher ($P < 0.05$) thigh weight compared to the weights obtained from the chickens fed T_1 and T_4 diets.

Chickens fed T_1, T_2 and T_4 diets had similar ($P > 0.05$) liver weight while those fed T_3 and T_4 diets also had their weights of liver to be similar ($P > 0.05$). However, birds fed T_3 diet had its liver weighing significantly lower than the weights of liver of the birds fed T_1 and T_2 diets. The weights of the gizzard of birds fed T_2, T_3 and T_4 diets were similar ($P > 0.05$) which were significantly lower than those obtained from the chicken subjected to T_1 diet.

Broiler chicken fed T_2 and T_4 diets had similar ($P>0.05$) weights of wings. Similarly, those fed T_3 and T_4 diets also had the weights of their wings to be similar ($P<0.05$).

However, chickens fed the basal diet had their wings weigh more than those fed T_2 and T_3 diets.

Furthermore, the weights of the shanks of broiler birds fed T_2 and T_3 diets were similar ($P<0.05$). Birds fed T_1 and T_3 diets also had similar ($P<0.05$) weights of shank. However, birds fed T_3 diet had a higher ($P<0.05$) shank weight compared to those subjected to T_1 and T_2 diets.

The weights of the intestine of broiler birds fed T_3 and T_4 diets were similar ($P<0.05$). Broiler chickens fed T_2 and T_4 diets also had the weights of their intestine to be similar ($P<0.05$). However, broiler chickens fed T_1 diet had a higher ($P<0.05$) intestine weight compared to those fed T_2 and T_3 diets.

4.1.7 Sensory properties of broiler chicken fed diets containing varying levels of molasses-flavoured sorghum distillers' wastes

The result of the sensory properties of broiler chicken fed diets containing varying levels of molasses-flavoured sorghum distillers' wastes is presented in Table 4.1.7. The result showed that the addition of varying levels of MFSDW in the diets of the broiler chicken significantly influenced ($P<0.05$) only the juiciness while other parameters like appearance, aroma, tenderness and overall acceptability were not influenced by the dietary treatments.

Broiler chickens fed 10 %, 20 % and 30 % MFSDW diets had similar ($P<0.05$) juiciness values which were significantly better ($P<0.05$) than values from chickens fed the control diet.

Table 4.1.6: Carcass characteristics of broiler chicken fed diets containing varying levels of MFSDW

Parameters (%)	T_1	T_2	T_3	T_4	SEM	P-value
Live weight (g)	1765.00^{a}	1666.67^{b}	1818.33^{a}	1858.33^{a}	25.16	0.010
Slaughter weight (g)	1547.33^{b}	1536.00^{b}	1592.33^{ab}	1633.67^{a}	15.34	0.064
Dressed weight (g)	1457.33	1479.33	1489.33	1552.67	17.88	0.291
Dressing %	83.54^{b}	88.81^{a}	81.88^{b}	82.58^{b}	0.99	0.018
Primal cuts/carcass weight (percentage of carcass weight, %)						
Breast	13.98^{b}	20.03^{a}	23.14^{a}	23.63^{a}	16.88	0.001
Thigh	11.12^{bc}	11.72^{a}	11.21^{ab}	10.18^{c}	1.99	0.008
Drumstick	10.64	10.65	10.34	10.65	2.29	0.161
Wing	10.80^{a}	8.79^{b}	8.01^{c}	8.01^{bc}	4.63	0.000
Organ's weight/live weight (percentage of live weight, %)						
Heart	0.53	0.58	0.57	0.50	0.40	0.835
Liver	2.27^{a}	2.58^{a}	1.87^{b}	2.01^{ab}	1.24	0.031
Lung	0.49	0.46	0.50	0.48	0.26	0.227
Gizzard	4.78^{a}	4.14^{b}	3.63^{b}	3.86^{b}	2.47	0.012
Shank	1.55^{c}	2.10^{b}	1.60^{bc}	2.03^{a}	1.50	0.012
Intestine	7.54^{a}	5.46^{c}	6.20^{b}	5.51^{bc}	5.00	0.001

^{a,b,c} Means on the same row with different superscripts were significantly different ($P < 0.05$)
T_1 = 0 % inclusion of MFSDW
T_2 = 10 % inclusion of MFSDW
T_3 = 20 % inclusion of MFSDW
T_4 = 30 % inclusion of MFSDW
SEM = Standard Error of the Mean
P-value = Probability value

Table 4.1.7: Sensory properties of broiler chicken fed diets containing varying levels of MFSDW

Parameters (%)	T_1	T_2	T_3	T_4	SEM	P - value
Appearance	6.87	7.00	6.95	6.89	0.15	0.11
Aroma	7.35	7.42	7.51	7.45	0.18	0.27
Tenderness	6.78	6.51	6.86	6.91	0.21	0.08
Juiciness	7.90^b	8.20^a	8.15^a	8.45^a	0.20	0.03
Overall acceptability	7.79	7.85	7.90	7.75	0.17	0.35

^{a,b} Means on the same row with different superscripts were significantly different ($P< 0.05$)
T_1 = 0 % inclusion of MFSDW
T_2 = 10 % inclusion of MFSDW
T_3 = 20 % inclusion of MFSDW
T_4 = 30 % inclusion of MFSDW
SEM = Standard Error of the Means
P-value = Probability value

4.2 Discussion

4.2.1 Growth performance of broiler chicken fed diets containing varying levels of molasses-flavoured sorghum distillers' wastes

There were significant (P < 0.05) improvement in both the FBW and TBWG of broiler chickens fed diets containing 20 and 30 % sorghum distillers' wastes flavoured with molasses. As the level of sorghum distillers' wastes increased, it was observed that these parameters also increased. This could be due to the reduced negative impact of undigested residues on digesta viscosity as reported by Khose *et al*. (2017) who studied the effect of feeding sorghum distiller dried grains with solubles and enzyme supplementation on performance of Vencobb broiler chickens. The result of the present study is at variance with that reported by Hassan and Al Aqil (2015) and Khose *et al*. (2017) who had observed no significant differences in the FBW and TBWG of broiler chickens fed sorghum distiller dried grains. The reason for the differences could be as a result of differences in the breeds of broiler chickens used as *CHI* chicks were used for the present study while Vencobb 400 was used by Khose *et al*. (2017).

The feed intake was significantly different upon feeding broiler chickens varying levels of sorghum distillers' wastes flavoured with molasses when compared to those chickens fed the basal diet. This reduction in feed intake however led to an increase in weight gain of the broiler birds, when compared to birds fed the control diet. This may be due to the palatability of the feed being reduced as the quantity of the distillers' wastes increased in the diet. This is contrary to the results of Min *et al*. (2012) and Khose *et al*. (2017) who reported that feeding sorghum distiller wastes had no effect on the feed intake of broiler chickens.

Supplementing 10 % sorghum distillers' wastes flavoured with molasses diet to broiler chickens significantly influenced their feed conversion ratio (FCR) at the end of the feeding trial when compared to birds fed 0, 20 and 30 % diets. This could imply that at higher levels of sorghum distillers' wastes, there is improved feed utilization when compared to the lower levels. Although, the differences is not significant compared to those obtained from birds fed the control diet, but broiler birds fed higher levels (30 % MFSDW) had better FCR values. This is in agreement with the result reported by Barekatain *et al*. (2013) and Khose *et al*. (2017) who also recorded a significant difference in the FCR of broiler chickens fed sorghum distiller dried grains. On the other hand, studies carried out by Damasceno *et al*. (2020) showed that feeding sorghum distillers' wastes to broiler chickens did not influence their FCR. This could be as a result of differences in the breeds of broiler chickens used for the study.

4.2.2 Apparent nutrient digestibility of broiler chicken fed diets containing varying levels of MFSDW

While there are recorded studies on the relationship between feeding DDGS diet to laying hens (Shalash *et al*., 2010; Ghazalah *et al*., 2011), there is limited information on the effect of feeding dietary molasses flavoured sorghum distillers' wastes on the apparent nutrient digestibility of broiler chickens. In the present study, varying the inclusion levels of MFSDW diet had influence on the nutrient digestibility of broiler chickens both at the starter and finisher levels of the experiment.

At the starter phase, chickens fed 30 % MFSDW diet had a low fat digestibility which was significantly lower than those chickens fed 0, 10 and 20 % MFSDW diets. This could be as a result of the inclusion of molasses to the sorghum distillers' wastes which enhanced the palatability of the feed, absorption of fat soluble vitamins and regulates the passage rate of the digesta in the gastrointestinal tract (Fouad and El-Senousey, 2014). This is in agreement with the result reported by Ashour *et al* (2019) who observed a significant difference in the ether extract digestibility of broiler chickens fed varying levels of dietary DDGS. Conversely, Shalash *et al*. (2010) and Ghazalah *et al*. (2011) recorded no significant difference in the ether extract digestibility of chickens fed dietary DDGS. The reason for the difference could be due to the differences in class of chickens used as broiler chickens were used for the current study while laying hens were used by the reported authors.

Broiler chickens fed both the basal and MFSDW diets had similar crude fibre digestibility values. This might imply that at the finisher phase, broiler chickens digested the crude fibre irrespective of whether there was inclusion of MFSDW in the diet or not. This is in line with the results obtained by Ghazalah *et al*. (2011) and Lawal *et al*. (2016) who reported a significant difference in the crude fibre digestibility of chickens fed DDGS diet. However, the result of the present study is in variance with that obtained by Shalash *et al*. (2010) who reported that feeding DDGS diet to chickens does not have any significant effect on their crude fibre digestibility.

Furthermore, the ash content of the broiler chickens fed graded levels of MFSDW was significant across the treatments. Chickens fed 20 and 30 % MFSDW diets had lower ash content digestibility compared to those fed the basal and 10 % MFSDW diets. As the inclusion rate of the test ingredient increases, the ash content digestibility reduced implying that less bone mineralization occur when chickens are fed higher amount of MFSDW diets. The result of the present study is in agreement with that of Ashour *et al*. (2019) as feeding broiler chickens dietary DDGS influenced their ash content.

4.2.3 Economy of feed conversion of broiler chicken fed diets containing varying levels of MFSDW

The results of the analysis of the economy of feed conversion of broiler chickens fed molasses flavoured sorghum distillers’ waste showed that the test ingredient could be included at 30 % in broiler diet at the starter phase. At this phase, the cost per kilogram weight gain was observed to be lower in broiler chickens at the starter phase compared to those chickens fed the conventional feed ingredients. The variation may be due to the cheaper and abundant nature of the sorghum distillers' wastes.

At the finisher phase, broiler chickens fed 30 % MFSDW diet had better cost per kilogram live weight; though this was not significantly different from those obtained from the chickens fed the basal and 20 % inclusion level of the test ingredient. However, there was a significant reduction in the values of cost per kilogram live weight of broiler chickens fed the test ingredient as the inclusion levels increased from 10 % to 30 %. This could be as a result of the lower quantity of maize used supplemented by higher amount of MFSDW at a cheaper rate.

4.2.4 Carcass characteristics of broiler chicken fed diets containing varying levels of MFSDW

There are numerous reports about the relationship between DDGS and growth performance (Thacker and Widyaratne, 2007; Barekatain *et al*., 2013; Khose *et al*., 2017), however, there is paucity of data regarding the effect of feeding sorghum DDG flavoured molasses on the carcass characteristics of broiler chickens.

Feeding varying levels of sorghum distiller wastes flavoured with molasses significantly influenced the slaughter weight of broiler chickens. The results showed that chickens fed 30 % molasses-flavoured sorghum distillers' wastes (MFSDW) diets had better values of slaughter weight than those fed the basal diet. This could be as a result of higher FBW and BWG observed in the birds ensuring better feed utilization. Furthermore, the dressing percentage of birds fed 10 % MFSDW diet was significantly different from those chickens fed the control diet. This could be due to the better FCR recorded for birds fed the experimental diet. This result is similar to the results of Gacche *et al*. (2016) and Ashour *et al*. (2019) who reported significant difference in the dressing percentage of broiler chickens fed MFSDW diets. On the contrary, studies carried out by Lukasiewicz *et al*. (2012) revealed that MFSDW had no effect on the dressing percentage of broiler chickens. The reason for the variations could be as a result of differences in the DDGS used as sorghum distillers waste was used in the present study while corn dried distiller grains was used by the reported authors.

Furthermore, feeding MFSDW significantly improved the breast weight of broiler chickens compared to the chickens fed the basal diet. This could be due to the better feed conversion ratio observed in the chickens fed the experimental diet since FCR is a function of the weight of breast meat. This result is in agreement with the result of Gacche *et al*. (2016) who reported significant differences in the breast meat of broiler chickens fed DDGS. On the contrary, Bolu *et al*. (2012) reported a not significant difference in the breast weight of broiler chickens. The reason for the variance may be due to the differences in DDGS used as sorghum distiller wastes was used in the present study while the reported authors used corn distiller wastes.

In the present study, feeding varying levels of sorghum distillers' wastes to broiler chickens significantly influenced the thigh weight at 10 % and 20 % inclusion rates when compared to the control diets. At higher levels, that is, 30 % inclusion rate, there is a reduction in the value of the weight and not significant with those birds fed the basal diet. This may implies that when MFSDW is fed at higher quantities, it produces similar effect with those fed the basal diet.

Furthermore, feeding MFSDW to broiler chickens produced an irregular pattern across the treatment levels. Though there is limited information on the relative weight of thighs and liver of chickens as influenced by feeding MFSDW. Chickens fed 20 % inclusion rate had significantly lower relative weights of both the thighs and liver when compared to those fed 0 and 10 % inclusion rates.

Feeding varying levels of MFSDW significantly influenced the relative weight of the gizzard of broiler chickens as lower weight was recorded for the birds fed diets containing the test ingredients as compared to those fed the basal diet. However, this might be the reason the birds fed MFSDW had lower feed intake values. This is contrary to the reports of Ashour *et al*. (2019) who found no significant differences in the relative weights of gizzard as affected by feeding the experimental diets.

4.2.5 Sensory properties of broiler chicken fed diets containing varying levels of molasses-flavoured sorghum distillers' wastes

In the present study, varying the inclusion levels of MFSDW diet had influence on the sensory properties of broiler chicken. Though there is paucity of data on the effect of MFSDW diet on the sensory properties of broiler chickens. The meat from broiler birds fed varying levels of MFSDW diets were juicier compared to those fed the basal diet. This may be due to the flavouring effect of molasses in the diet.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

From the results of this study, the following conclusions are made:

The addition of MFSDW at 30 % level in the diet of broiler chickens positively influenced their growth performance.

Broiler chickens fed basal and lesser (10 and 20 %) inclusion levels of MFSDW diets had better fat digestibility at the starter phase compared to those fed 30 % inclusion level.

The economy of feed conversion was significantly influenced by the addition of MFSDW at 30 % inclusion level compared to the basal diet.

Birds fed 30 % inclusion level of MFSDW diet had better carcass weight compared to those fed the control diet.

The meat of broiler chickens fed MFSDW diets had better meat juiciness values compared to those fed the basal diet.

5.2 Recommendations

The following are the recommendations from this study:

i.) Diets for broiler birds should be formulated using MFSDW at 30 % inclusion level in order to boost their growth performance and improve their carcass yield.

ii) Also, to achieve reduced cost of production and optimum economy of feed conversion, 30 % inclusion level of MFSDW is recommended for broiler chicken.

iii) Further research studies should be carried out on the use of MFSDW in the feeding of other species of farm animals.

5.3 Contributions to Knowledge

The research evaluated the performance of broiler chickens fed diets containing varying levels of molasses-flavoured sorghum distiller's wastes. The result of the study showed that feeding broiler chickens MFSDW diets at 30 % inclusion level improved the body weight gain (1734.22 g) and feed conversion ratio (4.37) compared to the control (1643.12 g and 4.63) respectively.

Additionally, at the same inclusion level, there was also a significant reduction in both total cost of feed intake (₦ 416.20) and feed cost per kg weight gain ((₦ 1241.68) compared to the chickens fed the basal diet ((₦ 596.93 and (₦753.30) respectively. Furthermore, at 10 % inclusion level, chickens had better dressing percentage values (88.81 %) compared to the control (83.54 %).

In this study it was discovered that the economy of feed conversion was significantly influenced by the addition of MFSDW at 30 % inclusion level compared to the basal diet. The implication is that it is more economical and profitable to include MFSDW at 30 % inclusion level in the diets of broiler chickens.

REFERENCES

Abdelgader, M., Haren, H. I. H, Ismoyowati, H., & Iriyanti, N. (2019). Effect of beet molasses as a source of energy on performance of broiler chickens. *Conference Series: Earth and Environmental Science*, 372.

Adama, T. Z., Ogunbajo, S. A. & Mambo, M. (2007). Feed intake, growth performance and nutrient digestibility of broiler chicks fed diets containing varying levels of sorghum dried brewers' grains. *International Journal of Poultry Science,* 6 (8), 592-598.

Adejinmi, O. O., Hamza, R.A. & Fpohunde, J. B. (2007). Performance and nutrient digestability of rabbits. *Nigerian Journal of Animal Production,* 34(1): 63 – 68.

Aderolu, A. Z., Aarode, O. O. & Bello, R. A. (2013). Inclusion effect of graded levels of molases in the diet of *Clarias gariepinus* juvenile. *InternationalJournal of Fisheries and Aquaculture*, 5(7), 172-176.

Aduku, A. O. (1993). Tropical Feedstuff Analysis Table. Department of Animal Science, Faculty of Agriculture, Ahmadu Bello University, Zaria, pp 5–9.

Aduku, A. O. & Olukosi, D. O. (1990). *Rabbit Management in the Tropics*. Abuja, Nigeria, Living Faith Book Publishers, Abuja, pages 1-42.

Al-Suwaiegh, S., Fanning, K. C., Grant, R.J., Milton, C. T. & Kloptenstein, T .J. (2002). Utilization of distillers grains from fermentation of sorghum or corn in diets for finishing beef and lactating dairy cattle. *Journal of Animal Science.,* 80,1105-1111.

Ashour, E. A., Abd El-Hack, M. E. El-Hindawy, M. M., Attia, A. I., Osman, A.O., Swelum, A. A., Alowaimer, A. N., Saadeldin, I.M. & Laudadio, V. (2019). Impacts of dietary inclusion of dried brewers’ grains on growth, carcass traits, meat quality, nutrient digestibility and blood biochemical indices of broilers. *South African Journal of Animal Science,* 49 (3), 573 – 584.

AOAC (2000). Association of Official Analytical Chemists. *Official Methods of Analysis*. *17th Edition*. The Association of Official Analytical Chemists, Gaithersburg, MD, USA.

Ayinde, O. E., Ojehomon, V.E.T., Daramola, F. S. & Falaki, A. A. (2013). Evaluation of the effects of climate change on rice production in Niger State, Nigeria. *Ethiopian Journal of Environmental Studies and Management*, 6(6), 763 – 773

Barekatain, M.R., Antipatis, C., Choct, M. & Iji, P.A. (2013). Interaction between protease and xylanase in broiler chicken diets containing sorghum distillers’ dried grains with solubles. *Animal Feed Science and Technology,* 182, 71 – 81.

Belyea, R. l., Rausch, K.D. & Tumbleson, M.E. (2004). Composition of corn and distillers dried grains with solubles from dry grind ethanol processing. *Technology,* 94, 293-298.

Bolu, S.A., Alli, O. I. & Esuola, P. D. (2012). Response of broilers to graded levels of distillers dried grain. *Sustainable Agriculture Research,* 1(1), 147.

Braver, C. L. (2014). Effects of treating sorghum wet distiller's grains with soluble with an enzyme complex on nutrient digestibility and performance in finishing beef steers. A Thesis submitted for the Award of Master's Degree in Animal Science by the West Texas A & M University, Canyon, Texas.

Buckner, C. D., Vanness, S. J. & Erickson, G. E. (2008). Sampling wet distillers grains plus solubles to determine nutrient variability. *Nebraska Beef Cattle Report*, 48, 25-27.

Buckner, C. D., Wilken, M. F., Benton, J. R. Vanness, S.J., Bremer, V.R., Klopfenstein, T. J., Kononoff, P. J. & Erickson, G. E, (2011). Nutrient variability for distillers grains plus solubles and dry matter determination of ethanol by-products. *Professional Animal Science,* 27, 57-64.

Chaouachi, K. (2009). Hookah (Shisha, Narghile) smoking and environmental tobacco smoke (ETS). A critical review of the relevant literature and the public health consequences. *International Journal of Environmental Research and Public Health*, 6(2), 798 – 843.

Church, D. C. (1988). *The Ruminant Animal: Digestive Physiology and Nutrition*. Englewood Cliffs, New Jersey: Prentice-Hall Inc.

Clarke, M.A. (2003). Molasses In: *Encyclopedia of Food Sciences and Nutrition (Second Edition)***.**

Corrigan, M. E., Erickson, G. E., Klopfenstein,T. J. & Meyer, N. F. (2008). Effect of distillers grains fat level on digestibility. *Nebraska Beef Report, Department of Animal Science, University of Nebraska, Lincoln*, 40 - 41.

Damasceno, J. L., Rocha, C. S., Eyng, C., Broch, J., Souza, C., Wachholz, L., Cirilo, E. H., Avila, A. S., PiresFilho, I. C. & Nunes, R. V. (2020). Effect of feeding dried distillers' grains with solubles to broiler chickens from day 0 to 21. *Livestock Science*, 241, 104232.

Damazia, K. A., Stelmasiak, J., Riedel, Ż., Zdanowska-Sąsiadek, M., Bucław, D., Gozdowski & Michalczuk, M. (2019). Sensory evaluation of poultry meat: A comparative survey of results from normal sighted and blind people. *Plos One,* 14(1): 0210722. https://doi.org/10.1371/journal.pone.0210722

Daryll, E. R. & Harwood, D. S. (2013). Broiler production and consumption trends. *Agricultural Policy Analysis Centre, University of Tehnessee, Knoxville* (865) 97–7407.

Depenbushch, B. E., Loe, E. R., Sindt, J. J., Cole, N. A., Higgins, J. J. & Drowillard, J. S. (2009). Optimizing use of distillers grains in finishing diets containing steam-flaked corn. *Journal of Animal Science,* 87, 2644-2652.

Dinneen, B. (2007). Ethanol. *Vital Speeches of the Day*, 73(4), 167.

Edwards, W. P. (2009). Molasses. In: Science and Technology of Enrobed and Filled Chocolate, Confectionery and Bakery Products. Geof Talbot (Editor). Oxford, UK: Woodhead Publishing Ltd.

Egbewande, D. O. (2009). Poultry Industry and alternative of Animal Science Association of Nigeria. Ladoke Akintola University of Technology, Ogbomoso, Nigeria. 385 – 388.

Eisa, B. M. B. (1996). Use of molasses based rations for fattening rabbitlets. An M.Sc. Degree Thesis, University of Khartoum, Khartoum, Sudan.

Eric, T. (2012). Why does my molasses say unsulphured? Was sulphur removed from it? Culinary Lore. Archived from the original on September 18, 2015. Retrieved 10 May, 2021.

Fasuyi, A. O. (2005). Maize-sorghum based brewery by-product as an energy substitute in broiler starter: Effect on performance, carcass characteristics, organs and muscle growth. *International Journal of Poultry Science*, 4 (5) 334-338.

FAO (2004). Food and Agricultural Organization. Energy in human nutrition. Report of a Joint FAO/WHO/UNU Expert Consultation. *FAO Food and Nutrition Paper No. 78. Rome.*

Fouad, A. M. & El-Senousey, H. K. (2014). Nutritional factors affecting abdominal fat deposition in poultry: A review. *Asian-Australasian Journal of Animal Sciences*, 27(7), 1057 – 1068.

Gacche, S. M., Kanduri, A. B., Patil, P.V. & Gaikwad, N. Z. (2016). Effect of distillers dried grains with solubles on the performance of broilers. *Indian Veterinary Journal*, 93(4), 54 – 57.

Ghazalah, A. A., Abd-Elsamee, M. O. & Moustafa, E. S. (2011). Use of distillers dried grains with solubles (DDGS) as replacement for soybean meal in laying hen diets. *International Journal of Animal Science*, 10(7), 505 – 513.

Gould, D. H. (1998). Polio encephalomalacia. *Journal of Animal Science*, 76(1), 309 – 314.

Grasser, L., Fadel, A., Garneth, I. & Depeters, E. J. (1995). Quantity and Economic Importance of Nine Selected by–products used in Californian dairy rations. *Journal of Dairy Science*, 78, 962–971.

Guiroy, P. G., Pike, J. N., Calk, C. B. & Messman, M. A. (2007). Corn by-Products: Considerations Involving Variability and Formulation. In: Production of the Plains. Nutrition Council Spring Conference. Plains Nutrient Council 6500 Amarillo Bird. West, Amarillo, TX.49-56.

Habibu, B., Ikira, N. M., Buhari, H. U., Aluwong, T., Kawu1, M. U., Yaqub, L. S., Tauheed, M. & Isa, H. I. (2014). Effect of Molasses Supplementation on Live Weight Gain, Haematologic Parameters and Erythrocyte Osmotic Fragility of Broiler Chickens in the Hot-dry Season. *International Journal of Veterinary Science*, 3(4), 181-188.

Hajer, M. E. (2007). The feeding value of sugar cane molasses in broiler diets. Unpublished M.Sc Thesis, University of Khartoum, Sudan.

Hassan, S. M. & Al Aqil, A. A. (2015). Effect of adding different dietary levels of distillers dried grains with solubles (DDGS) on productive performance of broiler chicks. *International Journal of Poultry Science*, 14(1), 13 – 18.

Heuzé, V., Tran, G., Giger-Reverdin, S., Renaudeau, D., Bastianelli, D. & Lebas, F. (2015). Sorghum by-products. *Feedipedia*, a programme by INRA, CIRAD, AFZ and FAO.http://feedipedia.org/node/752. Last updated on October 7, 2015, 14-50.

Holt, S. M. & Pritchard, R. H. (2004). Comparison and Nutritive Value of Corn Co-Products from Dry Milling Ethanol Plants. *South Dakofa Beef Report, Department of Animal and Range Science, South Dakota State University Brookings.* Retrieved from http//ars.sdstate.edu/exbeef/2004/beed2004-01Pritcharch.pdf on 25th May, 2016.
https://digitalcommons.unl.edu/animalscinbcr/48

Hutagalung, R. I. (1981). The use of tree crops and their by- products for intensive animal production. In: A.J. Smith and R. G. Gunn (eds). Intensive Animal Production in the Developing Countries. *British Society of Animal Production*, 4, 151-184.

ISI (2008). International Starch Institute, Technical memorandum on production of corn starch. International Starch Institute Science Park, Aarthus, Denmark.http://www.strach,dk/isi/starch/tm/8www.corn.htm.Retrieved:february29,2016.

INTSORMIL (2008). Sorghum Leger and Stoic Beer: A Boost to the African Economy. INTSORMIL Report No.17, January 15, 2008. http://intsormil.org/sm2007%20flyers/brief%2017%20sorghum%20beer%20.pdf.retrieved: February28, 2016

Jessen, H. (2010). Sorghum Surges. Ethanol Producer Magazine. http://www.ethanolproducer.com.retrived:february29,2016

Jung, B. Y., Sedlack, P. & Batal, A. B. (2008). Effect of High-Protein Distillers Dried Grains at various Levels on Performance of Laying Hens. *Poultry Science*, 87 (1), 28.

Khalid, S., Alatti, K. & Omer, M. I. (2007). The response of broiler chicks to different dietary molasses levels. *Albuhuth*, 11(1).

Khose, K., Manwar, S., Dhore, R., Kuralkar, S. & Waghmare, S. (2017). Effect of feeding corn distillers grains with solubles and enzyme supplementation on immune response and nutrient utilization. *International Journal of Science, Environment and Technology*, 6(6), 3460 – 3468.

Klopfenstein, T. J. (2008). Distillers Grains for Beef Cattle. In: National Corn Growers Association, Ethanol Co-Products Workshop, Lincoln, N.E.

Lardy, G. (2007). Feeding Co-Products of the Ethanol Industry to the Beef Cattle. North Dakola State University, Department of Animal and Range Sciences. Http://www.ng.ndsu.edu/publs/ansci/beef/as/1242whtm. Retrieved March 23rd, 2016.

Lardy, G. P., Karges, K. K., Gibson, M. L. & Caton, J. S. (2003). Feeding co-products of the ethanol industry to beef cattle. AS-1242, North Dakota State University, http://www.ext.nodak.edu/extpubs/ansci/beef/as 1242w.htm.

Lawal, T. E., Ademola, S. G., Owoseni, A. A., Atobatele, O. E. & Asuelimen, P. O. (2016). *Aspergillus flavus* degraded brewer dried grains for broiler chicken diet: Performance and nutrient digestibility parameters. *Journal of Advances in Biology and Biotechnology,* 11(1), 1 – 8.

Lazaro, E. & Favier, L. (2000). Alkali debranning of Sorghum and Millet. *Cereal Chemistry,* 77(6), 717–720.

Leeson, S. & J. D. Summers (2005). *Scott's Nutrition of the Chicken. 4th edition*. Guelph, Ontario, Canada: University Books.

Lin, J. G. & Chase, L. (1996). Using Distillers Grains in Dairy Cattle Rations in Production. *Professional Dairy Management Conference, Dubuque, IA. 1-11.*

Loar, R. E., Schilling, M. W., McDaniel, C. D., Coufal, C. D., Rogers, S. F., Karges, K. & Corzo, A. (2010). Effect of dietary inclusion level of distillers dried grains with solubles on layer performance, egg characteristics, and consumer acceptability. *Journal of Applied Poultry Research,* 19(1), 30-37.

Lodge, S. L., Stock, R. A., Klopfenstein, T. J., Shain, D. H. & Herold, D. W. (1997). Evaluation of Wet Distillers Composite for Finishing Ruminants. *Journal of Animal Science,* 75, 44-50.

Lukasiewicz, M., Pietrzak, D., Niemiec, J., Mroczek, J. & Michalczuk, M. (2012). Application of dried distillers grains with solubles (DDGS) as a replacer of soybean meal in broiler chickens feeding. *Archives Animal Breeding*, 55(5), 496 – 505.

Macdonald, J. C. (2011). Grain Ruling by-Products and Fibre Digestibility in Grazing and Finishing Beef Cattle. In: Production of South West Nutrition Management Conference University of Arizona, Tempe, AZ 43-60.

Masa'deh, M. K., Weber, P. & Scheideler, S. E. (2008). Dried Distillers Grains with solubles in Laying Hens Ration. *Poultry Science,* 87(1), 27-28.

May, M. L., Declerck, J. C., Quinn, M. J. N. Dilorenzo, J. Leibovich, D.R. Smith, K.E. Hales & M.L. Galyean (2010). Corn or Sorghum Wet Distiller's Grains with Soluble in Combination with Steam Flaked corn: Feedlot Cattle Performance, Carcass Characteristics and Apparent Total Tract Digestibility. *Journal of Animal Science,* 88, 2433 - 2443.

Min, Y. N., Hancock, A., Yan, F., Lu, C., Karimi, A., Park, J. H., Liu, F. Z. & Waldrawp, P. W. (2009). Use of Combinations of Canola Meal and Distillers Dried grains with Solubles in Broiler Starter Diets. *Journal of Poultry Research,* 18, 723-733.

Min, Y. N., Li, L., Waldroup, P. W., Niu, Z. Y., Wang, Z. P., Gao, Y. P. & Liu, F. Z. (2012). Effect of dietary distillers dried grains with solubles concentrations on meat quality and antioxidant status and capacity of broiler chickens. *Journal of Applied Poultry Research,* 21(3), 603 – 611.

Mirzael–Aghazaghali A. & Maherisis, N. (2008). Nutritive value of some Agro-Industrial by products for Ruminants: A Review. *World Journal,* 3 (2), 40-46

Mushtaq, M. M. H., Parvin, R. & Kim, J. (2014). Carcass and body organ characteristics of broilers supplemented with dietary sodium and sodium salts under a phase feeding system. *Journal of Animal Science and Technology,* (56) 4.

National Bureau for Statistics (2015). Animal Abstract of Statistics.

NRI (1999). National Resource Institute. Sorghum: Post Harvest Operations. National Resource Institute, Food Security Department, Edited by D. Mejia, FAO.

Ndelekwute, E. K., Okereke, C. O., Unah, U. I., Assam, E. D. & Okonkwo, A. C. (2015). Livestock unit, National Root Crops Research Institute, Umidike, Nigeria.

Ndelekwute, E. K., Uzegbu, H.O., Okereke, C. O. Odoemelam, V.U. & Assam, E.M. (2011). Effects of different levels of molasses fed through drinking water on growth and economic performance of chickens. *International Journal of Agriculture and Rural Development,* 14(2) 671 -676.

Olomu, J. N. (2011). Monogastric animal nutrition principles and practice. Jachern

Oltjen, J. W. & Beckett, J. L. (1996). Role of ruminants livestock in sustainable agricultural systems. *Journal of Animal Science,* 74,1406-1409.

Owens, F. N. (2008). Random Ruminations and Implications of Feeding Distillers Co-products In: Production of the Plains Nutrition Council Spring Conference. Texas A and M Agrilife Research and Extension Center, Amarillo, TX. Pp. 64-81.

Pérez, R. (1995). Molasses. In: Tropical Feeds and Feeding Systems, First FAO Electronic Conference.

Pritchard, R. H. (2007). Corn by-Products: Considerations Involving Sulfur in Production of the Plains Nutrition Council Spring Conference Pp. 43-48. Publication, Benin, Nigeria.

RFA (2014). Renewable Fuels Association. Ethanol Industry Outlook: Accelerating Industry Innovation.

Rosentrater, K. A. & Krishnan, M. (2006). Corn ethanol coproducts: generation, properties, and future prospects. *International Sugar Journal,* 108 (1295), 648-657.

Shalash, S. M. M., Abou El-Wafa, S., Hassan, R. A., Ramadan, N. A., Mohamed, M. S. & El-Gabry, H.S.E. (2010). Evaluation of distillers dried grains with solubles as feed ingredient in laying hen diets. *International Journal of Poultry Science,* 9(6), 537 – 545.

Shim, M. Y., Pest, G. M., Bakalli, R. I., Tillman, P. B. & Payne, R. L. (2008). Evaluation of corn distillers dried grains with solubles as an alternative ingredient for broilers. *Poultry Science*, 90, 369-376.

Shymaa, M. H. A. (2017). Impact of added graded levels of sugar cane molasses to drinking water on performance of broiler chicks. MSc. thesis submitted to the Sudan University of Science and Technology, College of Graduate Studies and Scientific Research

Sonaiya, E. B. & Swan, S. E. J. (2004). Small-Scale Poultry Production, Technical Guide Manual. FAO Animal Production and Health, 1.

Spiehs, M. J., Whitney, M. H. & Shurson, G. C. (2002). Nutrient Data Base for Distillers Dried Grains with Solubles Produced from New Generation Ethanol Plants in Minnesota and South DaKota. *Journal of Animal Science,* 80, 2639-2645

SPSS (2015). Statistical Programme for Social Sciences. SPSS for Windows. Released 2015, SPSS Inc.

Stock, R. A, Lewis, J. M., Klopfenstein, T. J. & Milton, C. T. (2000). Review of New Information on the Use of Wet and Dry Milling Feed by-Products in Feedlot Diets. 77, 1-12.

Taylor, J. N., Schober, T. J. & Bean, S. R. (2006). Novel Food and Non-Food Uses for Sorghum and Millets. *Cereal Science*, 44, 252-271.

Taylor, J. R. N. (2003). Importance of sorghum in Africa. In: Belton, P.S and Taylor, J.P.N (Eds). Afripro, Workshop on the Proteins of sorghum and Millets: Enhancing Nutritional and Functional Properties for Africa. Pretoria, South Africa, 2nd - 4th April, 2003.

Thacker, P. A. & Widyaratne, G. P. (2007). Nutritional value of diets containing graded levels of wheat distillers grains with solubles fed to broiler chicks. *Journal of the Science of Food and Agriculture,* 87(7), 1386 – 1390.

Tjardes, K. & Wright, C. (2002). Feeding Corn Distillers Co-products to Beef Cattle. Retrieved jfrom: http://agbiopubs.sdstate.educ/articles/Exex2036.pdf.on February19, 2016.

Tokach, M. D., Goodhand, B. & Derouchey, J. (2010). Sorghum in Swine Production: Feeding Guide. Sorghum Checkoff, Kansas State University, Manhattan, Kansas. http://www.sorghumcheckoff.corn/userfiles/file/swinegl91.pdf. retrieved February 28, 2016

Vander Pol, K. J., Luebble, M. K., Crawford, G. I., Erickson, G. E. & Klopfenstein, T. J. (2009). Performance and Digestibility Characteristics of Finishing Diets Containing Distillers Grains, Composes of Corn Processing Co-products, or Supplemental Corn Oil. *Journal of Animal Science,* 87, 637 - 652.

Vasconcelos, J. T., Shaw, L. M., Lemon, K. A., Cole, N. A. & Galyean, M. L. (2007). Effects of Graded Levels of Sorghum wet Distiller Grains and Degraded Intake Protein on Performance and Carcass Characteristics of Feed lot Cattle Fed Steam Flaked Corn Based Diets. *Professional Animal Science,* 23, 467-475.

Wang, D., Bean, S., McLaren, J., Seib, P., Madl, R., Tuinstra, M., Shi, Y., Lenz, M., Wu, X. & Zhao, R. (2008). Grain Sorghum is a Viable Feedstock for Ethanol Production. *Journal of Industrial Microbiology and Biotechnology,* 35, 313-320.

Wilkinson, J. M. (2011). Redefining Efficiency of Feed Use by Livestock. *Animal,* 5,1014-1022.