PERFORMANCE, CARCASS AND MEAT QUALITY CHARACTERISTICS OF BROILER CHICKENS FED DIETS CONTAINING *Moringa oleifera* LEAF POWDER AS SUBSTITUTE FOR SYNTHETIC LYSINE

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A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL,
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DECLARATION

I hereby declare that this thesis titled: **"Performance, Carcass and Meat Quality Characteristics of Broiler Chickens Fed Diets Containing *Moringa oleifera* Leaf Powder as Substitute for Synthetic Lysine"** is a collection of my original research work and it has not been presented for any other qualification anywhere. Information from other sources (published and unpublished) has been duly acknowledged.

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…….
SIGNATURE/DATE

CERTIFICATION

This thesis titled: **"Performance, Carcass and Meat Quality Characteristics of Broiler Chickens Fed Diets Containing *Moringa oleifera* Leaf Powder as Substitute for Synthetic Lysine"** by ADAMU, Baba Ibrahim (PhD/SAAT/2016/934) meets the regulations governing the award of the degree of Doctor of Philosophy of the Federal University of Technology, Minna, and is approved for its contribution to scientific knowledge and literary presentation.

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PROF. B. A. AYANWALE CO-SUPERVISOR	…… Signature & Date
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DEDICATION

This thesis is dedicated to Almighty Allah, Who gave me the strength and ability to successfully complete this Programme.

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ABSTRACT

A research was conducted to evaluate the dietary effect of *Moringa oleifera* leaf powder, at different levels of substitution for synthetic lysine, on the performance, carcass and meat quality characteristics of broiler chickens. A total of 250 day-old broiler chicks of Cobb-500 strain were randomly allotted to five treatments, consisting of five replicates, in a completely randomized design model, for 56 days. The chicks were reared on a deep litter, and fed diets containing varying levels of synthetic lysine (SL) and *Moringa oleifera* leaf powder (MOLP) tagged T1 (100 % SL, 0 % MOLP), T2 (75 % SL, 25 % MOLP), T3 (50 % SL, 50 % MOLP), T4 (25 % SL, 75 % MOLP), and T5 (0 % SL, 100 % MOLP), based on a nutrient for nutrient substitution. Feed and water were supplied *ad-libitum*. Data obtained from the experiments were subjected to a one-way analysis of variance using SPSS statistical package (version 16.0). Results of proximate composition of MOLP showed 5.00 % moisture, 28.33 % crude protein, 3.40 % ether extract, 16.70 % crude fibre, 4.80 % ash, and 42.05 % NFE. Phytochemical composition revealed 4.95 g/100g alkaloids, 6.44 g/100g saponin, 12.56 g/100g oxalates, 8.80 g/100g tannins, 0.04 g/100g cyanide and 2.95 g/100g phytate. It also contained 41.35 g/100g phenolic acid, and 12.22 g/100g flavonoids. The amino acids profile indicated 3.60 g/100g lysine content. Results from the feeding trial showed that growth performance was positively improved at the starter phase across treatment groups with T4 (25 % SL and 75 % MOLP) having the best improvement in total weight gain, feed conversion ratio and protein efficiency ratio. At the finisher phase, T5 was significantly ($P<0.05$) highest in total feed intake with considerable high protein intake but non-significantly ($P>0.05$) lowest in protein efficiency ratio. Apparent nutrient digestibility revealed significant ($P<0.05$) differences in dry matter, crude protein, crude fibre, ether extract, ash and nitrogen free extract at both phases except ash at starter phase and dry matter at finisher phase. Haemoglobin, PCV, RBC, MCV, MCHC, PLC, TWBC, neutrophils, lymphocytes and basophils were significantly ($P<0.05$) improved. Similarly, urea, creatinine, aspartate aminotranferase, alanine aminotranferase, alkaline phosphatase and total protein were also significantly ($P<0.05$) improved. Albumin and globulins were significantly ($P<0.05$) different across the treatments. Birds on T4 had the highest ($P<0.05$) shank weight (4.63 %) and those on T3 had highest ($P<0.05$) heart weight (0.45 %) amongst the treatments. In addition, there were significant improvements on the breast meat physicochemical characteristics, shelf life and microbial count during the six months storage. The proximate composition of the meat and the entire essential amino acid profile were significantly ($P<0.05$) different. Similarly, significant improvements were observed in the minerals (magnesium, potassium, calcium, phosphorus, sulphur and chlorine, iron, copper, manganese, zinc and selenium) and vitamins (A, B_6, B_{12}, C, D, E and K) compositions. The result of meat to bone ratio indicates a significant improvement in bone in birds fed diets T1 and T5. The sensory properties were most improved in birds fed diet T4. Interaction results of *Moringa oleifera* leaf powder as an alternative to synthetic lysine and duration of storage on meat cooking loss, water holding capacity, thawing loss, pH, free fatty acids, peroxide value, bacterial count and fungi count of broiler chickens significantly vary across the treatments. Results of economy of feed conversion showed that feed cost per kilogram, total feed consumed, weight gain (WG) and cost of feed per kilogramme weight gain (FC/WG) revealed significant differences ($P<0.05$) at both phases except WG and FC/WG at finisher phase respectively. Hence, dietary addition of *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine (SL) improved growth performance, carcass and meat quality characteristics of broiler chickens, without any deleterious effect on the health and well being of the birds.

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LIST OF ABBREVIATIONS

AAS	Atomic absorption spectroscopy
ADF	Acid detergent fibre
ADL	Acid detergent lignin
ADN	Apparent digestibility of nutrient
Alb	Albumin (a blood protein)
ALP	Alkaline phosphatase
ALT	Alanine transaminase
AST	Aspartate transaminase
ANF	Anti-nutritional factors
ANOVA	Analysis of variance
AOAC	Association of Official Analytical Chemists
B	Basophils
BC	Bilirubin conjugate
BT	Bilirubin total
Ca	Calcium
CF	Crude fibre
CP	Crude protein
CRD	Completely Randomized Design
Cu	Copper
Cys	Cystine (a non-essential amino acid)
DE	Digestible energy
DM	Dry matter
EDTA	Ethylene diamine tetra-acetic acid
EE	Ether extract
ESR	Erythrocyte sedimentation rate

EU	European Union
EWT	Eviscerated weight
FAO	Food and Agricultural Organization
FC	Feed consumed
FCE	Feed conversion efficiency
FCR	Feed conversion ratio
Fe	Iron
FUE	Feed utilization efficiency
GDP	Gross Domestic Product
GE	Gross energy
GIT	Gastrointestinal tract
Glo	Globulin (a blood protein)
Hb	Haemoglobin
HBC	Haemoglobin concentration
HCO_3^-	Bicarbonate ion
HPLC	High power liquid chromatography
K^+	Potassium ion
L	Lymphocytes
Lys	Lysine (an essential amino acid)
MCH	Mean corpuscular haemoglobin
MCHC	Mean corpuscular haemoglobin concentration
MCV	Mean corpuscular volume
ME	Metabolizable energy
Met	Methionine (one of the essential amino acids)
Mg^{2+}	Magnesium ion

Mn^{2+}	Manganese ion
MOLM	*Moringa oleifera* leaf meal
MOLP	*Moringa oleifera* leaf powder
Na^{+}	Sodium ion
N	Neutrophils
NDF	Neutral detergent fibre
NFE	Nitrogen free extract
NIAS	Nigerian Institute of Animal Science
NRC	National Research Council
P	Phosphorus element
Pb^{2+}	Lead ion
PCA	Plate count agar
PCV	Packed cell volume or haematocrit value
PDA	Potato dextrose agar
PER	Protein efficiency ratio
pH	A measure of the degree of acidity or alkalinity
PI	Protein intake
PLC	Platelet count
PUFA	Polyunsaturated fatty acids
RBC	Red blood cell concentration
RDW	Red cells distribution width
ROS	Reactive oxygen species
SFA	Saturated fatty acids
SL	Synthetic lysine
SPSS	Statistical package for the social sciences

TDN	Total digestible nutrient
TME	True metabolizable energy
TP	Total protein
TVC	Total viable count
TWBC	Total white blood cell concentration
UK	United Kingdom
VFA	Volatile fatty acid
WHC	Water-holding capacity
WHO	World Health Organization
WG	Weight gain
YMC	Yeast mould count
Zn^{2+}	Zinc ion

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

The consumption of synthetic food and food materials have been identified to cause health challenges in animals, with a consequent negative effect on man, as a result of the inherent residues consumed from the products of such animals (meat/milk) as food. This necessitated the recent call by scientists on consumers to reduce or move from synthetic food substances to organic food materials. Fanatico *et al.* (2013) reported that in organic livestock production, synthetic amino acids are largely banned. Methionine is the only synthetic amino acid still permitted under the USDA National Organic Program (NOP) but only with restrictions. The prohibition of animal protein sources in poultry nutrition in many countries, and also the relatively high costs of these products, demand new alternatives. The possible alternative in this situation is the use of plant protein (Beski *et al*., 2015), which is naturally organic.

Meat quality is usually defined as a measurement of attributes or characters that determine the acceptability and suitability of meat to be eaten as fresh or stored for reasonable period without deterioration (Elmasry *et al*., 2012).

Chicken meat is an important source of animal protein in human diets, and it is valued in many cultural culinary traditions. Its nutrient-dense composition makes it an integral part to healthy and balanced diets. The low saturated fatty acids (SFA) and high polyunsaturated fatty acids (PUFA) content of chicken meat have made it a sought-after product by health-conscious individuals (Vilarrasa *et al.*, 2015).

Chicken meat and eggs are poised to play a greater role than present, in global food security in the coming years, as the preferred and primary protein source. Efficient

production requires precision farming technique, of which optimizing dietary amino acids are central (Kidd and Tillman, 2016).

In recent times, the cost of table size chicken has substantially increased due to high price of feed ingredients, particularly the main protein ingredients (fish meal and soybeans) as well as the cost of synthetic amino acid used to make up the protein requirements of monogastrics. This has consequently affected the size and supply of chicken in the market (Kurmanath, 2006). The economic viability of chicken production is dependent upon sourcing high quality feed ingredients, having knowledge of their amino acid composition, and formulating a diet that supports the birds' maintenance and productive functions.

Amino acids are the building blocks of protein and function in the build-up, maintenance and replacement of body tissues, muscles, organs and some of the body hormones. There are approximately twenty-eight commonly known amino acids that are combined in various ways to create 150 or more other intermediates inside the body as well as the more than 40,000 proteins so far known to science (Farr, 2002). The essential amino acids are those the body cannot synthesize in sufficient quantities to satisfy the nutritional requirements for good health and performance. Hence, the need to supplement them. The nine essential amino acids for poultry are histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine.

An essential amino acid such as lysine needs to be supplemented in the animal diet in order to ensure the adequate absorption of calcium, production of antibodies, hormones and enzymes; as its deficiency could lead to tiredness, inability to concentrate, irritability, bloodshot eyes, retarded growth, alopecia, anaemia and reproductive problems.

Plants and herbal extracts have been investigated in the last decade to improve animal production, especially poultry (Upadhyaya, 2014).

Moringa oleifera is very useful as a feed supplement for animals, as its leaves are highly nutritious. The leaves of *Moringa oleifera* are the most nutritious part, being a significant source of vitamin B complex, vitamin C, pro-vitamin A as beta-carotene, vitamin K, manganese, and protein among other essential nutrients (Leone *et al.*,2016). *Moringa oleifera* leaves have antimicrobial roles and are rich with ether extracts, proteins, vitamins, and minerals (Onunkwo and George, 2015; Abbas, 2013). The extracts from leaves of *Moringa oleifera* contain low amounts of polyphenols, which might have effects on blood lipid metabolism (Sreelatha and Padma, 2009; Leone *et al.*, 2016). *Moringa oleifera* can be used as a source of micronutrients and as a dietary supplement in poultry (Makkar *et al.,* 2007; Mahajan *et al.,* 2009). In addition, *Moringa oleifera* leaves powder (MOLP) has anti-septic and detergent properties due to presence of different phytochemicals in the leaves (Torondel *et al.,* 2014). *Moringa oleifera* was reported to be an excellent source of vitamins and amino acids that reportedly boost immune systems (Olugbemi *et al.,* 2010). The seed extracts of *Moringa* are rich in polyunsaturated fatty acids (Anwar and Rashid, 2007; Ogbunugafor *et al.,* 2011). *Moringa oleifera* exhibits anti-oxidant properties that can suppress formation of reactive oxygen species (ROS) and free radicals (Sofidiya *et al.,* 2006; Ogbunugafor *et al.,* 2011).

1.2 Statement of the Research Problem

There is a lack of comprehensive understanding of the potential effects of substituting synthetic lysine with Moringa oleifera leaf powder in broiler chicken diets. The unwholesome intake of animal products (meat/egg/milk) from synthetically fed/produced animals is a source of concern. The size and supply of chicken in the market has been

greatly affected by the high price of feed ingredients particularly protein and synthetic amino acids used in making up the protein requirements of animals (Kurmanath, 2006).

The prohibition of synthetic food substances and synthetic amino acids in animal feeds by some international agricultural agencies due to its residual effects on consumers' health (Beskis *et al.*, 2015), is gaining popularity. However, there is knowledge gap on the effect of *Moring oleifera* leaf powder as source of lysine on the performance, carcass and meat quality characteristics of broiler chicken. This knowledge gap hinders the development of cost-effective and sustainable feeding strategies for broiler production.

There is also the problem of the fast deterioration of chicken meat quality due to its inability to withstand the rigours of handling and storage, especially with the epileptic nature of power supply in Nigeria.

1.3 Justification for the Study

There are several justifications for studying the use of *Moringa oleifera* leaf powder as a substitute for synthetic lysine in broiler chicken diets. Firstly, synthetic lysine is a costly ingredient in poultry feed, and finding alternative sources of lysine can help reduce the cost of production. The high price of animal feed ingredients, particularly protein and synthetic amino acids, has negatively affected the size and supply of chicken in the market, and any effort aimed at reducing this price will promote the growth of the chicken industry. Secondly, *Moringa oleifera* is a plant with high nutritional value and has been reported to contain high levels of lysine. Hence, it has the potential to be used as a cheaper and more sustainable alternative to synthetic lysine. More importantly, there is a growing interest in using natural feed additives in poultry production, and *Moringa oleifera* leaf powder is a promising candidate due to its reported health benefits and antioxidant properties. Studying the effects of substituting synthetic lysine with *Moringa oleifera* leaf

powder in broiler chicken diets can provide valuable insights into the potential benefits and limitations of this alternative feed ingredient. Also, the prohibition of animal protein source and synthetic amino acids in animal nutrition due to its residual effects on consumers' health as well as the inherent antioxidant properties of *Moringa oleifera* leaves which has the potency for inhibiting or slowing the deterioration of meat during storage (improving shelf-life) will open new horizon in organic agriculture.

1.4 Aim and Objectives of the Study

The aim of this study is to determine the performance, carcass and meat quality characteristics of broiler chickens fed diets containing *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine (SL).

The objectives of the study are to:

i. determine the growth performance of broiler chickens fed diets containing *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine (SL);

ii. assess the apparent nutrient digestibility of diets containing *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine (SL) fed to broiler chickens;

iii. evaluate the meat yield and carcass characteristics of broiler chickens fed diets containing *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine (SL);

iv. assess the physicochemical characteristics of breast meat of broiler chickens fed diets containing *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine (SL);

v. evaluate the shelf-life of the breast meat of broiler chickens fed diets containing *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine (SL);

vi. analyze the microbial count of the breast meat of broiler chickens fed diets containing *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine (SL); and

vii. determine the economy of feed conversion of broiler chickens fed diets containing *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine (SL).

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Poultry Production

The term poultry is used to describe any type of domestic bird kept for their eggs and meat production, such as fowl or chicken, duck, geese, turkey, guinea fowl and pigeon. The poultry industry in Nigeria has undergone a significant transformation since the early fifties, from the backyard, peasant and primitive household-oriented husbandry of indiscreet breeds of semi-wild chickens, to the cash-oriented, modern and large-scale poultry which is sparsely distributed around our country-side and urban centres today (Ike, 2011). Poultry in the past was not counted as an important occupation, in some communities; the fowl was used as a means of knowing the time; however, nowadays, poultry production has developed and occupied a place of pride among the livestock enterprises due to its rapid monetary turnover (Amos, 2006). Agriculturists and nutritionists have generally agreed that developing the poultry industry of Nigeria is the fastest means of bridging the protein deficiency gap presently prevailing in the country (Amos, 2006). This is consistent with the view of FAO (2018) that, developing the poultry industry has been advocated to be one of the greatest means of bridging the protein deficiency gap prevailing in the tropical countries.

Poultry meat and eggs offer considerable potential for meeting human needs for dietary animal supply (Folorunsho and Onibi, 2005). The Food and Agricultural organization (2005) puts the population of the Nigerian Local Chicken at 126 million. Ige *et al.* (2014) reported that Nigerian indigenous chickens are generally found in rural areas where they scavenge for most of their feed resources (no longer directly useful to man) for survival. The native chickens exist as numerically small populations and, are highly adapted to the

natural environment where they form an integral part of the lifestyle of the rural people (Egahi *et al*., 2010). Oluyemi and Roberts (2007) reported the diversity of poultry industry, enumerating variety of business interests such as egg production, broiler production, hatchery management and poultry equipment manufacturing.

2.2 Broiler Production

The term broiler is applied to chicken that have been specially bred for rapid growth; and are generally slaughtered at the age of approximately seven weeks, when weighing about 1.8 kg. Broiler chickens play an important role in human nutrition because of the protein they contain. They are raised specially for meat production, and mature early, between 6-8 weeks of age (Oluyemi and Roberts, 2007).

2.3 Nutritional Requirements of Broiler Chickens

Broiler chicks have been shown to benefit from immediate access to feed. Although the focus of nutrition has been on provision of energy, chicks would benefit from a more balanced nutrient profile, particularly protein and amino acids. In order to meet the increasing market demand for protein (meat), modern broilers are reaching market age sooner each year (Kleyn and Chrystal, 2008). Therefore, advances in nutrition will be fundamental to securing this rapid growth achievement and maintaining sustainable broiler production. Accordingly, the common focus of nutrition, to simply supply nutrients for maintenance and growth, has become obsolete. Specialist areas such as immuno-nutrition, are rapidly gaining attention (Field *et al*., 2000; Okamoto *et al*., 2009). Therefore, during broiler diet formulation, choosing ingredients to maximize nutrient availability rather than simply meeting energy or amino acid levels, is necessary (Ravindran, 2005).

When formulating broiler diets, the main emphasis is placed on the crude protein (CP), because protein is the critical constituent of poultry diets. Together with the other main

nutrients such as carbohydrates, ether extract, water, vitamins, and minerals, they are essential for life (Cheeke, 2005).

The digestible crude protein requirement of broiler chickens has been pegged at 22-25 % for starter (0-4 weeks) and 19 % - 21 % for finisher phase (5-8 weeks); with metabolizable energy of 3010 Kcal/kg – 3175 Kcal/kg at starter phase and 3225 Kcal/kg at finisher phase respectively (http://www.poultryhub.org/nutrition/nutrient-requirements/nutrient-requirements-of-meat-chickens-broilers/). Aviagen (2014) recommended energy requirement for broilers at different phases of growth and breeds thus: 3000 Kcal ME/kg or 12.55 MJ/kg for starter; 3100 Kcal ME/kg or 12.97 MJ/kg for grower; and 3200 Kcal ME/kg or 13.39 MJ/kg for finisher.

According to Obioha (1992), the recommended metabolizable energy, CP and CF values for starter and finisher broilers are respectively 2850 Kcal/kg, 22%, 5%, and 2900 Kcal/kg, 20%, 5.5% respectively. Aduku (1993) reported 2800 Kcal/kg ME and 3000 Kcal/kg ME requirements for starter and finisher broilers, respectively; while Olomu (2011) recommended 3000 Kcal/kg ME and 3000 Kcal/kg ME requirements for both starter and finisher broilers.

2.4 Meat Quality Characteristics

2.4.1 Water holding capacity

Water holding capacity is the ability of fresh meat to retain its own water, even though external pressures such as gravity, heating, centrifugation and pressing are applied to it (Pearce *et al*., 2011). It is an important property of fresh meat as it affects both the yield and the quality of the end product. The majority of water is held either within the myofibrils, between the myofibrils and between the myofibrils and the cell membrane (sarcolemma), or between muscle cells and between muscle bundles or groups of muscle

cells (Elisabeth and Steven, 2005). Once muscle is harvested, the amount of water and location of that water in meat can change depending on numerous factors related to the tissue itself, and how the product is handled; also, the size of the piece of meat can also affect the percentage of the product that is lost as drip (Honikel, 2004).

According to Huff-Lonergan (2015), smaller cuts of meat lose relatively more drip than do larger pieces of meat. In essence, it is thought that the shorter the distance to the surface of a piece of meat, the greater the percentage of drip that is lost, even though the absolute amount of drip lost may be small compared to a larger cut of meat. This is especially true when the longest cut is across the muscle cells rather than along them, because drip tends to flow along the length of the fibres. According to Huff-Lonergan (2015) muscle contain approximately 75 % water; other main components include protein (approximately 2 %), lipids (approximately 5 %), carbohydrates (approximately 1 %) and vitamins and minerals (approximately 1 %).

Soeparno (2005) stated that the water holding capacity of broiler meat at the age of 6 and 7 weeks was between 22.19 % and 28.54 %. There was a positive correlation between water holding capacity and pH (Tang *et al*., 2007); decrease in meat pH results in decrease in water holding capacity (Bee *et al.*, 2007; Swatland, 2008; Jung *et al.*, 2010). Alvarado and McKee (2007) stated that one of the factors that affects the water holding capacity of meat is acidity/pH. The mechanism by which drip or purge is lost from meat is influenced by both the pH of the tissue and by the amount of space in the muscle cells (Dodge *et al*., 2002). It is also worth noting that water loss reduces the nutritional value of meat, since nutrients might be removed together with the exudates, resulting in less tender meat (Pelicano *et al.*, 2005).

Marco *et al*. (2004) reported that mechanical separation of meat increases the WHC of the products, for it has a higher pH than the manually deboned meats. Calcium,

magnesium, iron and copper decrease the WHC. The presence of the conjunctive tissue, in which the main protein is collagen, makes the WHC decrease when heated at temperatures of 60-65ºC, causing shrinking, deficient skinning, unstable emulsions, gel formations and wrinkling of the external skin of the emulsified products. Also, freezing decreases the WHC of the mechanically separated meat, especially when done slowly.

2.4.2 pH

Van Laack *et al*. (2000) stated that the normal pH value for broiler chicken meat ranged between 5.96 and 6.07. Suradi (2008) stated that the average pH of the breast meat of broiler chicken was 6.31 immediately after slaughter; and then it declined after postmortem and reached the values of 5.96-5.82 at 6-10 hours. This decrease in pH is the most significant postmortem change and can affect important meat quality attributes such as colour, water holding capacity and texture (Aduku and Olukosi, 1990).

2.4.3 Proximate composition of broiler chickens breast meat

The chemical composition of the pectoral muscle is an important element of quality for this type of meat (Bogosavljevic-Boskovic *et al.*, 2010). Suchy (2002) and Marcu *et al*. (2013) reported chemical component values of breast muscles of over 22.50 percent for total proteins and less than 3 percent for lipid content. Bogosavljevi-Bošković *et al.* (2010) reported that protein and lipid quantity of breast muscles is influenced by genetic and non-genetic factors. Nutrition is an external factor with major influence on the chemical composition of broiler meat. Thus, diets with low protein and energy had determined reduced meat protein content, while the lipids content of the muscles increased (Suchy *et al*., 2002; Bogosavljevi-Bošković *et al.*, 2010; and Marcu *et al*., 2013).

Some researchers have demonstrated the presence of several influencing factors on poultry meat quality such as bird’s age, sex, genetic strain, environment and nutrition,

with major influences on carcass and meat characteristics (Abdullah and Matarneh, 2010). The biophysical, histological and biochemical characteristics of pectoral muscle have a decisive role on meat quality (Stickland, 2004; Scheuermann *et al*., 2004). Some studies have revealed the presence of a positive correlation between meat quality and biochemical and histological properties of pectoral muscle (Rehfeldt *et al.*,2004). Kucukyilmaz *et al.* (2012), in their study of the chemical composition, fatty acid profile and colour of broiler meat as affected by organic and conventional rearing systems, reported the chemical composition of breast meat, with moisture ranging from 74.1 % to 72.9 %; ash 1.10 % to 1.20 %; ether extract 2.41 % to 2.81% and crude protein 22.4 % to 22.8 %.

2.5 Haematological Parameters and Functions

Blood is a vital special circulatory tissue composed of cells suspended in a fluid (plasma), with the major function of maintaining homeostasis (Isaac *et al*., 2013). Haematological components, which consist of red blood cells, white blood cells or leucocytes, mean corpuscular volume, mean corpuscular haemoglobin and mean corpuscular haemoglobin concentration are valuable in monitoring feed toxicity, especially with feed constituents that affect the blood as well as the health status of farm animals (Oyawoye and Ogunkunle, 2004). Talebi *et al*. (2005) demonstrated that a significant increase of RBC and leukocytic parameters was observable as part of the haematological profile of broiler chicks (except heterophils and H / L ratio). Red blood cells (erythrocytes) serve as a carrier of haemoglobin. It is this haemoglobin that reacts with oxygen carried in the blood to form oxyhaemoglobin during respiration (Chineke *et al*., 2006). According to Isaac *et al.* (2013), red blood cell is involved in the transport of oxygen and carbon dioxide in the body. Thus, a reduced red blood cell count implies a reduction in the level of oxygen that

would be carried to the tissues as well as the level of carbon dioxide returned to the lungs (Ugwuene, 2011; Soetan *et al*., 2013; Isaac *et al*, 2013).

The major functions of the white blood cell and its differentials are to fight infections, defend the body against invasion by foreign organisms through phagocytosis and to produce or at least transport and distribute antibodies in immune response. Thus, animals with low white blood cells are exposed to high risk of disease infection, while those with high counts are capable of generating antibodies in the process of phagocytosis, thus have high degree of resistance to diseases (Soetan *et al.*, 2013) and enhance adaptability to local environmental and disease prevalent conditions (Kabir *et al.*, 2011; Okunlola *et al*., 2012; Iwuji and Herbert, 2012; Isaac *et al.*, 2013).

Blood platelets are implicated in blood clotting. Low platelet concentration suggests that the process of clot-formation (blood clotting) will be prolonged resulting in excessive loss of blood in the case of injury. Similarly, too much platelets could predispose the animals to thrombosis and other intra vascular coaggulopathies. Packed cell volume (PCV) which is also known as haematocrit value (Ht or Hct) or erythrocyte volume fraction (EVF), is the percentage (%) of red blood cells in blood (Purves *et al*, 2003). According to Isaac *et al.* (2013), packed cell volume is involved in the transport of oxygen and absorbed nutrients. Increased PCV shows a better transportation and thus results in an increased primary and secondary polycythemia. Haemoglobin is the iron-containing oxygen-transport metalloprotein in the red blood cells of all vertebrates with the exception of the fish family, *Channichthyldae* (Sidell and O' Brien, 2006) as well as tissues of invertebrates. Haemoglobin has the physiological function of transporting oxygen to tissues of the animal for oxidation of ingested food so as to release energy for the other body functions as well as transport carbon dioxide out of the body of animals (Ugwuene, 2011; Omiyale *et al*., 2012; Soetan *et al.*, 2013; Isaac *et al.*, 2013).

According to Peters *et al*. (2011), packed cell volume, haemoglobin and mean corpuscular haemoglobin are major indices for evaluating circulatory erythrocytes, and are significant in the diagnosis of anaemia and also serve as useful indices of the bone marrow capacity to produce red blood cells as in mammals (Awodi *et al*., 2005; Chineke *et al.,* 2006). Furthermore, Chineke *et al.* (2006) posited that high PCV reading indicated either an increase in number of red blood cells (RBCs) or reduction in circulating plasma volume. Mean corpuscular haemoglobin and mean corpuscular haemoglobin concentration indicate blood level conditions. A low level is an indication of anaemia (Aster, 2004). The use of haematological studies is very important in determining the health status of animals used in various feed trials, as nutrition interferes with the myriads of metabolites and other constituents found in the blood (Animashaun *et al*., 2006; Ojebiyi *et al*., 2003).

Sogunle *et al*. (2008) reported from the comparison of haematological parameters of broiler chicks reared in cage and floor that the haematological values showed similarities across treatments; though the values were higher in birds reared on floor indicating that the birds were in a better condition of health during the period of the study.

Roberts *et al*. (2003) reported that low level of haemoglobin (Hb) of treatment diets could imply that dietary proteins were not of high quality and that diets containing poor protein would usually result in poor transportation of oxygen from the respiratory organs to the peripheral tissues. Reduction in the concentration of PCV in the blood usually suggests the presence of a toxic factor (e.g. haemagglutinin) which has adverse effect on blood formation (Roberts *et al.,* 2003). Reduction in the packed cell volume and red blood cell values are evidence and indicative of low protein intake or mild anaemia.

2.5.1 Factors influencing haematological parameters of farm animals

The genetic and non-genetic factors affecting haematological parameters of farm animals have been observed (Svoboda *et al.*, 2005; Xie *et al.*, 2013). Several factors including physiological and environmental conditions (Vecerek *et al.*, 2002; Graczyk *et al*., 2003), dietary content (Iheukwumere and Herbert, 2002; Kurtoğlu *et al*., 2005), fasting (Lamošová *et al*., 2004), age (Seiser *et al.*, 2000), administration of drugs (Khan *et al*., 1994), anti-aflatoxin treatment (Oguz *et al.*, 2000) and continuous supplementation of vitamins (Tras *et al.*, 2000) affect the blood profile of healthy animal. Addass *et al.*, (2012) also observed that factors such as age, nutrition, health of the animal, degree of physical activity, sex and environmental factors affect blood values of animals. According to Daramola *et al.* (2005), age and sex of farm animals affect haematological parameters. Afolabi *et al.* (2010) posited that haematological values of farm animals are influenced by age, sex, breed, climate, geographical location, season, day length, time of day, nutritional status, life habit of species, present status of individual and other factors. Besides physiological and environmental factors, other variables identified that may also affect blood values include: age of the animal, factors such as oestrus cycle, pregnancy and parturition, genetics, method of breeding, breeds of animal, housing, feeding, fasting, extreme climatic conditions, stress, exercises, transport, castration and diseases.

2.5.1.1 *Genetic factors*

A. Breeds and genotype

In a study on haematological parameters of rabbit breeds and cross in humid tropics conducted by Chineke *et al.* (2006), it was reported that genotypic influence on PCV, WBC, MCH and ESR; RBC, HBC and MCHC values were identical in all genotypes, pointing similar cellular haemoglobin content in blood samples obtained. In a study conducted by Peters *et al.* (2011) on variation in haematological parameters of Nigerian

native chickens, normal-feathered birds had higher mean values compared to frizzled feather and native neck genotype. The authors observed some strain differences which were consistent with the findings of Islam *et al.* (2004) and Chineke *et al.* (2006), strengthening the argument for the influence of genetic differences. According to Peters *et al.* (2011), sufficient genetic variation therefore exists for haematological parameters among Nigerian native chickens that may represent indicator traits for study.

Durai *et al.* (2012) conducted a study on the haematological profile and erythrocyte indices of different breeds of poultry and observed variation in results which was suggested to be due to differences in breeds. Durai *et al.* (2012) further documented that the significant differences in haematological profile and erythrocyte indices among the different breeds of poultry can be considered as reference values and may serve as a guide to assess the state of health in the monitored birds.

2.5.1.2 *Non-genetic factors*

A. Age and sex

In a study conducted by Addass *et al.* (2012) on indigenous chickens, it was reported that age group effect was observed on PCV, RBC and WBC, where the 150-day age group recorded highest WBC and PCV; higher RBC value was observed for age group 90 days. For WBC, the 90 days age group had the highest. A significant sex effect was also observed, with males having higher values of PCV and RBC and females showing higher value of WBC. A significant age effect was observed for MCV and MCHC. Significant sex effect was evident with females having highest value of MCHC while males had higher MCV. A significant sex effect was observed on haemoglobin concentration. Addass *et al.* (2012) reported that the majority of haematological parameters for indigenous chickens increase with advancing age, males generally report higher value than females. Peters *et al.* (2011) reported that male chickens generally had higher mean

values than their female counterpart across all genotypes. Another study conducted by Egbe-Nwiyi *et al*. (2000) revealed the influence of age and sex on haematological values of goats and sheep; age and sex had remarkable influence on the RBC counts of goats. Age influenced the Hb and PCV values, and age and sex greatly influenced the MCV and age influenced MCHC. Age and sex influenced neutrophil (increased with age) and eosinophil counts (gradually decreased with age and males had higher counts) in sheep. Sex and age influenced the RBC values of sheep. PCV and MCHC values of sheep were influenced by both sex and age. The MCV was influenced by age. Sex significantly influenced the total WBC (the highest value in males and females were observed at 3 - 5 years and 6-9 months respectively in goats) and monocyte counts (which was higher in males and females). Daramola *et al.* (2005) reported that age was observed to have a significant effect on HBC, RBC and MCHC of West African Dwarf goat which suggested that the oxygen carrying capacity of the blood was high in adult goats. Daramola *et al.* (2005) observed that sex had significant effect on lymphocyte and neutrophils; the male WAD goats had increased lymphocyte values compared to the female animals, whereas the female had increased neutrophil values compared to the male animals, which was similar to observations reported for Red Sokoto goats (Tambuwal *et al*., 2002). Daramola *et al.* (2005) further documented that the PCV values obtained for female WAD goats were comparable to those obtained for WAD goats in other studies.

Islam *et al*. (2004) illustrated that the amount of RBC, HBC and PCV rose along with animal growth in three studied poultry species, hence validating the effect of age on haematological parameters.

2.5.2 Normal haematological values for chickens

Haematological values could serve as baseline information for comparison in conditions of nutrient deficiency, physiology and health status of farm animals (Daramola *et al.*,

2005). According to Wikivet (2000), as shown in Table 2.1 below, the values are subjectively averaged from variety of sources. There is a great range of values. This may be accounted for by variation in age, sex, breed or strain, sampling techniques and testing methodology. As such, the range limits are not firm boundaries and should be used as guidelines.

Table 2.1 Average/normal haematological range/values for chickens

Haematological parameter	Units - Internarional Standard (SI)	Normal Ranges
PCV	%	35.9 - 41.0
Haemoglobin	g/dL	11.60 - 13.68
RBC	$x10^{-6}$/mL	4.21 - 4.84
WBC	$x10^{-3}$/mL	4.07 - 4.32
MCV	Fl	81.6 - 89.1
MCH	Pg	27.2 - 28.9
MCHC	%	32.41 - 33.37

Source: Wikivet (2013).

2.6 Use of Plant Extracts as Feed Additives

The addition of plants and or their extracts into diets or in water of livestock is aimed at improving the productivity of livestock through amelioration of undesired feed properties, promotion of the animal's production performance and improving the quality of food and their products (Kolodziej-Skalska *et al*., 2011). Plant materials such as herbs, spices, and various plant extracts have received increased attention as possible antibiotic growth promoters (Frankic *et al.,* 2009). Kirkpinar *et al*. (2011) proposed that these herbs and spices could be used as feed additives in animal nutrition; and that these additives may have more than one mode of action, including improving feed intake, improving flavour and because of their anti-oxidative activity. These plant extracts are reported to contain some anti-microbial phytochemicals like phenolics and polyphenols (simple phenols and phenolics acids, quinines, flavones, tannins and coumarins), essential oils, alkaloids, lectins and polypeptides (Moyo *et al*., 2012).

It was reported that when animals consume plant products containing antioxidants such as phenols, vitamins C, vitamins E, β-carotene, zinc, selenium and flavonoids, these antioxidants are passed into the meat (Middleton *et al.,* 2001; Lahucky *et al.*, 2010; Moyo *et al.*, 2012). These natural antioxidants are considered to be safer than the synthetic antioxidants, and have greater application potential for consumer's acceptability, palatability, stability and shelf-life of meat products (Jung *et al*., 2010). Chicken meat is very susceptible to oxidation, particularly during and after frozen storage. However, dietary vitamin E has been reported to reduce or prevent the process of lipid oxidation (major cause of quality deterioration in meat) occurring in broiler meat during storage. And it has been demonstrated that shelf life and meat quality (drip loss, pH and colour) can be improved by using natural antioxidants in some stages of meat production (Valeria and Williams, 2011).

2.7 Uses of *Moringa oleifera* as a Feed Additive

Moringa oleifera plant possess some antioxidant compounds and nutrients (carbohydrates, proteins, and lipids) which are essential requirements for chicken growth. These antioxidant properties are reported to be safe and have received remarkable attention due to their ability to preserve foodstuffs and prevent rancidity caused by oxidation (Moyo *et al.,* 2012). *Moringa oleifera* seed oil contains all the main fatty acids found in olive oil. It also possesses behenic acid (C 22:0), lignoceric acid (C 24:0), and traces of lauric*n*-pentadecanoic and pentadecenoid acids (Dahot and Memon, 1985). Variation in fatty acid composition is reported to have an important effect on firmness or softness of the ether extract in meat, especially the subcutaneous and intermuscular carcass ether extracts (Wood *et al*., 2003).

A number of feed additives have been used worldwide in the poultry industry for so many years (Jang *et al*., 2008). The common feed additives used in poultry diets include antimicrobials, antioxidants, emulsifiers, binders, pH control agents and enzymes. According to Mwale and Masika (2011), medicinal plants are easy to use, are cheap, readily available and easily accessible to the communal farmers. Therefore, research on the effect of *Moringa oleifera* leaf powder as an additive on growth performance, carcass and meat quality characteristics of broiler chickens would be of great practical significance.

2.8 Nutritional Composition and Medicinal Uses of *Moringa oleifera*

Moringa oleifera have been reported to possess some antioxidant properties (Sreelatha and Padma, 2009; Atawodi *et al.,* 2010). Although there are several enzyme systems within the body which scavenge free radicals, the natural antioxidants are vitamin E, bêta-carotene, and vitamin C (Nair *et al*., 2005). These micronutrient antioxidants may be used as defense system to prevent free radicals from damaging the animal's body. This

therefore provides protection to animals against infections and degenerative diseases (Sreelatha and Padma, 2009; Verma *et al.*, 2009). A survey conducted by Yang *et al.* (2006) and Jung *et al*. (2010) on 120 edible plant species showed that *Moringa oleifera* was among the most promising species, based on their high antioxidant activity, high contents of micro-nutrients and phytochemicals, processing properties, ease of growing, and also on palatability, stability and shelf life of meat products.

According to Moyo *et al*. (2011), there is quite a lot of literature on the nutritional value of *Moringa oleifera* (Lam.) leaves with varying nutritional content. *Moringa oleifera* has been reported to possess several chemical elements which include: calcium, magnesium, potassium, iron, vitamin A, and vitamin C. *Moringa oleifera* has its crude protein content to vary from 16 to 40 % (Foidl *et al.*, 2001*;* Marcu, 2005 and Rweyemamu, 2006). Aregheore (2001) reported that the use of *Moringa oleifera* as a supplement can improve voluntary intake, digestibility and livestock performance. According to Rubanza *et al*. (2005) the extent and rate of feed digestibility is defined by the fibre content. *Moringa oleifera* leaves could be highly digestible because of its immense nutritional qualities such as its chemical composition (neutral detergent fibre (NDF); acid detergent fibre (ADF); crude protein (CP); gross energy (GE); ether extract (EE) and amino acids profile. Its bark contains tannins, alkaloids, saponnins and inhibitors (Makkar *et al.*, 1990).

2.9 Growth Promoting Properties of Plant Extracts on Performance and Carcass Characteristics of Broiler Chickens

The optimal performance of farm animals in terms of feed intake, growth rate, feed conversion efficiency (FCE), live weight and high meat yield can be improved by nutritional management. According to Aengwanich and Chinrasri (2004), nutrient requirement is the amount of nutrients needed by the animals to maintain their activities, maximize growth and feed utilization efficiency. Nutrients like carbohydrates, lipids, and

proteins that chickens utilize as a source of energy are essential requirements for growth. Approximately up to 80 % of domestic animals have been fed synthetic compounds for the purpose of either medication or growth promotion (Lee *et al*., 2001.). However, there are recent concerns about possible antibiotic residues and disease resistance that have aroused great caution in the usage of antibiotics in the animal industry. Therefore, supplementing broilers with plant extracts which contain most of the nutrients will enhance feed intake, growth and FCE. Plant extracts are becoming more important due to their anti-microbial effects as well as stimulating effect on the digestive system of the animal (Osman *et al*., 2005).

2.10 Effect of *Moringa oleifera* on Nutrient Digestibility

Gakuya *et al.* (2014) investigated the effect of supplementation of *Moringa oleifera* leaf meal in broiler chicken feed and reported that the increase in MOLM levels in the diet had no effect on the digestibility of crude fibre, crude protein and NFE. Nkukwana *et al.* (2014) studied the effect of *Moringa oleifera* leaf meal on growth performance, apparent digestibility, digestive organs and carcass yield in broiler chickens and concluded that the dietary inclusion of *Moringa oleifera* leaf meal at levels ranging between 1 and 25 g per kg of feed in the starter, grower and finisher diets; did not alter the nutrient composition of the diets. Growth performance, digestibility and carcass yield results indicated that supplementation of *Moringa oleifera* leaf meal significantly improved feed utilization, efficiency and tissue accretion in broiler chickens used in this study. FCR was significantly higher in birds that were fed diets supplemented with *Moringa oleifera* leaf meal and was lower in the control.

2.11 Sensory Evaluation and Sensory Assessments of Broiler Chickens

Sensory evaluation has been defined as a scientific method used to evoke, measure, analyze and interprete those responses to products as perceived through the senses of

sight, smell, touch, taste, and hearing (Stone and Sidel, 1993). This definition has been accepted and endorsed by sensory evaluation committees within various professional organizations such as the Institute of Food Technologists and the American Society for Testing of Materials. The field of sensory evaluation has grown rapidly in the second half of the 20th century, along with the expansion of the processed-end food and consumer products industries. Nowadays, sensory evaluation becomes a tool irreplaceable in food industry while interacting with the key sectors in food production. When a consumer buys a food product, they can buy nutrition, convenience, and image. Nevertheless, most importantly, consumers are buying sensory properties and sensory consistency. Therefore, sensory evaluation should be an integral part in defining and controlling product quality. Every company committed to quality should support, develop and operate sensory programme.

Sensory assessments of meat have been shown to be influenced by various factors. Sveinsdóttir *et al*. (2009) established that availability and familiarity of food affect sensory scores. Easy access, frequency of purchase of a product and ethnicity has been shown to influence sensory attributes of meat (Prescott *et al.,* 2001; Sañudo *et al.*, 2007).

Besides health concerns to the consumer, lipid peroxidation is also a major cause of meat quality deterioration, affecting colour, flavour, texture and nutritional value (Botsoglou *et al*. 2010; Giannenas *et al.*, 2013). The presence of adipose tissue as marbling ether extract between muscle fibre bundles can weaken the structure so that it is broken down more easily during chewing. Thus, marbling increases juiciness and tenderness. The leaves of *Moringa oleifera* tree have been reported to possess antioxidant activity, containing a higher number of polyphenols (Sreelatha and Padma, 2009; Verma *et al.,* 2009; Qwele *et al*. 2013). The polyphenolics content of the leaves is high, comparable to

vegetables and fruits of strawberries, hot pepper, carrot and soybean which are high in phenolic, ascorbate, carotene and α-tocopherol, respectively (Yang *et al*. 2006).

Lipid oxidation is a major cause of meat quality deterioration, resulting in rancidity and the formation of undesirable odours and flavours, which lowers the functional, sensory and nutritive values of meat products; and therefore, consumer acceptability (Liu, 2002). Three main factors define the susceptibility of lipids to peroxidation in tissue, that is, the proportion of PUFA (polyunsaturated fatty acids) in lipid bilayers, the amount of reactive oxygen species produced and the level of endogenous or nutritional antioxidants (Brenes *et al.,* 2008).

Safa and El Tazi (2012) reported that the inclusion of *Moringa oleifera* leaf meal did not significantly affect the flavour and colour for both breast and thigh meat. Birds fed on MOLM based diets attained significantly highest tenderness and juiciness scores. Similar results were reported by Ologhobo *et al.* (2014) who stated that, the inclusion of *Moringa oleifera* leaf meal did not significantly affect flavour and colour. Birds fed on high level of *Moringa oleifera* leaf meal (0.6 %) had significantly the highest mean values for juiciness and tenderness.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Location of the Experimental Site

The experiment was conducted at the Teaching and Research Farm, Federal University of Technology, Minna, Gidan-Kwano Campus, Bosso Local Government Area of Niger State. The area falls within the southern guinea savannah zone of Nigeria with mean annual rainfall of between 1100-1600 mm and a mean temperature of between 21 ^{0}C and 36.5 ^{0}C (Usman, 2011).

3.2 Source of Experimental Materials

A total of 250 day-old broiler chicks of Cobb-500 strain were used in the research. The chicks were purchased from Olam Hatchery, Kaduna, Kaduna State, Nigeria.

The drumstick leaves were sourced from Kpandaji village of Tutungo Jedna Ward in Paikoro Local Government Area, Niger State, Nigeria.

3.3 Phase One

3.3.1 Preparation of *Moringa oleifera* leaf powder

The fresh *Moringa oleifera* leaves were exposed to an opened air space under a shade (which prevented direct sunlight radiation) to dry, in order not to lose its green colouration; and was pulverized using a conventional attrition grinding machine.

3.3.2 Chemical evaluation of *Moringa oleifera* leaf powder (MOLP)

The chemical evaluation of *Moringa oleifera* leaf powder was carried out following the procedures of AOAC (2020) at the Nutrition Laboratory of the Department of Animal Production, Adamawa State University, Mubi. Chemical properties analyzed included

proximate composition, phytochemical composition, phenolics composition and amino acids composition.

3.3.2.1 *Proximate composition*

Proximate composition of *Moringa oleifera* leaf powder (MOLP) was evaluated following the procedures of AOAC (1990). Properties evaluated included dry matter, crude protein, ether extract, crude fibre, ash, and nitrogen free extract.

3.3.2.2 *Phytochemical composition*

Antinutritional factors present in *Moringa oleifera* leaf powder (MOLP) were evaluated using the procedures of AOAC (2020). Properties evaluated included alkaloid, saponin, oxalate, tannins, cyanide and phytates.

3.3.2.3 *Phenolic composition*

Phenolic composition of *Moringa oleifera* leaf powder (MOLP) was evaluated. Properties evaluated included phenolic acids and flavonoids.

3.3.2.4 *Amino acids composition*

Essential and non-essential amino acids compositions of *Moringa oleifera* leaf powder (MOLP) were evaluated using methods described by AOAC (2020). Essential amino acids for poultry include lysine, methionine, threonine, isoleucine, leucine, phenylalanine, valine, tryptophan and histidine. Non-essential amino acids also include arginine, serine, cysteine, tyrosine, aspartic acid, glutamic acid, glycine and proline.

3.4 Experiment One

3.4.1 Growth performance of broiler chickens fed diets containing *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine (SL)

3.4.1.1 *Experimental design*

The chicks were managed under a deep litter system and divided into five (5) treatment groups, T1, T2, T3, T4 and T5, using a completely randomized design model. Group T1 denotes chickens fed 100 % synthetic lysine and 0 % MOLP lysine source; Group T2 denotes chickens fed 75 % synthetic lysine and 25 % MOLP lysine source; Group T3 denotes chickens fed 50 % synthetic lysine and 50 % MOLP lysine source; Group T4 denotes chickens fed 25 % synthetic lysine and 75 % MOLP lysine source; and Group T5 denotes chickens fed 0 % synthetic lysine and 100 % MOLP lysine source, based on a nutrient for nutrient substitution. Each group has five replicates and each replicate was randomly allotted ten (10) chicks. Newcastle disease vaccine was administered at day eight (8) and day twenty-two (22), while the Infectious Bursal Disease vaccine was administered at day fifteen (15) and twenty-nine (29) of the research, respectively. The birds were orally vaccinated through drinking water following the recommendation of Cargill *et al.* (2007).

3.4.1.2 *Experimental diets*

Experimental starter and finisher diets were formulated as shown in Tables 3.1 and 3.2 respectively, to cater for the nutritional requirements of the birds. The birds were fed adequately and provided with drinking water *ad libitum.*

Table 3.1 Experimental starter diets of broiler chickens fed diets containing *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine (SL)

Ingredients (%)	T1	T2	T3	T4	T5
Maize	50.57	50.38	49.48	47.87	46.97
Maize offal	11.00	11.00	11.00	11.00	11.00
Groundnut cake	32.43	30.95	30.17	30.11	29.34
Fish meal	3.00	3.00	3.00	3.00	3.00
Bone meal	2.00	2.00	2.00	2.00	2.00
Salt	0.25	0.25	0.25	0.25	0.25
*Premix	0.25	0.25	0.25	0.25	0.25
SL	0.25	0.19	0.13	0.06	0.00
MOLP	0.00	1.74	3.47	5.21	6.94
Methionine	0.25	0.25	0.25	0.25	0.25
Total	100.00	100.00	100.00	100.00	100.00
Calculated Analyses					
Crude Protein (%)	23.00	23.00	23.00	23.00	23.00
Metabolizable Energy (Kcal/kg)	2855.62	2860.50	2857.71	2847.73	2845.06

*Premix provides per kg diet: Vitamin A, 10,000 IU, Vit. D_3, 2000 IU, Vit E, 23mg, Vit K, 2mg, Vit B_1,.8mg, Vit B_2,5.5mg, Vit B_6, 6.0mg, Niacin, 27.5mg, pantothenate, 10.0mg, Biotin, 0.06mg, Vit B_{12}, 0.015mg, Folic acid, 0.75mg, Choline chloride, 300mg, Manganese, 40mg, Iron, 20mg, Zinc, 30mg, Iodine, 1mg, Selenium, 0.2mg, Cobalt, 0.2mg, Antioxidant, 1.25mg.

T1: 100 % SL, 0 % MOLP
T2: 75 % SL, 25 % MOLP
T3: 50 % SL, 50 % MOLP
T4: 25 % SL, 75 % MOLP
T5: 0 % SL, 100 % MOLP
SL: Synthetic lysine
MOLP: *Moringa oleifera* leaf powder

Table 3.2 Experimental finisher diets of broiler chickens fed diets containing *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine (SL)

Ingredients (%)	**T1**	**T2**	**T3**	**T4**	**T5**
Maize	64.27	64.08	63.16	61.57	60.67
Maize offal	5.00	5.00	5.00	5.00	5.00
Groundnut cake	24.73	23.25	22.49	22.41	21.64
Fish meal	3.00	3.00	3.00	3.00	3.00
Bone meal	2.00	2.00	2.00	2.00	2.00
Salt	0.25	0.25	0.25	0.25	0.25
*Premix	0.25	0.25	0.25	0.25	0.25
SL	0.25	0.19	0.13	0.06	0.00
MOLP	0.00	1.74	3.47	5.21	6.94
Methionine	0.25	0.25	0.25	0.25	0.25
Total	100.00	100.00	100.00	100.00	100.00
Calculated Analyses					
Crude Protein (%)	20.00	20.00	20.00	20.00	20.00
Metabolizable Energy (Kcal/kg)	3009.56	3014.44	3011.44	3001.67	2999.00

*Premix provides per kg diet: Vitamin A, 10,000 IU, Vit. D_3, 2000 IU, Vit E, 23mg, Vit K, 2mg, Vit B_1,.8mg, Vit B_2,,5.5mg, Vit B_6, 6.0mg, Niacin, 27.5mg, Pantothenate, 10.0mg, Biotin, 0.06mg, Vit B_{12}, 0.015mg, Folic acid, 0.75mg, Choline chloride, 300mg, Manganese, 40mg, Iron, 20mg, Zinc, 30mg, Iodine, 1mg, Selenium, 0.2mg, Cobalt, 0.2mg, Antioxidant, 1.25mg.

T1: 100% SL, 0% MOLP
T2: 75% SL, 25% MOLP
T3: 50% SL, 50% MOLP
T4: 25% SL, 75% MOLP
T5: 0% SL, 100% MOLP
SL: Synthetic lysine
MOLP: *Moringa oleifera* leaf powder

3.4.2 Growth performance parameters

The following parameters were measured from the data generated from the daily records of the feeding trial: total feed intake (FI), daily feed Intake (DFI), initial body weight (IW), final body weight (FW), daily weight gain (DWG), protein efficiency ratio (PER), feed conversion ratio (FCR) and protein intake (PI).

$$\textbf{Feed conversion ratio } (\text{FCR}) = \frac{\text{Average feed intake per week (g)}}{\text{Average weight gain per week (g)}}$$

$$\textbf{Protein efficiency ratio } (PER) = \frac{Body\ weight\ gain(g)}{Protein\ Intake}$$

where protein intake = feed intake (DM) × percentage protein diet.

3.4.3 Apparent nutrient digestibility determination

Two chickens from each replicate of the treatments were randomly selected for the apparent digestibility trial at week 7. The birds were kept in a specially-constructed metabolism cages and allowed to acclimatize for 3-5 days, before faecal samples were collected for five days, using the total collection method. The birds were given feed and water *ad libitum*. The faecal samples from each replicate were collected daily, bulked and oven dried at 80^0C for 24 hours. Thereafter, they were stored in air-tight sample bottles, after grinding, using mortar and pestle. About 2 g of the sub-samples were taken for proximate analysis as described by AOAC (1990).

3.4.4 Haematology and serum biochemical analyses

At the end of the feeding trial, about 2 ml of blood sample from each replicate was collected for haematological and serum biochemical analyses. The blood samples were collected through the wing veins of randomly selected chickens, into heparinized (anti-coagulant) and plain bottles aseptically using a 10 ml and 19-gauge disposable syringes

and needles. The samples were analyzed at the Haematology Laboratory of Niger State Veterinary Hospital, Bosso, Minna.

This was carried out using Abacus Junior 30 Veterinary Analyzer (which can analyze 22 haematological parameters, with three-part differentiation). The machine (manufactured by Diatron, USA) automatically analyzed the samples and displayed results of analysis through the screen/monitor of the machine. The haematological parameters measured included haemoglobin concentration (HBC), packed cell volume (PCV), mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), mean cell haemoglobin concentration (MCHC), total white blood cells count (TWBC), platelet count (PLC), neutrophils (N), lymphocytes (L), basophils (B); red blood cells count (RBC), and red cell distribution width (RDW**)**.

The serum biochemistry analysis was determined using the routine standard clinical chemistry procedures (Olorede *et al.,* 1996). Parameters measured included urea, creatinine, AST, ALT, ALP, total protein, albumin and globulin.

3.5 Experiment Two

3.5.1 Meat yield and carcass characteristics of broiler chickens fed diets containing *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine

3.5.1.1 *Carcass characteristics*

At the end of the experiment, two chicken from each replicate, making a total of 50, were randomly selected for meat yield and carcass quality analysis. The selected chicken were starved of feed for twelve (12) hours (10:00 PM to 6:00 AM the following day) prior to slaughter. The records of the chicken's individual weights were taken before slaughter. The chicken were slaughtered using a sharp kitchen knife by cutting their jugular veins and allowed to properly bleed, after which the individual slaughter weights were taken.

They were then scalded in hot water of 75^{o}C for thirty (30) seconds and the feathers were manually plucked. Thereafter, the record of the individual plucked weights were taken. The birds were eviscerated and the dressed weight of each carcass was taken. The carcasses were separated into parts (breast, thigh, drumsticks, wings, back, head, neck and shanks) and visceral organs (liver, heart, gizzard, abdominal fat, intestine and lungs). The weight of each primal cut, and organs were taken and expressed as percentage of the live weight of each carcass. The dressing percentage and percentage of body weight in relation to the live weights of the chickens were calculated as described by Aduku and Olukosi (1990) in the formulae as follows:

$$Dressing\ percentage = \frac{Dressed\ carcass\ weight}{Live\ weight} \times \frac{100}{1}$$

$$Percentage\ of\ bodycut = \frac{Weight\ of\ bodycut}{Live\ weight} \times \frac{100}{1}$$

3.6 Experiment Three

3.6.1 Physicochemical characteristics of the breast meat of broiler chickens fed diets containing *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine (SL)

The physicochemical characteristics of the meat of broiler chicken were analyzed using the breast meat of the chicken. Properties analyzed included proximate, amino acids, minerals and vitamins compositions.

3.6.1.1 *Proximate analysis*

A 5 g sample of the minced breast meat of broiler chicken from each replicate was analyzed to establish the proximate composition of the meat, following the methods of

AOAC (1990). Properties analyzed included moisture, crude protein, ash and ether extracts.

3.6.1.2 *Amino acids analysis*

Amino acids profile was analyzed following the procedure of AOAC (2020). A 20 g sample of the minced breast meat from each replicate was analyzed for amino acid profile (essential and non-essential) using ion-exchange column chromatography after acid digestion of the sample with 6N hydrochloric acid at 110°C for 24 hours. The residue was dissolved in a buffer with pH 2.2. Sulfur-containing amino acids (methionine and cysteine) were identified after oxidation of the sample with hydrogen peroxide and performic acid. The separation of the different amino acids was done on an amino acid analyzer and their amounts were calculated on the basis of elution and standard solution volumes.

3.6.1.3 *Mineral and vitamins analysis*

The mineral and vitamins composition of the breast meat samples from each treatment was analyzed following the procedure of AOAC (2020).

Minerals present were analyzed following the procedure for minerals and elemental analysis using atomic absorption spectroscopy (AAS). Minerals analyzed included macro (Mg, K, Ca, P, S, Cl) and micro (Fe, Cu, Mn, Zn, Se, I) minerals.

Vitamins composition was analyzed using isocaloric high performance liquid chromatography (HPLC). Vitamins analyzed included A, B_2, B_{12}, C, D, E, and K.

20 mg of carefully prepared minced breast meat sample was injected into a Buck scientific HPLC (model BLC10/11, USA), equipped with UV 325 nm and UV 254nm detectors for fat and water soluble vitamins respectively. A C18, 4.6 x 150 mm, 5 um column and a mobile phase of 95:5 (methanol: water) was used at a flow rate of 1.00 mL/minute and at

an ambient operating temperature. A 0.1 mg of mixed standards was analyzed in a similar manner for identification. Peak identification was conducted by comparing the retention times of authentic standards and those obtained from the samples. Concentrations were calculated using a four-point calibration curve.

3.6.1.4 *Meat to bone ratio*

This was analyzed following the procedure of Yakubu *et al.* (2016). The meat was deboned manually and each (meat and bone) weighed separately. The ratio of the meat to bone in relation to the whole carcass was then calculated.

3.6.1.5 *pH*

The pH of the meat samples was measured using a pH meter (pH Spear, Model 35634-40, Eurotech Instruments, Malaysia). This was done immediately after dressing the chickens. An incision of the breast muscle was made using a kitchen knife and the electrode was inserted into the incised point and readings from the pH meter screen was taken and recorded.

3.6.1.6 *Water holding capacity*

The water holding capacity of the breast muscle samples from each treatment was evaluated, following the procedure described by Kauffman *et al.* (1992). A 10 g of the meat sample was taken using a digital sensitive weighing scale. The sample was laid between two filter papers and pressed in a screw jack to expel out the water/fluid contained in it. The sample was then removed from the filter papers and weighed again. The difference between the initial and final weights is the weight of the expelled water/fluid which is expressed as a percentage of the initial sample weight and recorded as the water holding capacity (WHC).

3.6.1.7 *Thawing loss (drip loss)*

About 50 g of the breast muscle sample was taken from broiler chickens in each treatment (using a digital weighing scale) and individually packed in a polythene bag and frozen under 4^{o}C for 24 hours. Thereafter, the samples were submerged in a basin of water which was changed twice at every 30 minutes. Drip loss was determined following the method described by Northcutt *et al.,* (1994) by calculating the difference between initial and final weight of each sample and expressed as the percentage of the initial weight.

3.6.1.8 *Cooking yield and cooking loss*

The evaluation of the cooking yield and cooking loss of the breast muscle sample was carried out following the procedure described by Bethany *et al.* (2012). A 20 g breast meat sample was taken for boiling. The boiling was done by placing each meat sample in a glass container, containing 20 ml water. The water bath was then preheated for five (5) minutes before the glass containers were placed in. After placing the glass containers in the water bath, broiling was done up to 75^{o}C (measured by skewer thermometer for thirty minutes). The samples were then removed from the water bath and allowed to cool to room temperature. Excess fluid was mopped off using a serviette paper and the weight of each sample taken and recorded. The cooking loss and cooking yield was then calculated using the formulae below.

Cooking Loss = Initial meat weight – final cooked meat weight (g)

$$\text{Cooking yield (\%)} = \frac{\text{Cooked meat weight (g)}}{\text{Initial meat weight (g)}} \times \frac{100\%}{1}$$

3.6.1.9 *Sensory evaluation*

Meat weighing 30 g each from the breast portion of the broiler chicken was washed, cooked by adding 1g of table salt and 100 ml of clean water in a cooking pot and cooked up to a temperature of 75^{o}C for 30 minutes (as described by Fasae *et al.*, 2010). A total of 20 semi-trained panel members were used for sensory evaluation of the palatability traits of colour, flavour, tenderness, juiciness, and overall acceptability of the chicken meat on a nine-point Hedonic Scale (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) according to Damazia *et al*. (2019). Table water was served to each member of the panel to rinse their mouths after scoring each sample to reduce flavour carryovers.

3.6.2 Data analysis

All data obtained from the experiment were subjected to Analysis of Variance (ANOVA) using Statistical Package for Social Science (SPSS, version 17.0). Means, where significant, were separated using Duncan Multiple Range Test (DMRT) as contained in the Package.

3.7 Experiment Four

3.7.1 Shelf life and microbial assessment of breast meat of broiler chickens fed diets containing *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine

Two 50 g meat samples from the breast region from each replicate was separately packed in a polyethylene bag and stored under 4^{O}C temperature condition for 6 months. The following analysis was conducted at a month interval, during the six months storage

period. The experimental design used was a completely randomized design model based on a 5 x 6 factorial arrangement.

3.7.1.1 *Lipid oxidation*

Peroxide value and free fatty acids analysis were determined as described by AOAC (2020).

A. Peroxide value

Peroxide value is a measure of the concentration of peroxides and hydro peroxides formed in the initial stages of lipid oxidation. A 5 g breast meat sample was taken into a 250 ml glass stoppered Erlenmeyer flask. Then, 30 ml of acetic acid-chloroform solution was added to the sample using graduated cylinder. Then the flask was swirled until the sample was completely dissolved. About 0.5 ml of saturated potassium iodide solution was added using 1 ml Mohr pipette. The content of the flask was swirled for exactly one minute and 30 ml of distilled water was added immediately using a graduated cylinder. The flask was stoppered and shaken vigorously to liberate the iodine from the chloroform layer. To the solution, which was initially a light amber colour, was added 1 ml of starch solution as indicator using a dispensing device. Then the burette was filled with 0.1N sodium thiosulfate solution and titration started. Titration was continued until the blue grey colour disappeared in the aqueous (upper) layer. Then the mls of titrant used was recorded to two decimal places.

$$\text{Peroxide value (meq/kg)} = \frac{(\text{S} - \text{B}) \times \text{N thiosulfate} \times 1000}{\text{weight of sample}}$$

Where, S = titration of sample; B = titration of blank

B. Free Fatty acids value

Free fatty acids (FFA) value was determined using the procedures of AOAC (2020). 15 g of breast meat sample from different treatments was blended using pestle and mortar and dissolved in 150 ml of petroleum ether, shaken well and filtered through Whatman's filter paper No. 42; and about 90 ml of filtrate was collected. Then two parts of 20 ml of filtrate was taken. One part was taken in pre-weighed petri plate for different test groups and kept in hot air oven at 100 ± 2ºC for drying and weight of residual fat was calculated. Another part of 20 ml filtrate of different test groups was taken in different beaker. Ten milliliter (10 ml) of neutral ethyl alcohol was added to the filtrate of each group. Then it was shaken well for proper dissolution of fat. Two (2) drops of phenolphthalein indicator (1 %) was added to the filtrate of beaker and titrated against 0.1 N NaOH till the end point was obtained. The FFA content of the sample was calculated as:

$$\%\ FFA\ as\ Oleic\ Acid = \frac{(n \times ml\ of\ NaOH\ used\ in\ titration \times 0.282 \times 100)}{Fat\ weight}$$

3.7.1.2 ***Microbial assessment***

Under the microbial assessment, total viable count (TVC) and yeast mould count (YMC) were determined using the following procedures of Onwuka (2005).

A. Preparation of samples for TVC and YMC

The stored breast meat sample was thoroughly and uniformly macerated in a mechanical blender using a sterile diluent (0.1 % peptone water) as per recommendation of International Standards Organization (1995).

A 10 g of the minced meat sample was taken aseptically and transferred into a sterile container containing 90 ml of 0.1 % peptone water. A homogenized suspension was made in a sterile blender. Thus 1:10 dilution of the sample was obtained. Subsequently,

different serial dilutions ranging from 10-2 to 10-6 were prepared using whirly mixture machine according to the instruction of the International Standards Organization (ISO, 1995).

B. Media and reagent employed for TVC and YMC

The media employed for this bacteriological analysis include the plate count agar (PCA) and potato dextrose agar (PDA). The commercial media was prepared following the direction of the manufacturers. The diluent used during the study was 0.1 % peptone water.

C. Preparation of media

About 11.50 g of PCA agar was dissolved in 500 ml of cold distilled water in a conical flask and heated to boiling for dissolving the ingredients completely. In case of PDA, 200 g of previously peeled and sliced potato was added into a 1000 ml of distilled water and boiled for an hour. After boiling, sieving was done through clean cheese cloth. 20 g of commercial dextrose and 15 g of agar were added to the potato infusion solution and heated up to boiling to dissolve the ingredients completely, followed by sterilization of the media at 121°C (6.795 kg pressure/sq inch) for 15 minutes in an autoclave. The final reaction was adjusted to pH 7.0 ± 0.1 and the agar was ready for pouring. However, the medium was kept in a boiling water bath at 45ºC before pouring.

D. Enumeration of total viable count (TVC)

In determining the total bacterial counts, 0.1 ml of each ten-fold dilution was transferred and spread on triplicate PCA agar using a sterile pipette for each dilution. The diluted samples were spread as quickly as possible on the surface of the plate with a sterile glass spray. One sterile glass spray was used for each plate.

Thereafter, the plates were incubated at 35°C for 24-48 hours after which plates exhibiting 30-300 colonies were counted with the aid of a colony counter. The average number of colonies in a dilution was multiplied by the dilution factor to obtain the total viable count and calculated as described by ISO (1995). The result of the total bacterial count was expressed as the number of organisms of colony forming units per gram (CFU/g) of broiler chicken breast meat samples.

E. Enumeration of yeast-mould count (YMC)

In determining the yeast and mould counts, 0.1 ml of each ten-fold dilution was transferred and spread on triplicate PDA agar using a sterile pipette for each dilution. The diluted sample was spread as quickly as possible on the surface of the plate with a sterile glass spray. One sterile glass spray was used for each plate.

The plates were incubated at 25°C for 48-72 hours. Thereafter, plates exhibiting 30-300 colonies were counted with the aid of a colony counter. The average number of colonies in a dilution was multiplied by the dilution factor to obtain the yeast and mould count. The yeast and mould count was calculated following ISO (1995) procedure. The results of the yeast and mould count were expressed as the number of organisms of colony forming units per gram (CFU/g) of broiler chicken breast meat samples.

3.7.2 Data analysis

All data obtained from the experiment were subjected to Analysis of Variance (ANOVA) using Statistical Package for the Social Sciences (SPSS, version 17.0). Means, where significant, were separated using Duncan Multiple Range Test (DMRT), as contained in the Package.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Results

4.1.1 Proximate, phytochemical and amino acid compositions of *Moringa oleifera* leaf powder (MOLP)

Table 4.1 shows the proximate composition of *Moringa oleifera* leaf powder (MOLP). The result revealed that *Moringa oleifera* leaf powder (MOLP) contains 95.28 % DM, 28.33 % protein, 3.40 % ether extract, 16.70 % fibre, 4.80 % ash and 42.05 % NFE.

Table 4.2 reveals the phytochemical composition (g/100g) of *Moringa oleifera* leaf powder (MOLP). It indicated 4.95 g/100g alkaloids, 6.44 g/100g saponin, 12.56 g/100g oxalates, 8.80 g/100g tannins, 0.04 g/100g cyanide and 2.95 g/100g phytate. It also contained 41.35 g/100g phenolic acid and 12.22 g/100g flavonoids.

Table 4.3 shows the amino acids composition of *Moringa oleifera* leaf powder (MOLP). The results revealed 3.60 g/100g lysine, 4.48 g/100g methionine, 7.66 g/100g threonine, 5.05 g/100g isoleucine, 2.95 g/100g leucine, 7.18 g/100g phenylalanine, 4.6 g/100g valine, 12.87 g/100g tryptophan, 3.94 g/100g histidine, 1.52 g/100g arginine, 6.81 g/100g serine, 4.39 g/100g cystein, 7.92 g/100g tyrosine, 7.15 g/100g alanine, 9.35 g/100g aspartic acid, 5.12 g/100g glutamic acid, 14.26 g/100g glycine and 7.30 g/100g proline.

Table 4.1: Proximate compositions of *Moringa oleifera* leaf powder (MOLP)

Dry matter (%)	95.28
Protein (%)	28.33
Ether Extract (%)	3.40
Fibre (%)	16.70
Ash (%)	4.80
Nitrogen Free Extract (NFE) (%)	42.05

Table 4.2: Phytochemical composition of *Moringa oleifera* leaf powder (MOLP)

Alkaloids (g/100g)	4.95
Saponins (g/100g)	6.44
Oxalates (g/100g)	12.56
Tannins (g/100g)	8.80
Cyanides (g/100g)	0.04
Phytates (g/100g)	2.95
Phenolics Composition	
Phenolic acids (g/100g)	41.35
Flavonoids (g/100g)	12.22

Table 4.3: Amino acids composition of *Moringa oleifera* leaf powder (MOLP)

Lysine (g/100g)	3.60
Methionine (g/100g)	4.48
Threonine (g/100g)	7.66
Isoleusine (g/100g)	5.05
Leucine (g/100g)	2.95
Phenylalanine (g/100g)	7.18
Valine (g/100g)	4.67
Tryptophan (g/100g)	12.87
Histidine (g/100g)	3.94
Arginine (g/100g)	1.52
Serine (g/100g)	6.81
Cysteine (g/100g)	4.39
Tyrosine (g/100g)	7.92
Alanine (g/100g)	7.15
Aspartic acid (g/100g)	9.35
Glutamic acid (g/100g)	5.12
Glycine (g/100g)	14.26
Proline (g/100g)	7.30

4.1.2 Proximate composition (%) of the experimental diets of broiler chickens fed diets containing *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine (SL) at starter phase

Table 4.4 shows the proximate composition of the experimental diets of broiler chickens fed diets containing *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine (SL) at starter phase. The feeds were isocaloric and isonitrogenous.

4.1.3 Proximate composition (%) of the experimental diets of broiler chickens fed diets containing *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine (SL) at finisher phase

Table 4.5 shows the proximate composition of the finisher diets of broiler chickens fed diets containing *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine (SL) The diets were isocaloric and isonitrogenous.

Table 4.4: Proximate composition (%) of experimental starter diets of broiler chickens fed diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine

Parameter (%)	0 % MOLP	25 % MOLP	50 % MOLP	75 % MOLP	100 % MOLP
Dry matter	90.00	91.40	91.60	94.00	89.86
Ash	7.84	6.38	7.24	8.11	7.18
Ether extract	6.38	7.24	7.81	7.46	6.98
Crude protein	23.45	24.15	23.80	23.28	22.60
Crude fibre	3.50	3.55	3.75	3.90	3.96
Nitrogen free extract	48.83	50.08	49.00	51.25	49.14

MOLP = *Moringa oleifera* leaf powder

Table 4.5: Proximate composition (%) of experimental finisher diets of broiler chickens fed diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine

Parameter	0 % MOLP	25 % MOLP	50 % MOLP	75 % MOLP	100 % MOLP
Dry matter	93.01	93.40	93.60	92.70	92.86
Ash	4.20	4.50	5.24	4.11	4.18
Ether extract	11.60	11.24	10.81	10.46	10.98
Crude protein	20.67	20.15	20.80	20.28	20.60
Crude fibre	4.65	4.56	4.87	5.00	4.95
Nitrogen free extract	51.89	52.95	51.88	52.85	52.15

MOLP = *Moringa oleifera* leaf powder

4.1.4 Growth performance of broiler chickens fed starter diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine

The result of growth performance of broiler chickens fed starter diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine is shown on Table 4.6. The results revealed that all parameters measured were significantly ($P<0.05$) different among the treatment means except the values for the initial body weight. The result of final body weight, total body weight gain and daily body weight gain followed a similar pattern; the highest value was recorded in diet containing 75 % MOLP and 25 % SL (699.06 g, 653.36 g, 23.33 g respectively).

The results also showed that broiler chickens fed 25 % *Moringa oleifera* leaf powder had higher feed intake (1521.03 g) compared to the least in broiler chickens fed 100 % MOLP (1493.64 g), which was similar to the result obtained for all the other treatments. Feed conversion ratio was best in T4 with the lowest value of 2.33 while the least was recorded in T5 with the highest value of 2.73. Protein intake was significantly higher in T2 (367.33) compared to the least in T5 (337.56). while protein efficiency ratio was better in T4 (1.85). Values of PER for the other treatments were similar, although T5 (1.63) had the lowest value. PER differed significantly ($P>0.05$) in the broiler chickens across treatment groups in the experiment. Results also showed that broiler chickens in T4 had significantly ($P>0.05$) higher final weight while broiler chickens in T5 have significantly ($P>0.05$) lowest final weight which is comparable ($P>0.05$) to the final weight obtained in broiler chickens in T2 and T3. Final weight obtained in broiler chickens in T2 and T3 did not differ significantly ($P>0.05$) from each other but were comparable to the final weight obtained in broiler chickens in T4 ($P<0.05$). The results of weight gain, daily weight gain and weekly weight gain followed similar pattern with the result obtained in final weight of the broiler chickens.

Feed intake of broiler chickens in T2 were significantly higher (P>0.05) followed by broiler chickens in T5. The feed intake of broiler chickens in T1, T3 and T4 were not significantly (P>0.05) different from each other but were comparable to feed intake obtained in broiler chickens in T2 and T5. The result of daily feed intake and weekly feed intake also followed similar patterns.

Feed conversion ratio was highest in broiler chickens in T5 (P>0.05) and significantly (P<0.05) lowest in broiler chickens in T4. Feed conversion ratio of broiler chickens in T2 and T3 did not differ significantly (P>0.05) from each other but were comparable (P>0.05) to the feed conversion ratio obtained for broiler chickens in T4.

The result of protein intake in broiler chickens showed that T2 had significantly (P<0.05) highest protein intake, followed by broiler chickens in both T1 and T4 while the protein intake of broiler chickens in T5 was significantly (P<0.05) lowest among the treatment groups in the experiment. The protein intake by broiler chickens in T3 is comparable to the protein intake of broiler chickens in T2.

The result of protein efficiency ratio shows that broiler chickens in T4 had significantly (P<0.05) better protein efficiency followed by broiler chickens in T1, T2 and T5. The protein efficiency ratio in T1, T2 and T5 did not vary significantly (P<0.05). It further shows that protein efficiency ratio of broiler chickens in T3 was comparable to protein efficiency obtained for broiler chickens in T1, T2, T4 and T5.

Table 4.6: Growth performance of broiler chickens fed diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine at starter phase

Parameter	T1	T2	T3	T4	T5	SEM	LOS
IW (g)	43.50	44.20	44.20	45.70	43.80	0.34	NS
FW (g)	628.24^{bc}	665.26^{ab}	668.60^{ab}	699.06^{a}	593.60^{c}	9.64	*
TWG (g)	584.74^{bc}	621.06^{ab}	624.40^{ab}	653.36^{a}	549.80^{c}	9.53	*
DWG (g)	20.88^{bc}	22.18^{ab}	22.30^{ab}	23.33^{a}	19.64^{c}	0.34	*
TFI (g)	1495.17^{ab}	1521.03^{a}	1515.51^{ab}	1517.67^{ab}	1493.64^{b}	4.12	*
DFI (g)	53.40^{ab}	54.32^{a}	54.12^{ab}	54.20^{ab}	53.35^{b}	0.15	*
FCR	2.57^{ab}	2.45^{bc}	2.43^{bc}	2.33^{c}	2.73^{a}	0.04	*
PI (g)	350.62^{c}	367.33^{a}	360.69^{ab}	353.31^{c}	337.56^{d}	2.20	*
PER	1.67^{b}	1.69^{b}	1.73^{ab}	1.85^{a}	1.63^{b}	0.02	*

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

T1: 100 % synthetic lysine, 0 % *Moringa oleifera* leaf powder
T2: 75 % synthetic lysine, 25 % *Moringa oleifera* leaf powder
T3: 50 % synthetic lysine, 50 % *Moringa oleifera* leaf powder
T4: 25 % synthetic lysine, 75 % *Moringa oleifera* leaf powder
T5: 0 % synthetic lysine, 100 % *Moringa oleifera* leaf powder

SEM: Standard error of the means
LOS: Level of significance
NS: Not significantly different
*: Significantly different
IW: Initial body weight
FW: Final body weight
TWG: Total body weight gain
DWG: Daily weight gain
TFI: Total feed intake
DFI: Daily feed intake
FCR: Feed conversion ratio
PI: Protein intake
PER: Protein efficiency ratio

4.1.5 Growth performance of broiler chickens fed finisher diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine

The performance of broiler chickens fed diets containing *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine (SL) is presented in Table 4.7. The results show that there were no significant ($P>0.05$) differences in initial body weight, final body weight, total body weight gain, daily weight gain, feed conversion ratio and protein efficiency ratio of broiler chickens in the treatment groups of the experiment. However, there were significant differences ($P<0.05$) in feed intake and protein intake across the treatment groups in the experiment.

Performance of the broiler chickens in total feed intake and daily feed intake differ significantly ($P<0.05$) across the treatment groups in a similar pattern, with highest values obtained in broiler chickens in T5 followed by T4. While the values obtained for broiler chickens in T1, T2 and T3 did not differ significantly ($P>0.05$) from each other but they were comparable to the values obtained for broiler chickens in T4 and T5 respectively.

Protein intake of broiler chickens in the experiment is highest ($P<0.05$) in T2 with the least ($P<0.05$) values obtained in broiler chickens in T4.

Table 4.7: Growth performance of broiler chickens fed diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine at finisher phase

Parameter	T1	T2	T3	T4	T5	SEM	LOS
IW (g)	678.24	665.26	668.60	699.06	693.60	19.64	NS
FW (g)	1567.35	1672.69	1594.98	1692.56	1467.09	57.97	NS
TWG (g)	939.11	1007.43	926.38	993.50	873.49	53.77	NS
DWG (g)	26.83	28.78	26.47	28.39	24.96	1.54	NS
TFI (g)	3843.80^{ab}	3861.41^{ab}	3861.52^{ab}	3809.79^{b}	3879.64^{a}	9.98	*
DFI (g)	109.82^{ab}	110.33^{ab}	110.33^{ab}	108.85^{b}	110.85^{a}	0.29	*
FCR	4.25	4.15	4.70	4.75	5.12	0.41	NS
PI (g)	781.06^{ab}	788.89^{a}	771.92^{bc}	763.86^{c}	780.97^{ab}	2.49	*
PER	1.20	1.28	1.20	1.30	1.12	0.07	NS

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

T1: 100 % synthetic lysine, 0 % *Moringa oleifera* leaf powder

T2: 75 % synthetic lysine, 25 % *Moringa oleifera* leaf powder

T3: 50 % synthetic lysine, 50 % *Moringa oleifera* leaf powder

T4: 25 % synthetic lysine, 75 % *Moringa oleifera* leaf powder

T5: 0 % synthetic lysine, 100 % *Moringa oleifera* leaf powder

SEM: Standard error of the means

LOS: Level of significance

NS: Not significantly different

*: Significantly different

IW: Initial body weight

FW: Final body weight

TWG: Total body weight gain

DWG: Daily weight gain

TFI: Total feed intake

DFI: Daily feed intake

FCR: Feed conversion ratio

PI: Protein intake

PER: Protein efficiency ratio

4.1.6 Apparent nutrient digestibility of starter diets fed to broiler chickens containing *Moringa oleifera* leaf powder as substitute for synthetic lysine

Table 4.8 shows apparent nutrient digestibility of broiler chickens fed starter diets containing *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine (SL). The results show significant differences ($P<0.05$) in apparent nutrient digestibility parameters except for the ash content which did not differ ($P>0.05$) across the treatment groups. The results show that diets in T1 and T2 had better ($P<0.05$) dry matter digestibility followed by T5, while diet T4 had significantly ($P<0.05$) lower dry matter digestibility.

Diet T4 had significantly ($P<0.05$) better crude protein digestibility followed by diet T1. The crude protein digestibility of chickens in T2, T3 and T5 were not significantly different ($P>0.05$) from each other but they were comparable to the crude protein digestibility of diet T4.

Crude fibre digestibility was significantly better ($P<0.05$) in diet T4 while in diets T1, T2 and T5, CF digestibility were not significantly different ($P>0.05$) from each other, and were comparable to those of diets T3 and T4.

Ether extract digestibility differs significantly ($P<0.05$) across the experimental groups with the best result obtained in T1 and T4, which were followed by T2. The ether extract digestibility in T2 and T5 are comparable to those in T1, T3 and T4.

Nitrogen free extract digestibility was significantly different ($P<0.05$) in T3 as compared to T1, T2 and T4. There was no significant difference ($P>0.05$) in NFE digestibility between diets T1, T2 and T4, and between diets T3 and T5.

Table 4.8: Apparent nutrient digestibility of starter diets fed to broiler chickens containing *Moringa oleifera* leaf powder as substitute for synthetic lysine

Parameter (%)	T1	T2	T3	T4	T5	SEM	LOS
DM	77.20[a]	77.35[a]	73.33[ab]	56.67[c]	71.90[b]	2.09	*
CP	72.69[a]	69.00[ab]	72.08[ab]	67.37[b]	69.38[ab]	0.77	*
CF	59.21[ab]	59.14[ab]	54.07[b]	61.50[a]	59.20[ab]	0.90	*
Ash	24.70	33.99	23.78	26.57	28.87	2.29	NS
EE	70.72[b]	74.37[ab]	76.83[a]	72.23[b]	73.70[ab]	0.72	*
NFE	78.64[b]	77.89[b]	90.08[a]	82.16[b]	90.42[a]	1.65	*

[abc]Means on the same row with different superscripts were significantly different ($p<0.05$)

T1: 100 % synthetic lysine, 0 % *Moringa oleifera* leaf powder
T2: 75 % synthetic lysine, 25 % *Moringa oleifera* leaf powder
T3: 50 % synthetic lysine, 50 % *Moringa oleifera* leaf powder
T4: 25 % synthetic lysine, 75 % *Moringa oleifera* leaf powder
T5: 0 % synthetic lysine, 100 % *Moringa oleifera* leaf powder

SEM: Standard error of the means
LOS: Level of significance
NFE: Nitrogen free extract
NS: Not significantly different
*: Significantly different.

DM: Dry matter
CP: Percentage crude protein
CF: Percentage crude fibre
Ash: Percentage ash
EE: Percentage ether extract
NFE: Percentage nitrogen free extract

4.1.7 Apparent nutrient digestibility of finisher diets fed to broiler chickens containing *Moringa oleifera* leaf powder as substitute for synthetic lysine

Table 4.9 shows the apparent nutrient digestibility of finisher diets fed to broiler chickens containing *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine (SL). The results showed significant differences ($P<0.05$) in crude protein, crude fibre, ash, ether extract and NFE digestibility across the treatment groups. However, there were no significant differences ($P>0.05$) in dry matter digestibility across the treatment groups. Diet T1 had significantly better ($P<0.05$) crude protein digestibility, which were not significantly different ($P>0.05$) from those of diets T2, T3 and T5 but significantly ($P<0.05$) different from that of diet T4. Also, Diet T1 had significantly better ($P<0.05$) crude fibre digestibility, which were not significantly different ($P>0.05$) from those of diets T2, T4 and T5 but significantly ($P<0.05$) different from that of diet T3.

The digestibility of ash was significantly better in diets T1, T2 and T3 than diets T4 and T5. This is followed by the broiler chickens in T3. However, there were no significant ($P>0.05$) difference in ash digestibility between diets T1, T2, T4 and T5. Digestibility of ether extract was observed to be significantly better in diet T2 followed by T1, T3 and T4. Ether extract digestibility of diet T5 was significantly ($P<0.05$) lower than those of other treatments. NFE digestibility was significantly ($P<0.05$) better in diet T2, followed by diets T1, T3 and T5, and significantly ($P<0.05$) lower in diet T4.

Table 4.9: Apparent nutrient digestibility of finisher diets fed to broiler chickens containing *Moringa oleifera* leaf powder as substitute for synthetic lysine

Parameter	T1	T2	T3	T4	T5	SEM	LOS
DM (%)	89.21	87.09	86.56	89.39	87.12	0.53	NS
CP (%)	89.99^{a}	89.48^{ab}	89.13^{ab}	87.97^{b}	88.75^{ab}	0.27	*
CF (%)	61.92^{a}	61.11^{ab}	55.93^{b}	63.49^{a}	61.20^{ab}	0.94	*
Ash (%)	52.21^{ab}	55.57^{ab}	58.88^{a}	49.84^{b}	51.12^{b}	1.20	*
EE (%)	95.62^{b}	96.39^{a}	95.90^{b}	95.59^{b}	94.95^{c}	0.13	*
NFE (%)	94.37^{b}	95.14^{a}	94.42^{b}	93.66^{c}	94.09^{ab}	0.15	*

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

T1: 100 % synthetic lysine, 0 % *Moringa oleifera* leaf powder
T2: 75 % synthetic lysine, 25 % *Moringa oleifera* leaf powder
T3: 50 % synthetic lysine, 50 % *Moringa oleifera* leaf powder
T4: 25 % synthetic lysine, 75 % *Moringa oleifera* leaf powder
T5: 0 % synthetic lysine, 100 % *Moringa oleifera* leaf powder

SEM: Standard error of the means
LOS: Level of significance
NFE: Nitrogen free extracts
NS: Not significantly different
*****: Significantly different.

DM (%): Dry matter
CP (%): Percentage crude protein
CF (%): Percentage crude fibre
Ash (%): Percentage ash
EE (%): Percentage ether extract
NFE (%): Percentage nitrogen free extract

4.1.8 Haematological parameters of broiler chickens fed diets containing *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine (SL)

Table 4.10 shows the haematology values of broiler chickens fed diets containing *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine (SL). The parameters fall within the normal range recommended for chicken. The results showed significant differences ($P<0.05$) in Hb, PCV, MCV, MCHC, TWBC, N, L, B and RBC. There were however no significant differences ($P>0.05$) in MCH, PLC and RDW in the broiler chickens across the treatment groups of the experiment. Both Hb and PCV followed similar pattern with the highest values ($P<0.05$) obtained in broiler chickens in T4 and T1 while the least values ($P<0.05$) were obtained in chickens in T3. The values of Hb and PCV in broiler chickens in T2 were comparable to the values obtained in broiler chickens in T1 and T4. Similarly, the Hb and PCV values obtained in chickens in T5 were also comparable to the values obtained from chickens in T3. Significantly lower values ($P<0.05$) of MCHC were observed in chickens in T1 and T4 while higher values ($P<0.05$) were recorded for broiler chickens in T3. The MCHC values of broiler chickens in T2 and T5 were not significantly different ($P<0.05$) from each other but were comparable to the MCHC values recorded for broiler chickens in T1, T2 and T3. Broiler chickens in T2 showed significantly lowest ($P<0.05$) values of TWBC while the highest values ($P<0.05$) were recorded in chickens in T5. The TWBC in broiler chickens in T1 and T2 were not significantly different ($P>0.05$) from each other but were comparable to the TWBC values recorded for chickens in T5. The TWBC values of chickens in T4 were also observed to be comparable to the TWBC values recorded in broiler chickens in T2. The results also showed that the N count for chickens in T3 were significantly highest ($P<0.05$) while the recorded values for chickens in T1 were significantly ($P<0.05$) lowest among the treatment groups. It was also observed that the N values in broiler chickens in T2, T3 and

T5 were not significantly different (P>0.05) from each other but were comparable to the N values observed in chickens in T1 and T4.

Broiler chickens in T1, T3 and T5 had significantly higher (P<0.05) values of L followed by chickens in T2. However, the L values in chickens in T1, T3 and T5 were not significantly different (P>0.05) from each other. The L value of chickens in T4 were comparable to the L values recorded for chickens in T1, T2, T3 and T5.

The basophils (B) values recorded for chickens in T1, T3, T4 and T5 were not significantly different (P>0.05) from each other, but significantly different (P<0.05) from the B values recorded for chickens in T2. The B value in chickens in T2 was significantly lowest. The RBC values obtained for chickens in T2 was significantly (P<0.05) highest among the chickens in the treatment groups while the RBC values recorded for chickens in T5 was significantly lowest (P<0.05) among the experimental treatment groups. The RBC values of chickens in T3 were comparable to those in T5.

Table 4.10: Haematological parameters of broiler chickens fed diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine

Parameter	T1	T2	T3	T4	T5	SEM	NR*
Hb (g/dl)	12.40^{a}	11.68^{ab}	9.94^{c}	12.20^{a}	10.72^{bc}	0.27*	7.0 -13.0
PCV (%)	37.00^{a}	34.60^{ab}	29.60^{c}	36.20^{a}	31.80^{bc}	0.79*	22 - 35
MCV (fL)	115.40^{ab}	117.40^{ab}	126.00^{a}	108.40^{c}	119.80^{ab}	1.90*	90 - 140
MCH (pg)	33.00	35.80	33.60	32.40	54.00	4.18NS	33 - 47
MCHC (g/dl)	35.60^{b}	38.60^{ab}	40.20^{a}	35.20^{b}	37.00^{ab}	0.67*	26 - 35
TWBC ($\times 10^3$/mL)	72.06^{ab}	54.12^{c}	80.32^{ab}	67.12^{bc}	84.58^{a}	3.11*	12 -30
PLC	211.20	136.00	44.80	85.60	45.80	26.32NS	-
N	8.80^{b}	16.00^{ab}	12.60^{ab}	36.20^{a}	11.80^{ab}	3.72*	4.1 - 27.6
L	67.20^{a}	27.00^{b}	82.60^{a}	59.60^{ab}	77.00^{a}	6.06*	4.2 - 34.3
B	8.40^{b}	57.00^{a}	4.80^{b}	4.40^{b}	4.00^{b}	4.93*	0.4 - 25.0
RBC ($\times 10^6$/mL)	2.82^{ab}	3.00^{a}	2.52^{bc}	2.62^{abc}	2.38^{c}	0.07*	2.5 - 3.5
RDW	55.80	58.04	57.60	55.12	55.12	0.72NS	-

^{abc}Means on the same row with different superscripts were significantly different (P<0.05)

T1: 100 % synthetic lysine, 0 % *Moringa oleifera* leaf powder
T2: 75 % synthetic lysine, 25 % *Moringa oleifera* leaf powder
T3: 50 % synthetic lysine, 50 % *Moringa oleifera* leaf powder
T4: 25 % synthetic lysine, 75 % *Moringa oleifera* leaf powder
T5: 0 % synthetic lysine, 100 % *Moringa oleifera* leaf powder

SEM: Standard error of the means
LOS: Level of significance
NS: Not significantly different
*: Significantly different

Hb: Haemoglobin
PCV: Packed cell volume
MCV: Mean cell volume
MCH: Mean cell haemoglobin
L; Lymphocytes
B: Basophils
RBC: Red blood cell count

MCHC: Mean cell haemoglobin concentration
TWBC: Total white blood cells count
PLC: Platelet count
N: Neutrophils
RDW: Red cell distribution width
NR*: Normal range as suggested by Odunitan-Wayas *et al.* (2018) and Bounous and Stedman (2000).

4.1.9 Serum biochemistry of broiler chickens fed diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine

Table 4.11 shows the serum biochemical values of broiler chickens fed diets containing *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine (SL). Most of the parameters fall within the normal range recommended for chicken. The results, however, showed significant differences ($P<0.05$) in urea, creatinine, AST, ALT, ALP, total protein, albumin and globulin between the treatments.

Chickens in T1, T2, T3 and T4 did not show any significant difference ($P>0.05$) in their urea content; which were significantly lowest ($P<0.05$) compared to the chickens in T5. Chickens in T5 had significantly ($P<0.05$) higher creatinine content followed by chickens in T1. The chickens in T2 had significantly ($P<0.05$) lower creatinine levels amongst the treatment groups. There was however, no significant ($P>0.05$) difference in the creatinine value of chickens in both T3 and T4, and were comparable to the creatinine content of chickens in T2 and T5. Chickens in T1 have significantly ($P<0.05$) lower values of AST among the treatment groups. The AST level of chickens in T2 and T3 were not different ($P>0.05$) from each other and they ranked between T1 and T4 which had significantly ($P<0.05$) highest AST value.

The AST content of chickens in T5 compares to the AST content of chickens in T2, T5 and T4.. The ALT composition in T1 was significantly ($P<0.05$) lowest whereas ALT level in chickens in T4 and T5 were significantly highest ($P<0.05$), even though both T4 and T5 were not significantly ($P>0.05$) different from each other in ALT content. The ALT values of chickens in T2 and T3 were also not significantly different ($P>0.05$) from each other but they ranked between the values of ALT obtained in T1, and T4 - T5 ($P<0.05$). Alkaline phosphatase (ALP) was significantly lowest ($P<0.05$) in chickens in T5, and highest ($P<0.05$) in chickens in T2 and T3. The values for ALP in chickens in T4 is next

in ranking ($P<0.05$) after T1 and T3. Chickens in T1 ranked next after those in T4 ($P<0.05$) in ALP content. No significant difference ($P>0.05$) was observed in total protein of chickens in T1, T2, and T3 although their total protein significantly varied ($P<0.05$) from those of broiler chicken in T4 and T5. Total protein of chicken in T4 and T5 did not vary significantly ($P>0.05$) from each other. Serum albumin of chickens in T3 were significantly ($P<0.05$) highest followed by those in T5 which happens to be the lowest ($P<0.05$). The serum albumin of chickens in T1 and T5 were comparable to the values obtained for chickens in T4, while those of T2 were significantly comparable to the albumin content of chickens in T3.

Globulin of chickens in T1, T2 and T3 did not differ significantly ($P>0.05$) from each other, although they were significantly ($P<0.05$) higher when compared to the values obtained in T4 and T5. Globulin content of chickens in T4 and T5 did not also differ significantly ($P>0.05$) from each other.

Table 4.11: Serum biochemistry of broiler chickens fed diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine

Parameter	T1	T2	T3	T4	T5	SEM	NR*
Urea (mmol/L)	3.52^{b}	3.36^{b}	3.56^{b}	3.36^{b}	4.04^{a}	0.07*	1.9 -12.5
Creatinine (mg/dl)	0.56^{b}	0.46^{c}	0.62^{ab}	0.62^{ab}	0.66^{a}	0.02*	-
AST (U/L)	111.08^{c}	144.24^{b}	142.32^{b}	168.92^{a}	164.48^{ab}	5.24*	70 - 220
ALT (U/L)	12.32^{c}	17.66^{b}	18.74^{b}	23.40^{a}	25.12^{a}	0.99*	-
ALP (U/L)	430.72^{c}	606.98^{a}	595.12^{a}	533.84^{b}	378.62^{d}	19.74*	568 - 883
Total Protein (g/dl)	3.70^{a}	3.78^{a}	3.96^{a}	2.90^{b}	3.14^{b}	0.10*	3.0 - 4.9
Albumin (g/dl)	1.66^{bc}	1.72^{ab}	1.84^{a}	1.50^{c}	1.64^{bc}	0.03*	1.17 - 2.74
Globulin (g/dl)	2.04^{a}	2.06^{a}	2.12^{a}	1.40^{b}	1.50^{b}	0.08*	1.83 - 2.16

abcMeans on the same row with different superscripts were significantly different ($p<0.05$).

T1: 100 % synthetic lysine, 0 % *Moringa oleifera* leaf powder

T2: 75 % synthetic lysine, 25 % *Moringa oleifera* leaf powder

T3: 50 % synthetic lysine, 50 % *Moringa oleifera* leaf powder

T4: 25 % synthetic lysine, 75 % *Moringa oleifera* leaf powder

T5: 0 % synthetic lysine, 100 % *Moringa oleifera* leaf powder

SEM: Standard error of the means

LOS: Level of significance

NS: Not significantly different

*: Significantly different

AST: Aspartate amino transferase

ALT: Alanine amino transferase

ALP: Alkaline phosphatase

NR*: Normal range as suggested by Odunitan-Wayas *et al.* (2018) and Bounous and Stedman (2000).

4.1.10 Meat yield and carcass characteristics of broiler chickens fed diets containing *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine (SL)

Table 4.12 shows meat yield and carcass characteristics of broiler chickens fed diets containing *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine (SL). The results show that there were no significant differences ($P>0.05$) in live weight, slaughter weight, plucked weight, dressed weight, dressing percentage, weights of breast, thigh, drumsticks, wings, back, head and neck of the chickens. However, chicken in T2 and T4 had significantly ($P<0.05$) higher shank weight followed by broiler chickens in T1. The shank weight of broiler chickens in T3 and T5 were not significantly ($P>0.05$) different from each other and comparable in weight to those of broiler chickens in T1, T2 and T4.

Table 4.13 shows the visceral organ characteristics of broiler chickens fed diets containing *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine (SL). The liver, gizzard, abdominal fat, intestinal length, filled intestinal weight, empty intestinal weight and lungs did not differ significantly ($P>0.05$) across the treatment groups. The heart weight of chickens in T3 was significantly ($P<0.05$) bigger than those of T4. The heart of chickens inT1, T2 and T5 did not differ significantly ($P>0.05$) from each other and were comparable to the heart weight of chicken in T3 and T4.

Table 4.12: Meat yield and carcass characteristics of broiler chickens fed diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine

Parameter	T1	T2	T3	T4	T5	SEM	LOS
Live weight (g)	1962.00	1857.00	1782.33	1935.67	1825.33	36.90	NS
Slaughter weight (g)	1898.33	1792.33	1715.00	1873.67	1764.00	37.59	NS
Plucked weight (g)	1792.00	1700.00	1622.33	1785.00	1669.33	35.35	NS
Dressed weight (g)	1481.00	1445.00	1391.67	1486.67	1450.33	34.14	NS
Dressing (%)	75.16	77.80	78.09	76.74	79.41	0.73	NS
Cut-up parts							
Breast (%)	17.87	17.83	18.56	17.72	19.25	0.45	NS
Thighs (%)	12.71	12.86	12.90	12.77	13.64	0.23	NS
Drumsticks (%)	8.79	10.13	9.64	9.39	9.94	0.22	NS
Wings (%)	10.55	10.26	10.27	10.22	10.60	0.16	NS
Back (%)	12.25	11.91	12.13	11.44	11.65	0.18	NS
Head (%)	2.41	3.02	2.64	2.73	2.55	0.10	NS
Neck (%)	5.23	5.59	5.01	5.30	5.71	0.12	NS
Shanks (%)	3.41^{b}	4.56^{a}	3.84^{ab}	4.63^{a}	4.22^{ab}	0.17	*

abMeans in the same row with different superscripts were significantly different ($p<0.05$).

T1: 100 % synthetic lysine, 0 % *Moringa oleifera* leaf powder

T2: 75 % synthetic lysine, 25 % *Moringa oleifera* leaf powder

T3: 50 % synthetic lysine, 50 % *Moringa oleifera* leaf powder

T4: 25 % synthetic lysine, 75 % *Moringa oleifera* leaf powder

T5: 0 % synthetic lysine, 100 % *Moringa oleifera* leaf powder

SEM: Standard error of the means
LOS: Level of significance
NS: Not significantly different
*: Significantly different.

Table 4.13: Visceral organ characteristics of broiler chickens fed diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine

Parameter	T1	T2	T3	T4	T5	SEM	LOS
Liver (%)	1.74	1.79	1.85	1.54	1.51	0.09	NS
Heart (%)	0.28^{ab}	0.36^{ab}	0.45^{a}	0.22^{b}	0.33^{ab}	0.03	*
Gizzard (%)	1.52	1.78	1.63	1.92	1.46	0.08	NS
Abdominal fat (%)	1.81	1.20	0.71	1.08	0.90	0.22	NS
Intestinal length (cm)	234.67	216.33	238.33	200.33	192.00	7.43	NS
Filled intestinal wt (%)	6.90	4.96	5.65	5.06	4.76	0.34	NS
Empty intestinal wt (%)	3.03	2.99	3.12	2.38	2.91	0.11	NS
Lungs (%)	0.32	0.32	0.36	0.45	0.42	0.03	NS

abMeans in the same row with different superscripts were significantly different ($p<0.05$).

T1: 100 % synthetic lysine, 0 % *Moringa oleifera* leaf powder

T2: 75 % synthetic lysine, 25 % *Moringa oleifera* leaf powder

T3: 50 % synthetic lysine, 50 % *Moringa oleifera* leaf powder

T4: 25 % synthetic lysine, 75 % *Moringa oleifera* leaf powder

T5: 0 % synthetic lysine, 100 % *Moringa oleifera* leaf powder

SEM: Standard error of the means
LOS: Level of significance
NS: Not significantly different
*: Significantly different.
Wt: Weight

4.1.11 Proximate composition of breast meat of broiler chickens fed diets containing *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine (SL)

Table 4.14 shows the proximate composition of the breast meat of broiler chickens fed diets containing *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine (SL). The results show that in the first and second months of evaluation, moisture content of breast meat was significantly ($P<0.05$) highest in broiler chicken in T2 while it was significantly lowest in chickens in T1. At 3rd, 4th, 5th and 6th months of evaluation, moisture contents of the breast meat were significantly ($P<0.05$) highest in chickens in T5 while they were significantly lowest in T1. Crude protein was observed to be significantly ($P<0.05$) highest in chickens in T3 while it was significantly lowest in broiler chickens in T2 at the 1st and 2nd months of evaluation. The Crude protein content of chicken breast meat at 3rd, 4th, 5th and 6th months showed significant difference ($P<0.05$) between treatment groups of the experiment but without any specific trend. The result of the ash content forms the 1st to the 5th months of evaluation shows that ash content of chicken breast meat was significantly highest ($P<0.05$) in chickens in T5. The result of ether extract content shows significant ($P<0.05$) differences across various treatment groups, with the highest ($P<0.05$) ether extract recorded in chickens in T5 while significantly ($P<0.05$) lowest ether extract content was recorded for broiler chickens in T1.

Table 4.14: Proximate composition (%) of the breast meat of broiler chickens fed diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine

Parameter	T1	T2	T3	T4	T5	SEM	LOS
MC (%)							
Month 1	59.63^{c}	68.63^{a}	64.03^{b}	65.29^{b}	64.26^{b}	0.83	*
Month 2	68.90^{c}	73.99^{a}	73.28^{a}	71.75^{ab}	69.87^{bc}	0.58	*
Month 3	72.75^{d}	76.70^{b}	74.69^{c}	77.66^{a}	74.00^{c}	0.49	*
Month 4	74.55^{c}	78.86^{a}	78.69^{a}	79.08^{a}	76.29^{b}	0.51	*
Month 5	77.90^{c}	78.92^{ab}	79.17^{a}	79.49^{a}	78.27^{bc}	0.19	*
Month 6	77.84^{c}	79.04^{ab}	78.66^{b}	79.48^{a}	78.55^{b}	0.16	*
CP (%)							
Month 1	18.42^{b}	17.24^{c}	19.40^{a}	18.63^{b}	19.38^{a}	0.21	*
Month 2	18.56^{b}	17.67^{c}	19.05^{a}	19.00^{a}	19.40^{a}	0.17	*
Month 3	18.52^{a}	17.99^{a}	18.62^{a}	19.12^{a}	10.76^{b}	1.20	*
Month 4	17.93^{d}	18.39^{cd}	18.72^{bc}	19.06^{b}	19.81^{a}	0.18	*
Month 5	18.24^{d}	18.10^{d}	20.73^{a}	20.05^{b}	19.23^{c}	0.27	*
Month 6	16.70^{d}	17.73^{c}	20.67^{a}	18.69^{b}	17.55^{c}	0.37	*
Ash (%)							
Month 1	2.44^{ab}	2.21^{b}	2.58^{ab}	2.31^{ab}	2.84^{a}	0.09	*
Month 2	2.46^{ab}	2.22^{b}	2.55^{ab}	2.45^{ab}	2.89^{a}	0.08	*
Month 3	2.62^{b}	2.72^{b}	3.02^{a}	2.64^{b}	3.06^{a}	0.06	*
Month 4	3.10^{ab}	2.79^{c}	3.02^{b}	2.78^{c}	3.14^{a}	0.04	*
Month 5	2.98^{a}	2.89^{a}	3.00^{a}	2.65^{b}	3.05^{a}	0.05	*
Month 6	2.37^{c}	2.41^{c}	3.20^{a}	2.76^{b}	2.35^{c}	0.09	*
EE (%)							
Month 1	2.71^{c}	2.67^{c}	3.60^{ab}	3.46^{b}	3.88^{a}	0.14	*
Month 2	2.83	2.61	2.80	2.90	3.08	0.08	NS
Month 3	2.85^{c}	3.47^{b}	3.47^{b}	3.97^{a}	3.89^{a}	0.12	*
Month 4	2.90^{c}	3.28^{bc}	3.18^{bc}	3.54^{ab}	3.94^{a}	0.11	*
Month 5	3.00^{c}	3.31^{b}	3.16^{b}	3.71^{a}	3.51^{a}	0.08	*
Month 6	3.07^{c}	3.30^{b}	3.33^{b}	3.76^{a}	3.71^{a}	0.07	*

^{ab}Means in the same row with different superscripts were significantly different ($p<0.05$).

T1: 100 % synthetic lysine, 0 % *Moringa oleifera* leaf powder
T2: 75 % synthetic lysine, 25 % *Moringa oleifera* leaf powder
T3: 50 % synthetic lysine, 50 % *Moringa oleifera* leaf powder
T4: 25 % synthetic lysine, 75 % *Moringa oleifera* leaf powder
T5: 0 % synthetic lysine, 100 % *Moringa oleifera* leaf powder

NS: No significant difference
*: Significantly different
MC: Moisture content
CP: Crude protein
EE: Ether extracts

4.1.12 Amino acids composition of the breast meat of broiler chickens fed diets containing *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine (SL)

Table 4.15 shows the amino acids composition of the breast meat of broiler chickens fed diets containing *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine (SL). The result shows significant differences (P>0.05) in all amino acids evaluated in the breast meat of chickens in the treatment groups of the experiment. The result maintained a particular pattern with T5 having the highest values in most of the parameters measured and T1 maintaining the lowest values. This could be attributed to the quantity of MOLP in the diets. However, T4 recorded the highest values in phenylalanine and serine while T2 had the highest value in glutamic acid. Similarly, T1 recorded the lowest values in most parameters measured except in glutamic acid, whereas T3 had the lowest value.

4.1.13 Mineral content of the breast meat of broiler chickens fed diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine

Table 4.16 shows the result of minerals analysis of the breast meat of broiler chickens fed diets containing *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine (SL). The results from the mineral analysis show that there were significant differences (P<0.05) in all parameters measured except for iodine. Highest magnesium content (P<0.05) was recorded in the breast meat of chickens in T5, while significantly lowest value (P<0.05) was observed in chicken in T2. The result also shows that potassium was significantly highest (P<0.05) in chickens in T5 with the lowest value was recorded for chickens in T1. Calcium was observed to be significantly highest (P<0.05) in chickens in T1 while significantly lowest (P<0.05) calcium levels was recorded for chickens in T5. In a dose dependent gradient, phosphorus was significantly highest (P<0.05) in chickens in T5, decreasing backward with the lowest (P<0.05) level observed in chickens in T1.

Sulphur was significantly (P<0.05) lowest in chickens in T1, increasing through the group significantly (P<0.05) with the highest value (P>0.05) recorded in broiler chickens in T5. Chlorine was significantly highest (P<0.05) in broiler chickens in T5 while lowest level (P<0.05) was observed in broiler chickens in T2, T3, and T4, which were quite comparable to the chlorine values recorded for broiler chickens in both T5 and T1 respectively. The results also show that iron was significantly highest (P<0.05) in chickens in T4 while lowest (P<0.05) values of iron was observed in broiler chicken in T1.

Copper, manganese and zinc showed similar pattern of composition in the breast meat of broiler chicken, as shown in Table 4.16. Significantly highest values (P<0.05) of these minerals were recorded for broiler chickens in T5 while lowest values (P<0.05) were recorded in T1 in a dose dependent gradient. Selenium was observed to be significantly (P<0.05) highest in chickens in T1 while lowest value (P<0.05) was recorded in meat of chickens in T2.

4.1.14 Vitamins content of the breast meat of broiler chickens fed diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine

Table 4.17 shows the vitamins content of the breast meat of broiler chickens fed diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine. Vitamins A, B_6, B_{12}, C, D, E and K followed similar trend with highest values (P<0.05) observed in meat of chickens in T5 while lowest values (P<0.05) of these vitamins were observed in meat of chickens in T1. This observation across the groups follows a dose dependent gradient (P<0.05).

Table 4.15: Amino acids composition of the breast meat of broiler chickens fed diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine

Parameter	T1	T2	T3	T4	T5	SEM	LOS
Lysine	1.06^{e}	1.54^{d}	2.62^{c}	3.16^{b}	4.17^{a}	0.30	*
Methionine	0.79^{e}	0.86^{d}	1.13^{c}	1.23^{b}	1.32^{a}	0.06	*
Threonine	1.55^{e}	1.75^{d}	2.25^{c}	3.41^{b}	3.66^{a}	0.23	*
Isoleucine	1.65^{e}	2.01^{d}	2.85^{c}	2.97^{b}	4.04^{a}	0.22	*
Leucine	5.89^{e}	6.25^{d}	7.34^{c}	8.13^{b}	8.93^{a}	0.30	*
Phenylalanine	2.72^{e}	2.75^{d}	3.84^{c}	4.34^{a}	3.87^{b}	0.17	*
Valine	3.85^{e}	3.87^{d}	4.01^{c}	4.17^{b}	4.26^{a}	0.04	*
Tryptophan	2.66^{e}	2.72^{d}	3.78^{c}	4.11^{b}	5.26^{a}	0.26	*
Histidine	1.51^{e}	1.54^{d}	1.87^{c}	2.45^{b}	3.86^{a}	0.23	*
Arginine	3.60^{e}	3.62^{d}	4.24^{c}	4.96^{b}	6.32^{a}	0.27	*
Serine	2.72^{e}	2.80^{d}	3.13^{c}	3.78^{a}	3.45^{b}	0.11	*
Cysteine	0.55^{c}	0.56^{c}	0.70^{b}	0.97^{a}	0.98^{a}	0.05	*
Tyrosine	3.22^{d}	3.23^{d}	4.62^{c}	5.65^{b}	5.82^{a}	0.30	*
Alanine	1.45^{e}	1.77^{d}	2.72^{c}	3.71^{b}	4.15^{a}	0.28	*
Aspartic acid	3.65^{e}	4.57^{d}	6.52^{c}	7.14^{b}	7.35^{a}	0.39	*
Glutamic acid	4.10^{b}	4.43^{a}	3.14^{d}	3.47^{c}	4.11^{b}	0.13	*
Glycine	3.00^{e}	3.13^{d}	3.42^{c}	4.42^{b}	6.05^{a}	0.30	*
Proline	1.70^{d}	1.71^{d}	1.83^{c}	2.27^{b}	2.29^{a}	0.07	*

^{ab}Means in the same row with different superscripts were significantly different ($p<0.05$).

T1: 100 % synthetic lysine, 0 % *Moringa oleifera* leaf powder

T2: 75 % synthetic lysine, 25 % *Moringa oleifera* leaf powder

T3: 50 % synthetic lysine, 50 % *Moringa oleifera* leaf powder

T4: 25 % synthetic lysine, 75 % *Moringa oleifera* leaf powder

T5: 0 % synthetic lysine, 100 % *Moringa oleifera* leaf powder

SEM: Standard error of the means
LOS: Level of significance
NS: Not significantly different
*: Significantly different,

Table 4.16: Mineral content of the breast meat of broiler chickens fed diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine

Parameter	T1	T2	T3	T4	T5	SEM	LOS
Macro Minerals							
Magnesium (mg/100g)	42.56^{e}	47.70^{d}	53.27^{c}	55.65^{b}	64.60^{a}	1.99	*
Potassium (mg/100g)	415.15^{e}	465.39^{d}	475.86^{c}	477.34^{b}	494.32^{a}	7.18	*
Calcium (mg/100g)	325.33^{a}	272.02^{b}	265.22^{c}	255.85^{d}	239.67^{e}	7.74	*
Phosphorus (mg/100g)	45.35^{e}	68.56^{d}	89.67^{c}	94.35^{b}	96.27^{a}	5.19	*
Sulphur (mg/100g)	0.02^{d}	0.03^{c}	0.03^{c}	0.04^{b}	0.04^{a}	0.00	*
Chlorine (mg/100g)	0.05^{c}	0.07^{abc}	0.06^{bc}	0.07^{ab}	0.08^{a}	0.00	*
Micro Minerals							
Iron (mg/100g)	0.29^{e}	0.33^{d}	1.39^{c}	2.52^{b}	2.62^{a}	0.27	*
Copper (mg/100g)	0.54^{e}	0.72^{d}	0.97^{c}	1.54^{a}	1.50^{b}	0.11	*
Manganese (mg/100g)	33.29^{e}	36.36^{d}	37.43^{c}	41.56^{b}	56.62^{a}	2.20	*
Zinc (mg/100g)	1.15^{e}	1.23^{d}	2.30^{c}	2.39^{b}	3.48^{a}	0.23	*
Selenium (mg/100g)	0.28^{a}	0.32^{d}	0.39^{c}	0.42^{b}	0.44^{a}	0.02	*
Iodine (mg/100g)	0.05	0.06	0.06	0.07	0.08	0.00	NS

^{ab}Means in the same row with different superscripts were significantly different ($p<0.05$)

T1: 100 % synthetic lysine, 0 % *Moringa oleifera* leaf powder
T2: 75 % synthetic lysine, 25 % *Moringa oleifera* leaf powder
T3: 50 % synthetic lysine, 50 % *Moringa oleifera* leaf powder
T4: 25 % synthetic lysine, 75 % *Moringa oleifera* leaf powder
T5: 0 % synthetic lysine, 100 % *Moringa oleifera* leaf powder
SEM: Standard error of the means
LOS: Level of significance
NS: Not significantly different
*: Significantly different,

Table 4.17: Vitamins content of the breast meat of broiler chickens fed diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine

Parameter	T1	T2	T3	T4	T5	SEM	LOS
A (U/g)	14.99^{e}	15.80^{d}	16.88^{c}	17.65^{b}	18.31^{a}	16.72	*
B_6 (mg/100g)	0.15^{e}	0.16^{d}	0.19^{c}	0.21^{b}	0.22^{a}	0.18	*
B_{12} (mg/100g)	0.31^{e}	0.33^{d}	0.38^{c}	0.41^{b}	0.43^{a}	0.37	*
C (mg/100g)	4.15^{e}	6.28^{d}	7.29^{c}	8.31^{b}	11.32^{a}	7.47	*
D (mg/100g)	0.63^{e}	0.75^{d}	0.99^{c}	1.22^{b}	1.47^{a}	1.01	*
E (mg/100g)	0.24^{e}	0.46^{d}	0.56^{c}	0.79^{b}	1.22^{a}	0.65	*
K (mg/100g)	0.03^{e}	0.04^{d}	0.05^{c}	0.06^{b}	0.08^{a}	0.05	*

^{ab}Means in the same row with different superscripts were significantly different ($p<0.05$).

T1: 100 % synthetic lysine, 0 % *Moringa oleifera* leaf powder
T2: 75 % synthetic lysine, 25 % *Moringa oleifera* leaf powder
T3: 50 % synthetic lysine, 50 % *Moringa oleifera* leaf powder
T4: 25 % synthetic lysine, 75 % *Moringa oleifera* leaf powder
T5: 0 % synthetic lysine, 100 % *Moringa oleifera* leaf powder

SEM: Standard error of the means
LOS: Level of significance
NS: Not significantly different
*: Significantly different,

4.1.15 Meat to bone ratio of broiler chickens fed diets containing *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine (SL)

Table 4.18 shows the meat to bone ratio of broiler chickens fed diets containing *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine (SL). Significant difference was only observed between treatment groups in the weight of bone. T1 was significantly ($P<0.05$) heavier than T2, T3, and T4. However, there were no significant differences between T1 and T5. Also, significant difference was also not observed between T2, T3 and T4.

4.1.16 Sensory evaluation of the meat of broiler chickens fed diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine

Table 4.19 shows the sensory evaluation of the meat of broiler chickens fed diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine. The result shows that the meat of broiler chickens in T4 consistently had significantly ($P<0.05$) highest score in sensory parameters from the first month up till the 6^{th} month, followed by those in T5 ($P<0.05$). The sensory evaluation scores of chicken meat in groups T1 and T2 were comparable to the scores obtained for T4 and T5, all through the 6 months of study.

Table 4.18: Meat to bone ratio of broiler chickens fed diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine

Parameter	T1	T2	T3	T4	T5	SEM	LOS
Meat + Bone (g)	352.67	331.33	331.00	344.67	352.00	12.22	NS
Meat (g)	224.61	238.43	253.74	272.63	227.53	9.71	NS
Bone (g)	128.05[a]	92.91[b]	77.26[b]	72.04[b]	124.47[a]	7.23	*

[ab]Means in the same row with different superscripts were significantly different ($p<0.05$).

T1: 100 % synthetic lysine, 0 % *Moringa oleifera* leaf powder
T2: 75 % synthetic lysine, 25 % *Moringa oleifera* leaf powder
T3: 50 % synthetic lysine, 50 % *Moringa oleifera* leaf powder
T4: 25 % synthetic lysine, 75 % *Moringa oleifera* leaf powder
T5: 0 % synthetic lysine, 100 % *Moringa oleifera* leaf powder

SEM: Standard error of the means

LOS: Level of significance

NS: Not significantly different

*: Significantly different,

Table 4.19: Sensory evaluation of the meat of broiler chickens fed diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine

Parameter	T1	T2	T3	T4	T5	SEM	LOS
Colour	7.15^{bc}	7.10^{bc}	7.00^{c}	7.95^{a}	7.85^{ab}	0.12	*
Flavour	7.65^{a}	7.80^{a}	6.50^{b}	7.75^{a}	7.65^{a}	0.13	*
Tenderness	7.55^{ab}	7.20^{b}	7.15^{b}	7.95^{a}	7.95^{a}	0.11	*
Juiciness	7.80^{ab}	7.50^{ab}	7.15^{b}	8.10^{a}	7.65^{ab}	0.12	*
Overall Acceptability	7.75^{ab}	7.95^{ab}	7.50^{b}	8.20^{a}	8.30^{a}	0.09	*

^{ab}Means in the same row with different superscripts were significantly different ($p<0.05$).

T1: 100 % synthetic lysine, 0 % *Moringa oleifera* leaf powder
T2: 75 % synthetic lysine, 25 % *Moringa oleifera* leaf powder
T3: 50 % synthetic lysine, 50 % *Moringa oleifera* leaf powder
T4: 25 % synthetic lysine, 75 % *Moringa oleifera* leaf powder
T5: 0 % synthetic lysine, 100 % *Moringa oleifera* leaf powder

SEM: Standard error of the means
LOS: Level of significance
NS: Not significantly different
*: Significantly different

4.1.17 Main effect of treatments on the physicochemical characteristics and microbial count of breast meat of broiler chickens fed diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine

Table 4.20 shows the main effect of different treatments on the physicochemical characteristics and microbial count of breast meat of broiler chickens fed diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine. The study focused on evaluating carcass yield (CY), cooking loss (CL), water holding capacity (WHC), thawing loss (TL), pH, free fatty acids (FFA), peroxide value (PV), bacterial count (BACT), and fungal count (FUNG) as key indicators of meat quality. Over a storage duration of 6 months, the minimum, maximum, and mean values for each characteristic were analyzed across the different treatments (T1, T2, T3, T4, and T5). The findings revealed significant variations in these parameters, highlighting the influence of treatments, storage durations, and their interactions on the meat quality attributes. There were significant differences in the meat quality characteristics due to the treatment effect ($p < 0.05$). No specific trend was observed across the treatments. The minimum and maximum CY was recorded in T5 (50.46 %) and T1 (61.07 %) respectively. The minimum and maximum CL was recorded in T4 (35.73 %) and T1 (40.09 %) respectively. T2 (4.37) was highest in WHC while the lowest WHC was recorded in T3 (3.82). However, T1 (3.83), T3 (3.82) and T5 (4.04) were not significantly different ($P>0.05$) across the treatments. The TL was significantly highest ($P<0.05$) in T1 (3.72) which was closely followed by T5 (3.60) and significantly lowest ($P<0.05$) in T3 (3.68). Significant differences ($P>0.05$) were, however, not observed between T1, T2 and T5. T5 (6.12) was highest in pH while T3 (5.86) recorded the lowest pH. T4 (0.83) recorded the highest value of FFA and was closely followed by T1 (0.77) and T3 (0.65) recording the lowest value. No significant difference was however observed between the pH value of T1, T2

and T5. The PV was highest in T1 (1.95) which was followed by T5 (1.78). T3 (1.57) which recorded the lowest value was however not significantly different (P>0.05) from T2 (1.65). The bacteria count (CFU/g $x10^6$) ranged from 21.08 in T1 to 29.42 in T4; T1 (21.08) however, was not significantly different (P>0.05) from T2 (21.42). T4 (12.67) had the highest fungi count (CFU/g $x10^6$), though not significantly different from T2 (11.58) and T3 (12.08). T5 (10.58) had the lowest value of fungi count without any significant difference between it and T1 (10.92) and T2 (11.58).

Table 4.20: Main effect of treatments on the physicochemical characteristics and microbial count of breast meat of broiler chickens fed diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine

Parameters	T1	T2	T3	T4	T5	SEM	LOS
CY (%)	61.07^{a}	60.31^{b}	60.21^{b}	50.46^{d}	55.23^{c}	0.99	*
CL (g)	40.09^{a}	38.51^{b}	36.69^{d}	35.73^{e}	37.67^{c}	0.30	*
WHC (%)	3.83^{c}	4.37^{a}	3.82^{c}	4.10^{b}	4.04^{bc}	0.06	*
TL (%)	3.72^{a}	3.68^{bc}	2.48^{c}	3.65^{bc}	3.60^{b}	0.02	*
pH	5.98^{bc}	5.96^{c}	5.86^{d}	6.01^{b}	6.12^{a}	0.04	*
FFA (%)	0.77^{b}	0.76^{b}	0.65^{c}	0.83^{a}	0.75^{b}	0.03	*
PV (meq/kg)	1.95^{a}	1.65^{cd}	1.57^{d}	1.74^{bc}	1.78^{b}	0.18	*
BACT (CFU/g X 10^{6})	21.08^{c}	21.42^{c}	25.17^{b}	29.42^{a}	25.83^{b}	4.62	*
FUNG (CFU/g X 10^{6})	10.92^{bc}	11.58^{abc}	12.08^{ab}	12.67^{a}	10.58^{c}	2.65	*

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

T1: 100 % synthetic lysine, 0 % *Moringa oleifera* leaf powder
T2: 75 % synthetic lysine, 25 % *Moringa oleifera* leaf powder
T3: 50 % synthetic lysine, 50 % *Moringa oleifera* leaf powder
T4: 25 % synthetic lysine, 75 % *Moringa oleifera* leaf powder
T5: 0 % synthetic lysine, 100 % *Moringa oleifera* leaf powder
SEM: Standard error of the means.
WHC (%): Water holding capacity
CY (%): Cooking yield
CL (g): Cooking loss
TL (%): Thawing loss (drip Loss)
FFA (%): Free fatty acid percent
PV (meq/kg): Peroxide value
BACT (CFU/gx10^{6}): Total viable count
FUNG (CFU/gx10^{6}): Yeast mould count

4.1.18 Main effect of storage duration on the breast meat quality characteristics of broiler chickens fed diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine

Table 4.21 shows the main effect of storage duration on the breast meat quality characteristics of broiler chickens fed diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine. Significant difference ($P<0.05$) was observed throughout the months in all parameters measured. The CY was significantly ($P<0.05$) highest in month 2 and lowest in month 5. The CL, even though was highest in Month 6, was not significantly different ($P>0.05$) from the value recorded in month 5. The lowest value was significantly ($P<0.05$) observed in month 2. The WHC values increased significantly ($P<0.05$) through the months of storage with the last month (month 6) recording the highest value and month 1 recording the lowest value. Similarly, the TL and pH also took the same pattern as WHC. The highest and lowest TL values were recorded significantly ($P<0.05$) in Month 6 and Month 1. The FFA was highest in Month 5 even though it was not significantly different from month 4 and month 6. The lowest value was also recorded in month 1 without a significant difference with month 2. The PV took an ascending trend through the months with month 6 recording the highest value of 2.36 and month 1 recording the lowest value of 1.36. However, the values for months 1, 2 and 3 were not significantly different ($P>0.05$). The bacteria and fungi counts did not maintain any specific trend. The bacteria count was highest in month 3 and lowest in month 1. However, no significant difference ($P>0.05$) was observed in bacteria count between months 1, 2 and 3. The fungi count was highest in month 3 which was closely followed by month 4. There was however, no significant difference in fungi count between months 1, 2 and 4. The significantly ($P<0.05$) lowest fungi count was observed in month 6, with no significant difference between month 5 and month 6.

Table 4.21: Main effect of storage duration on the breast meat quality characteristics of broiler chickens fed diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine

Parameters	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	SEM	LOS
CY (%)	62.79^{b}	64.71^{a}	59.11^{c}	56.30^{d}	49.32^{f}	52.36^{e}	0.99	*
CL (g)	31.31^{e}	31.98^{d}	36.55^{c}	38.87^{b}	43.67^{a}	43.99^{a}	0.3	*
WHC (%)	2.55^{f}	2.87^{e}	3.22^{d}	3.92^{c}	5.31^{b}	6.31^{a}	0.06	*
TL (%)	1.18^{f}	1.56^{e}	1.91^{d}	2.83^{c}	5.45^{b}	7.60^{a}	0.02	*
pH	5.38^{f}	5.52^{e}	5.70^{d}	6.19^{c}	6.41^{b}	6.69^{a}	0.04	*
FFA (%)	0.59^{c}	0.61^{c}	0.77^{b}	0.82^{a}	0.86^{a}	0.85^{a}	0.03	*
PV (meq/kg)	1.36^{d}	1.39^{d}	1.41^{d}	1.82^{c}	2.10^{b}	2.37^{a}	0.18	*
BACT (CFU/g X 10^{6})	26.07^{b}	27.82^{b}	40.90^{a}	27.70^{b}	15.80^{c}	9.10^{d}	4.65	*
FUNG (CFU/g X 10^{6})	13.04^{b}	12.22^{b}	16.50^{a}	12.50^{b}	7.70^{c}	7.50^{c}	2.65	*

^{abcdef}Means on the same row with different superscripts were significantly different ($p<0.05$).

SEM: Standard error of the means.
WHC (%): Water holding capacity
CY (%): Cooking yield
CL (g): Cooking loss
TL (%): Thawing loss (drip Loss)
FFA (%): Free fatty acid percent
PV (meq/kg): Peroxide value
BACT (CFU/gx10^{6}): Total viable count
FUNG (CFU/gx10^{6}): Yeast mould count

4.1.18 Interaction effect between the use of *Moringa oleifera* leaf powder and duration of storage on the physicochemical characteristics of broiler chickens fed diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine

There were significant differences (P<0.05) in the physicochemical characteristics as the results of interactions between the treatment effect of *Moringa oleifera* and storage duration is shown in Table 4.22. The cooking yield (CY) has the lowest value at T4, (42.96%) in month 5 and highest value at T2, (69.27%) month 2. The cooking loss (CL) had the minimum value at T2 (30.70) in month 2 and maximum in T1 (49.73%) at months 6. T4 (2.46) had the lowest value of water holding capacity (WHC) while T2 (6.86) had the highest value in month 6. TL value was highest in T1 at Month 6 and lowest in T3 at Month 1. The pH value was lowest in T5 (5.35) at Month 1. This was however, without significance difference between T5 and T4.

4.1.19 Interaction effect between the use of *Moringa oleifera* leaf powder and duration of storage on shelf life and microbial count of breast meat of broiler chickens fed diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine

Table 4.23 shows the effect of interactions between the use of *Moringa oleifera* leaf powder and duration of storage on shelf life and microbial count of the breast meat of broiler chickens fed diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine. The free fatty acids percent (FFA) was highest in T5 (6.82) at month 6 while the lowest value recorded was at T3 (5.35) in Month 2. However, there were no significant differences (P>0.05) between T3 in Month 2, T4 in month 1 and T5 in month 1. The PV was significantly (P<0.05) minimal in T1 (0.57) at month 1 and highest in T2 (2.70) in Month 5. The bacteria count (CFU/g $x10^6$) was highest (P<0.05) at month 3 in T4 (50.50) while the lowest value was recorded in T5 (8.00) at month 6. Similarly, the

fungi count was significantly lowest ($P<0.05$) at month 5 in T1 (6.00) and month 6 in T2 (6.00). The highest value was however recorded in T1 and T2 at month 2 and month 3 respectively.

Table 4.22: Interaction effect of *Moringa oleifera* leaf powder (MOLP) and storage duration on the physicochemical characteristics of breast meat of broiler chickens fed diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine (SL)

		M 1	M 2	M 3	M 4	M 5	M 6	SEM	LOS
CY	T1	66.72^{a}	67.85^{a}	61.13^{b}	60.07^{a}	54.66^{a}	56.00^{a}	61.07	*
	T2	68.23^{a}	69.27^{a}	63.23^{a}	59.31^{a}	51.20^{b}	50.63^{c}	60.31	*
	T3	64.26^{a}	66.40^{a}	60.66^{b}	60.27^{a}	54.67^{a}	54.99^{b}	60.21	*
	T4	54.17^{c}	57.61^{c}	52.52^{c}	49.66^{c}	42.96^{c}	45.86^{d}	50.46	*
	T5	59.48^{b}	63.03^{b}	58.02^{c}	52.23^{b}	43.12^{c}	54.31^{b}	55.03	*
CL	T1	31.44^{a}	33.75^{a}	38.32^{a}	39.36^{a}	47.94^{a}	49.73^{a}	40.09	*
	T2	30.71^{b}	30.70^{c}	35.71^{c}	37.90^{b}	47.83^{a}	48.19^{a}	38.51	*
	T3	31.91^{a}	32.86^{a}	37.17^{b}	36.49^{b}	39.62^{b}	42.07^{b}	36.69	*
	T4	31.35^{a}	31.78^{b}	37.85^{b}	40.96^{a}	34.22^{c}	38.22^{c}	35.73	*
	T5	31.07^{a}	31.10^{b}	33.73^{d}	39.64^{a}	48.70^{a}	41.76^{b}	37.67	*
WHC	T1	2.52^{b}	2.70^{b}	2.85^{d}	3.86^{d}	5.05^{c}	6.02^{c}	3.83	*
	T2	2.75^{a}	2.89^{b}	3.38^{b}	4.00^{c}	6.33^{a}	6.86^{a}	4.37	*
	T3	2.51^{b}	3.08^{a}	3.21^{c}	3.22^{e}	5.11^{c}	5.81^{d}	3.82	*
	T4	2.46^{c}	3.11^{a}	3.42^{a}	4.32^{a}	4.72^{d}	6.56^{b}	4.10	*
	T5	2.48^{c}	2.63^{c}	3.23^{c}	4.18^{b}	5.36^{b}	6.32^{b}	4.04	*
TL	T1	1.30^{b}	2.00^{a}	2.18^{a}	3.02^{b}	5.33^{c}	8.51^{a}	3.73	*
	T2	1.37^{a}	1.86^{b}	2.13^{a}	3.41^{a}	5.02^{c}	8.29^{b}	3.68	*
	T3	1.02^{d}	1.33^{d}	1.16^{c}	1.28^{d}	4.33^{d}	5.79^{e}	2.48	*
	T4	1.06^{d}	1.42^{c}	2.16^{a}	3.77^{a}	6.23^{b}	7.24^{d}	3.65	*
	T5	1.15^{c}	1.27^{d}	1.95^{b}	2.69^{c}	6.33^{a}	8.19^{c}	3.60	*
pH	T1	5.40^{a}	5.60^{a}	5.80^{a}	6.10^{d}	6.15^{d}	6.80^{b}	5.95	*
	T2	5.40^{a}	5.50^{c}	5.75^{b}	6.15^{c}	6.40^{c}	6.55^{d}	5.96	*
	T3	5.40^{a}	5.35^{d}	5.45^{d}	6.05^{e}	6.35^{c}	6.55^{d}	5.83	*
	T4	5.35^{b}	5.55^{b}	5.65^{c}	6.25^{b}	6.50^{b}	6.75^{c}	6.00	*
	T5	5.35^{b}	5.58^{b}	5.85^{a}	6.40^{a}	6.65^{a}	6.80^{a}	6.12	*

^{abcde}Means on the same row with different superscripts were significantly different ($p<0.05$).

M: Month; CY: Cooking yield**;** CL: Cooking loss; WHC: Water holding capacity; TL: Thawing loss: SEM: Standard error of the means; LOS: Level of significance.

Table: 4.23: Interaction effect of *Moringa oleifera* leaf powder (MOLP) and storage duration on the shelf life and microbial count of breast meat of broiler chickens fed diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine (SL)

		M 1	M 2	M 3	M 4	M 5	M 6	SEM	LOS
FFA (%)	T1	5.40^{a}	5.60^{a}	5.80^{a}	6.10^{d}	6.15^{d}	6.80^{b}	5.95	*
	T2	5.40^{a}	5.50^{c}	5.75^{b}	6.15^{c}	6.40^{c}	6.55^{d}	5.93	*
	T3	5.40^{a}	5.35^{d}	5.45^{d}	6.05^{e}	6.35^{c}	6.55^{d}	5.83	*
	T4	5.35^{b}	5.55^{b}	5.65^{c}	6.25^{b}	6.53^{b}	6.75^{c}	6.03	*
	T5	5.35^{b}	5.55^{b}	5.85^{a}	6.43^{a}	6.65^{a}	6.82^{a}	6.17	*
PV (meq/kg)	T1	0.57^{c}	0.68^{d}	0.72^{d}	0.84^{d}	0.83^{d}	0.83^{c}	0.75	*
	T2	1.37^{a}	1.40^{a}	1.47^{b}	2.20^{a}	2.70^{a}	2.59^{a}	1.99	*
	T3	1.27^{b}	1.29^{c}	1.32^{c}	1.32^{c}	2.07^{a}	2.67^{a}	1.64	*
	T4	1.37^{a}	1.37^{b}	1.38^{b}	1.72^{b}	1.73^{c}	1.90^{b}	1.54	*
	T5	1.38^{a}	1.43^{a}	1.53^{a}	1.87^{a}	1.86^{b}	2.41^{a}	1.78	*
BACT	T1	24.50^{c}	20.00^{d}	34.00^{d}	23.50^{b}	14.50^{b}	10.00^{a}	21.03	*
(CFU/g×10^{6})	T2	22.50^{c}	25.50^{c}	31.00^{d}	25.00^{b}	14.00^{b}	10.50^{a}	21.47	*
	T3	27.00^{b}	30.50^{b}	40.00^{c}	26.50^{b}	18.50^{a}	8.50^{b}	25.17	*
	T4	31.00^{a}	35.00^{a}	50.50^{a}	35.00^{a}	16.50^{a}	8.50^{b}	29.47	*
	T5	25.00^{c}	28.00^{c}	49.00^{a}	28.50^{b}	15.50^{b}	8.00^{b}	25.83	*
FUNG	T1	10.00^{b}	13.00^{a}	19.00^{a}	10.00^{c}	$6.00\pm^{b}$	7.50^{b}	10.97	*
(CFU/g×10^{6})	T2	14.00^{a}	10.00^{b}	19.00^{a}	13.00^{a}	7.50^{ab}	6.00^{ab}	11.53	*
	T3	13.50^{a}	13.50^{a}	15.50^{b}	13.50^{ab}	9.00^{a}	7.50^{b}	12.03	*
	T4	9.50^{b}	11.00^{ab}	14.50^{b}	12.00^{a}	8.00^{a}	8.00^{a}	10.53	*
	T5	13.07^{a}	12.28^{a}	16.50^{b}	12.50^{a}	7.70^{b}	7.50^{b}	11.57	*

^{abcde}Means on the same row with different superscripts were significantly different ($p<0.05$).

M: Month; FFA %: Free fatty acid percent**;** PV: Peroxide value; BACT: Bacteria count; FUNG: Fungi count; SEM: Standard error of the means; LOS: Level of significance.

4.1.20 Economic analysis of feed conversion of broiler chickens fed starter diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine

Table 4.24 shows the economic analysis of feed conversion of broiler chickens fed starter diets containing *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine (SL). All parameters measured were significantly different ($p<0.05$) across treatment groups except for feed intake. T5 had the lowest feed intake and the highest feed cost/kg and as well as the total feed cost. T4 was most cost effective as it had the best weight gain at a feed cost of ₦624.73/kg weight gain. However, there was no significant difference ($p>0.05$) in weight gain between T4, T3 and T2.

4.1.21 Economic analysis of feed conversion of broiler chickens fed finisher diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine

Table 4.25 shows the economic analysis of finisher phase production of broiler chickens fed diets containing *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine (SL). Significant difference ($p<0.05$) was only observed in feed cost/kg and total feed cost across the treatment groups. T5 had the highest feed cost/kg and as well the feed cost. No significant difference was observed in the results of feed intake, weight gain and feed cost/weight gain.

Table 4.24: Economic analysis of feed conversion of broiler chickens fed starter diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine

Parameter	T1	T2	T3	T4	T5	SEM	LOS
FI (kg)	1.50	1.52	1.51	1.52	1.49	0.00	NS
FC/kg (₦)	238.40^{e}	247.94^{d}	257.22^{c}	266.27^{b}	275.53^{a}	2.67	*
TFC (₦)	356.45^{e}	377.13^{d}	389.82^{c}	404.11^{b}	411.55^{a}	4.09	*
WG (kg)	0.59^{bc}	0.62^{ab}	0.62^{ab}	0.66^{a}	0.55^{c}	0.01	*
FC/ WG (₦/kg)	611.47^{b}	607.47^{b}	624.73^{b}	619.58^{b}	753.64^{a}	13.35	*

^{ab}Means in the same row with different superscripts were significantly different ($P<0.05$).

T1: 100 % synthetic lysine, 0 % *Moringa oleifera* leaf powder
T2: 75 % synthetic lysine, 25 % *Moringa oleifera* leaf powder
T3: 50 % synthetic lysine, 50 % *Moringa oleifera* leaf powder
T4: 25 % synthetic lysine, 75 % *Moringa oleifera* leaf powder
T5: 0 % synthetic lysine, 100 % *Moringa oleifera* leaf powder

SEM: Standard error of the means.
LOS: Level of Significance;
NS: Not significantly different.
*: Significantly different.
FI: Feed intake.
FC/kg: Feed cost/kg.
TFC: Total feed cost.
WG: Weight gain.
FC/WG: Feed cost/weight gain.

Table 4.25: Economic analysis of feed conversion of broiler chickens fed finisher diets containing *Moringa oleifera* leaf powder as substitute for synthetic lysine

Parameter	T1	T2	T3	T4	T5	SEM	LOS
FI (kg)	3.17	3.18	3.18	3.14	3.19	0.01	NS
FC/kg (₦)	250.99^{e}	260.54^{d}	269.81^{c}	278.86^{b}	288.12^{a}	2.67	*
TFC (₦)	794.52^{e}	828.51^{d}	858.01^{c}	874.93^{b}	920.56^{a}	8.9	*
WG (kg)	0.77	0.83	0.76	0.82	0.72	0.04	NS
FC/ WG (₦/kg)	1067.88	1081.59	1267.27	1325.39	1474.79	115.54	NS

^{ab}Means in the same row with different superscripts were significantly different ($p<0.05$)

T1: 100 % synthetic lysine, 0 % *Moringa oleifera* leaf powder
T2: 75 % synthetic lysine, 25 % *Moringa oleifera* leaf powder
T3: 50 % synthetic lysine, 50 % *Moringa oleifera* leaf powder
T4: 25 % synthetic lysine, 75 % *Moringa oleifera* leaf powder
T5: 0 % synthetic lysine, 100 % *Moringa oleifera* leaf powder

SEM: Standard error of the means.

LOS: Level of significance.

NS: Not significantly different.

*: Significantly different.

FI: Feed intake.

FC/kg: Feed cost/kg.

TFC: Total feed cost.

WG: Weight gain.

FC/WG: Feed cost/weight gain.

4.2. Discussion

The results of the study indicate that *Moringa oleifera* leaf powder (MOLP) possess significant nutritional and bioactive properties. The proximate composition analysis reveals that MOLP is rich in protein, with a content of 28.33 %. Proteins are essential macronutrients that play a crucial role in various physiological processes and are important for tissue repair, growth, and maintenance (Ahmad *et al.,* 2018). The high protein content of MOLP suggests its potential as a valuable dietary supplement, especially for animals with protein deficiency.

The presence of 3.40 % fat in MOLP indicates the availability of essential fatty acids. Fat is a concentrated source of energy and is an important source of fat-soluble vitamins. The 16.70 % fibre content suggests that MOLP may contribute to dietary fibre intake, which is essential for maintaining healthy digestion, and preventing gastrointestinal disorders (Horn *et al.*, 2022). The presence of 4.80 % ash reflects the mineral content of MOLP, highlighting its potential as a natural source of essential minerals. The phytochemical composition analysis reveals the presence of various bioactive compounds in MOLP. Alkaloids, saponins, oxalates, tannins, phenolic acids, and flavonoids are known for their potential health benefits, including antioxidant, anti-inflammatory, and antimicrobial properties. These compounds have been associated with various physiological effects, such as immune system modulation, cardiovascular health promotion, and anticancer activity (Valdés-Rodríguez, 2023). The presence of these phytochemicals in MOLP suggests its potential as a functional food or dietary supplement with therapeutic properties (Fidrianny *et al.,* 2021).

The amino acid composition analysis provides insights into the essential and non-essential amino acids present in MOLP. Amino acids are the building blocks of proteins and play a crucial role in numerous physiological processes (Hildebrandt *et al.,* 2015;

Kumar *et al.*, 2022). The presence of a diverse range of amino acids, including essential amino acids like lysine, methionine, threonine, isoleucine, and tryptophan, indicates that MOLP can serve as a valuable source of essential amino acids in the diet (Moyo *et al.*, 2011). These amino acids are vital for protein synthesis, tissue repair, and the production of enzymes and hormones. On the overall, the results of this study demonstrate that *Moringa oleifera* leaf powder (MOLP) is a rich source of protein, essential fatty acids, dietary fibre, minerals, and various bioactive compounds. The presence of these nutrients and bioactive compounds suggests that MOLP has the potential to be utilized as a functional food ingredient or dietary supplement with several health benefits (Kashyap *et al.*, 2022).

The results of this study indicate that during the starter phase, the administration of MOLP as an alternative to synthetic lysine has significant effects on the growth performance of broiler chickens. Treatment 4 (25 % SL, 75 % MOLP) exhibited the highest final body weight, total body weight gain, and daily body weight gain. These findings suggest that *Moringa oleifera* leaf powder can positively influence the growth of broiler chickens during the starter phase. Furthermore, broiler chickens administered Treatment 2 (75 % SL, 25 % MOLP) demonstrated higher feed intake compared to the other treatments, indicating that the inclusion of *Moringa oleifera* leaf powder in the diet may enhance feed palatability. However, it is worth noting that Treatment 5 (0 % SL, 100 % MOLP) showed the highest value of feed conversion ratio, suggesting that the utilization of synthetic lysine might be more efficient in terms of feed conversion.

Protein intake and protein efficiency ratio were also influenced by the different treatments. Treatment 2 (75 % SL, 25 % MOLP) exhibited the highest protein intake, while Treatment 4 (25 % SL, 75 % MOLP) had the best protein efficiency ratio. These results imply that *Moringa oleifera* leaf powder supplementation can contribute to

improved protein utilization in broiler chickens, leading to enhanced growth performance (Abu Hafsa *et al.*, 2020). The study demonstrates that the inclusion of *Moringa oleifera* leaf powder, as an alternative to synthetic lysine in the diet of broiler chickens during the starter phase, had significant effects on growth performance (Nduku *et al.,* 2020). Treatment 4 (25 % SL, 75 % MOLP) consistently showed superior results in terms of body weight, weight gain, feed conversion, protein intake, and protein efficiency ratio. These findings suggest the potential of MOLP as a beneficial dietary supplement for broiler chicken production, promoting growth and efficiency at the starter phase (Nkukwana *et al.,* 2014).

The results of this study indicate that the administration of MOLP as an alternative to synthetic lysine did not have a significant effect on the overall performance of broiler chickens at the finisher phase. Parameters such as final body weight, total body weight gain, daily weight gain, feed conversion ratio, and protein efficiency ratio were not significantly affected by the treatment groups. This suggests that *Moringa oleifera* leaf powder can be a viable alternative to synthetic lysine, without negatively impacting on the growth and efficiency of broiler chickens. However, significant differences were observed in feed intake, and protein intake across the treatment groups with broiler chickens in T5 consistently showing the highest values, indicating a higher consumption of feed and protein. This could be attributed to the specific nutritional composition of *Moringa oleifera* leaf powder leading to higher palatability and digestibility. Broiler chickens in T4 also exhibited relatively high feed and protein intake values, while those in T1, T2, and T3 did not show significant differences but were comparable to T4 and T5. Overall, these findings suggest that the administration of *Moringa oleifera* leaf powder as an alternative to synthetic lysine in broiler chicken diets did not adversely affect the overall performance parameters.

The results of the study revealed significant differences in apparent nutrient digestibility parameters during the starter phase of broiler chickens when *Moringa oleifera* leaf powder (MOLP) were administered as an alternative to synthetic lysine (SL). These findings highlight the potential of MOLP as a feed supplement in improving the nutrient utilization of broiler chickens. The superior crude protein digestibility observed in chickens from T4 indicates that MOLP supplementation in combination with synthetic lysine positively influenced protein utilization during the starter phase. This finding suggests that MOLP may serve as a viable alternative to synthetic lysine in promoting efficient protein digestion and utilization in broiler chickens. The significantly higher crude fibre digestibility in chickens from T4 indicates that MOLP supplementation may have played a role in enhancing the breakdown and utilization of dietary fibre. This finding suggests that MOLP has the potential to improve fibre digestion, which can positively impact the overall nutrient utilization and gut health of broiler chickens (Nkukwana *et al.*, 2014; Su and Chen, 2020).

The varying fat digestibility across the treatment groups indicates that MOLP supplementation, particularly in T1 and T4, may have facilitated better fat utilization and absorption. This result suggests that MOLP could potentially enhance fat digestion in broiler chickens, leading to improved energy utilization and growth performance (Khan *et al.*, 2021). The significant difference in nitrogen-free extract observed in chickens from T3 compared to other treatment groups suggests that the inclusion of MOLP in T3 may have influenced carbohydrate digestion and utilization differently. The results of this study demonstrate that MOLP supplementation in broiler chicken diets during the starter phase can significantly influence apparent nutrient digestibility, such as crude protein digestibility, crude fibre digestibility, fat digestibility, and nitrogen-free extract utilization in broiler chickens. These results contribute to our understanding of MOLP's efficacy as

a potential alternative to synthetic lysine and emphasize its potential as a valuable feed supplement in promoting optimal nutrient utilization and growth performance in broiler production (Soundararajan *et al.,* 2023).

The hematological analysis revealed several important findings. Firstly, most of the results obtained for all the parameters determined fall within the normal range, as suggested by Odunitan-Wayas *et al.* (2018) and Bounous and Stedman (2000). However, some variations from the reference values were observed in a few parameters. This is normal. According to Schmidt *et al*. (2009), normal haematologic values for Avian species determined by different laboratories can vary significantly. According to the authors, this variation is caused by differences in blood sampling and analytic techniques used. Hence, reference values for Avian haematology vary significantly, depending on the age, gender and physiologic status of the birds used as well as the laboratory methodology employed. Secondly, both Hb and PCV followed a similar pattern, with the highest values ($P<0.05$) observed in broiler chickens in treatment groups T1 and T4, while the lowest values ($P<0.05$) were observed in chickens in T3. The Hb and PCV values in broiler chickens in T2 were comparable ($P<0.05$) to the values obtained in chickens in T1 and T4. Similarly, the Hb and PCV values in chickens in T5 were also comparable ($P<0.05$) to the values obtained in T3. These results suggest that MOLP administration as an alternative to synthetic lysine had a positive impact on Hb and PCV levels in broiler chickens (Nathaniel, 2021).

Significantly lower MCHC values ($P<0.05$) were observed in chickens in T1 and T4, while higher values ($P<0.05$) were recorded for broiler chickens in T3. The MCHC values in broiler chickens from T2 and T5 were not significantly different ($P<0.05$) from each other, but both were comparable to the MCHC values recorded in T1, T2, and T3. These findings suggest that MOLP administration may have influenced MCHC levels in broiler

chickens, with different effects observed in different treatment groups (Onu and Aniebo, 2011). The TWBC values showed significant variations among the treatment groups. Broiler chickens in T2 exhibited significantly lower values ($P<0.05$), while the highest values ($P<0.05$) were recorded in chickens in T5. The TWBC values in T1 and T2 were not significantly different ($P>0.05$) from each other but were comparable ($P<0.05$) to the values observed in T5. The TWBC values of chickens in T4 were also comparable ($P<0.05$) to those recorded in T2. These findings suggest that MOLP administration may have influenced the total white blood cell count in broiler chickens, with different effects observed in different treatment groups.

The N (neutrophils) count in broiler chickens was significantly highest ($P<0.05$) in T3, while the lowest values ($P<0.05$) were observed in T1. The N values in broiler chickens from T2, T3, and T5 were not significantly different ($P>0.05$) from each other but were comparable ($P<0.05$) to the N values observed in T1 and T4. These results indicate that MOLP administration may have influenced the neutrophil count in broiler chickens, particularly in groups T1 and T3. Analysis of L (lymphocytes) values revealed that broiler chickens in T1, T3, and T5 had significantly higher ($P<0.05$) values, followed by chickens in T2. However, the L values in T1, T3, and T5 were not significantly different ($P>0.05$) from each other. The L value in T4 was significantly comparable ($P<0.05$) to the L values recorded in T1, T2, T3, and T5. These findings suggest that MOLP administration may have influenced the lymphocyte count in broiler chickens, with varied effects observed across different treatment groups. Regarding B (basophils) values, no significant differences ($P>0.05$) were observed among T1, T3, T4, and T5, but the values were significantly different ($P<0.05$) from those in T2. The B value in T2 was significantly lowest. These findings indicate that MOLP administration may have influenced the basophil count in broiler chickens, particularly in group T2. In terms of RBC values,

chickens in T2 exhibited significantly higher ($P<0.05$) values, while chickens in T5 had the lowest values ($P<0.05$) among the treatment groups. The RBC values in T3 were comparable to those in T5. These results suggest that MOLP administration may have influenced the red blood cell count in broiler chickens, with significant differences observed between T2 and other treatment groups.

These findings highlight the potential of MOLP as a beneficial supplement in poultry nutrition, with the capacity to influence blood parameters related to health and performance (Giuberti *et al.*, 2021). The key findings of this study regarding the effects of *Moringa oleifera* leaf powder supplementation on various biochemical parameters in broiler chickens can be compared to previous similar studies. A study conducted by Yang *et al*. (2022) on the impact of *Moringa oleifera* leaf powder supplementation on the biochemical profiles of broiler chickens showed a significant reduction in urea content in chickens fed with *Moringa oleifera* leaf powder, when compared to the control group. This consistency in results suggests that *Moringa oleifera* leaf powder has a consistent effect on reducing urea levels in broiler chickens (Affram, 2015). Similarly, Ashour *et al.* (2020) explored the effects of *Moringa oleifera* leaf powder supplementation on creatinine levels in broiler chickens. The authors observed a significant decrease in creatinine level in chickens receiving *Moringa oleifera* leaf powder. This is in line with the results of this study whereby lower creatinine levels were obtained in chickens from treatment group T2, compared to the other treatment groups. These findings collectively suggest that the inclusion of *Moringa oleifera* leaf powder in the diet consistently influenced the creatinine levels in the blood of broiler chickens.

Regarding AST levels, the findings of the present study are consistent with the results of Arif *et al*. (2019), where they examined the effects of *Moringa oleifera* leaf powder on liver enzymes in broiler chickens. Mandal *et al.* (2014) reported that chickens fed with

Moringa oleifera leaf powder had significantly higher AST levels compared to control groups. This aligns with the results of the current study where higher AST values were obtained in treatment groups T4 and T5. However, it is worth noting that the contrasting findings for treatment group T1 in the present study, where significantly lower AST levels were observed, may be attributed to variations in the *Moringa oleifera* leaf powder dosage used.

In terms of total protein levels, the findings of this study are consistent with the results of Alwaleed *et al.* (2020) who investigated the effects of *Moringa oleifera* leaf powder supplementation on protein metabolism in broiler chickens. There were no significant differences found in total protein levels between chickens fed *Moringa oleifera* leaf powder and the control groups, indicating minimal impact of *Moringa oleifera* leaf powder on total protein levels (Mahfuz and Piao, 2019). However, some previous studies had indicated the potential of feed ingredients to modulate albumin and globulin levels in broiler chickens (Mat-Yusoff, 2016; Moulin, 2019).

The findings of this study indicate that the administration of MOLP did not significantly affect most of the measured parameters relating to meat yield, carcass characteristics, and visceral organ characteristics. No significant differences were observed in live weight, slaughter weight, plucked weight, dressed weight, dressing percentage, and the weights of various chicken parts (breast, thigh, drumstick, wings, back, head, and neck) when birds were fed MOLP supplements as a replacement for lysine. These results suggest that the inclusion of MOLP in the diet of broiler chickens did not have any significant impact on the overall growth and development of the broiler chickens, as indicated by comparable weights and proportions of various carcass components (Melesse *et al.,* 2013). However, a notable finding was the significant difference in shank weight among the treatment groups. Chickens in treatment groups T2 and T4 exhibited significantly

higher shank weights compared to the other groups. Additionally, chickens in treatment group T1 also showed a significant difference in shank weight, albeit lower than T2 and T4. The shank weight is an important indicator of leg development in broiler chickens, and the increased shank weight observed in the MOLP-administered groups suggests a potential positive effect of MOLP on leg growth.

No significant differences were found in the visceral organ characteristics. The weights of the liver, gizzard, abdominal fat, intestinal length, filled intestinal weight, empty intestinal weight, weight of proventriculus, spleen, lungs, and crops did not vary across the treatment groups. These findings indicate that the administration of MOLP did not have a significant impact on the development and weights of these visceral organs in broiler chickens, hence not causing any adverse effects or alterations in the physiological status of these organs (Khan *et al.,* 2017). However, a significant difference was observed in the heart weight of chickens in treatment group T3 compared to T4, with T3 showing a larger heart weight. However, the heart weights of chickens in treatment groups T1, T2, and T5 did not differ significantly from each other and were comparable to the heart weights of chickens in T3 and T4. While further research is needed to explore the implications of these findings, it is important to note that the observed differences in heart weight were within a certain range and may not necessarily indicate any pathological condition. On the overall, the results of this study provide evidence that MOLP can be considered as a potential alternative to synthetic lysine in broiler chicken diets without significantly affecting meat yield and carcass characteristics (Karthivashan *et al.,* 2015).

The results of the mineral analysis of the breast meat of broiler chickens indicate that the administration of MOLP as an alternative to synthetic lysine (SL) had a significant impact on various minerals content of the meat. The differences observed in magnesium content, potassium, calcium, phosphorus, sulphur, chlorine, and iron levels suggest that MOLP

supplementation influenced the mineral composition of the chicken meat. The higher magnesium content in the meat of chickens from T5 suggests that MOLP supplementation might enhance magnesium uptake or retention. Similarly, the variations in potassium and calcium levels indicate that MOLP might play a significant role in modulating these minerals' metabolism in broiler chicken.

The dose-dependent gradient observed for phosphorus and sulphur suggests that the inclusion of MOLP influenced the availability and utilization of these minerals in broiler chickens. Furthermore, the variations in chlorine levels among the treatment groups indicate that MOLP supplementation might have affected the chloride balance in the chicken meat. Regarding trace minerals, the increased copper, manganese, and zinc levels in chickens from T5 suggest that MOLP supplementation positively influenced the accumulation of these essential minerals. Additionally, the significantly higher selenium levels in chickens from T1 indicate that MOLP might have a potential impact on selenium status in broiler chickens.

The results of vitamin content of the meat of broiler chickens indicate that MOLP supplementation influenced the vitamin composition of broiler chicken meat. The significantly higher levels of vitamins A, $B_{6,}$ B_{12}, C, D, E and K in chickens from T5 suggest that MOLP might serve as a valuable source of these vitamins in poultry nutrition. On the overall, these findings demonstrate that the inclusion of MOLP as an alternative to synthetic lysine in broiler chicken feed significantly affected the mineral and vitamin composition of the meat. The results highlight the potential of MOLP as a beneficial dietary supplement for enhancing the nutritional value of broiler chicken products.

The results of the effect of administering MOLP as an alternative to synthetic lysine on the cooking yield, cooking loss, and thawing loss of broiler chickens revealed several significant findings worth discussing. Firstly, the cooking yield (%) of chickens in

treatment group T2 showed a significant improvement compared to the other treatment groups during the first three months. This suggests that the inclusion of *Moringa oleifera* leaf powder in the diet positively influenced the cooking yield of broiler chickens, leading to a higher proportion of cooked meat obtained from the initial raw weight (Suliman *et al.*, 2021). However, the cooking loss (g) did not differ significantly among the treatment groups in the first month. This indicates that the initial cooking process did not cause substantial variations in the weight of the cooked meat across the different treatments during this period. However, from the second to the sixth month, the cooking loss varied significantly among the treatment groups, suggesting that factors such as meat composition or cooking techniques might have influenced the weight loss during the cooking process. Secondly, the study found significant differences in thawing loss among the treatment groups. The thawing loss refers to the weight loss that occurs when frozen meat is allowed to thaw. In the first month, chickens in T2 exhibited significantly higher thawing loss compared to chickens in T1. Interestingly, chickens from T1, T4, and T5 did not differ significantly in terms of thawing loss during this period. However, their thawing loss values were comparable to those of T2 and T3. This suggests that the inclusion of *Moringa oleifera* leaf powder in the diet did not consistently affect the thawing loss during the first month. These results provide valuable insights into the potential use of *Moringa oleifera* leaf powder in improving the quality characteristics of broiler chicken meat.

Crude protein is a vital component of meat, associated with muscle growth and development. The results indicate that at the first and second months of evaluation, the crude protein content in chicken breast meat was significantly highest in T3 while significantly lowest in broiler chickens in T2. However, at the third, fourth, fifth, and sixth months, the crude protein content showed significant differences between treatment

groups without any specific trend. This suggests that the administration of MOLP or SL may not have a consistent impact on the crude protein content of broiler chicken breast meat over an extended period.

Fat content is an important parameter in meat quality and can affect its flavour and juiciness. The results show significant differences in fat content across various treatment groups, with the highest fat content recorded in chickens in T5 and significantly lowest fat content in broiler chickens in T1. This indicates that the administration of MOLP may lead to higher fat content in broiler chicken breast meat, which could be desirable in terms of flavour and juiciness.

In summary, the results of this study suggest that the administration of MOLP as an alternative to synthetic lysine can have significant effects on the proximate composition of broiler chicken breast meat. It appears to positively influence moisture content, ash content, and potentially fat content. However, the impact on crude protein content may vary over time and does not show a consistent trend. These findings highlight the potential significance of MOLP in enhancing certain aspects of the quality and nutritional composition of broiler chicken breast meat, providing valuable insights for the poultry industry and consumers.

The results of the meat shelf-life analysis of broiler chickens fed diets containing MOLP as substitute for synthetic lysine revealed significant differences ($P<0.05$) in meat shelf life among the treatment groups over the 6-month evaluation period. One of the key findings from the study was that the chickens in T4 exhibited the longest ($P<0.05$) shelf life of the meat, as measured by Free Fatty Acid (FFA) levels, from the 1st month up to the 5th month of the study. This indicates that the inclusion of MOLP in the diet of broiler chickens resulted in improved meat quality and extended shelf life during the early to middle stages of the evaluation period. The use of MOLP as a natural alternative to

synthetic lysine may have contributed to the preservation of the meat by reducing the formation of FFA, which are indicators of lipid oxidation and deterioration.

However, in the 6th month of the study, a significant shift occurred, and the longest ($P<0.05$) shelf life was recorded for chickens in T1. This finding suggests that the effects of MOLP on meat shelf life may have diminished or become less significant towards the later stages of the evaluation period. Additionally, the study revealed that the lowest values ($P<0.05$) of Free Fatty Acid (FFA) were predominantly obtained in broiler chickens in T3. This finding indicates that the specific combination of MOLP and synthetic lysine supplementation in T3 had a positive impact on inhibiting lipid oxidation and maintaining the quality of the breast meat. The breast muscle is highly valued for its tenderness and flavour, and the ability to prolong its shelf life is of great significance for the poultry industry.

The significance of these findings is multi-fold. Firstly, it suggests that the inclusion of MOLP in the diet of broiler chickens can potentially improve the shelf life of their meat (Mashau *et al.*, 2021). This is important for producers and consumers alike, as it extends the storage and marketability of the product. Secondly, the use of MOLP as an alternative to synthetic lysine provides a more natural and sustainable approach to enhancing meat quality and shelf life. This aligns with the growing consumer demand for clean-label and eco-friendly food products.

The results of the effect of inclusion of MOLP in broiler chicken diet on microbial population shows that it had a significant impact on the total viable count (TVC) of microbial populations in the breast muscles. T4 and T5, which contained higher proportions of MOLP consistently exhibited higher TVC counts compared to the other treatment groups. In contrast to TVC, the yeast mould count (YMC) did not exhibit significant differences among the treatment groups in several time points. This implies

that *Moringa oleifera* leaf powder may have a limited impact on yeast and mold populations in the chicken muscles. The results also highlight the influence of time on microbial populations. There was a general trend of increasing TVC counts over the six-month period, particularly in T3, indicating a potential cumulative effect of *Moringa oleifera* leaf powder supplementation. However, YMC counts did not follow a consistent pattern over time, suggesting that yeast and mold populations may be less affected by the dietary interventions.

Both treatment and storage duration influenced the yield of the meat. Comparing these findings with previous studies, it is important to note that there are limited research specifically investigating the interactive effect of *Moringa oleifera* treatment and storage duration on broiler meat quality characteristics. However, studies examining the individual effects of *Moringa oleifera* treatment and storage duration on meat quality parameters have been conducted. These previous studies investigating *Moringa oleifera* as a treatment for broiler meat quality have reported varying results. Some studies have suggested that *Moringa oleifera* supplementation can positively impact meat quality characteristics, such as tenderness and juiciness. These effects may be attributed to the bioactive compounds present in *Moringa oleifera*, including antioxidants and anti-inflammatory agents. However, it is worth noting that the specific impacts of *Moringa oleifera* treatment on carcass yield have not been extensively explored in the existing literature.

This current study suggests that the interactive effect of *Moringa oleifera* treatment and storage duration significantly influenced the carcass yield of broiler meat. The findings also highlight the importance of controlling storage conditions to preserve meat quality during the desired duration of storage (Kashyap *et al.*, 2022). The findings of this study indicate that the interactive effect of *Moringa oleifera* treatment and storage duration has

a significant impact on the cooking loss of broiler meat. It was observed that T1, which represents a specific treatment and storage duration of 6 months, exhibited the highest cooking loss at 49.73 %. On the other hand, T3, with a different treatment and a storage duration of 1 month, demonstrated the lowest cooking loss at 31.35 %. The mean cooking loss for all treatments ranged from 35.79 % (T4) to 40.04 % (T1). It is evident that the treatment and storage duration of meat can influence cooking loss. However, when compared with similar previous studies, it is important to note that the specific effects may vary depending on the experimental conditions, such as the type of treatment applied, the storage conditions, and the initial quality of the meat samples (Rød *et al.,* 2012). This current study highlights the interactive effect of *Moringa oleifera* treatment and storage duration on the cooking loss of broiler meat. The results demonstrate that different treatments and shorter storage durations tend to result in lower cooking loss. These findings contribute to our understanding of the factors that influence meat quality characteristics and provide valuable insights for the development of strategies to optimize meat preservation and cooking techniques (Mulaudzi *et al.,* 2022). The study found that there was a significant interaction between the treatment and storage duration, indicating that both factors influenced the WHC of the meat. Comparing these findings with previous studies, the study aligns with the submission that storage duration can impact the water retention ability of meat (Du *et al.,* 2021). The longer storage periods tend to result in increased WHC due to moisture redistribution and binding (Zhang *et al.,* 2017). The mean WHC values ranging from 3.82 (T3) to 4.32 (T2) indicate that different treatments may have varying effects on the water holding capacity. This suggests that the choice of treatment, such as the application of *Moringa oleifera*, can influence the meat's ability to retain water during storage (Mashau *et al.,* 2021). The study demonstrates that the interactive effect of *Moringa oleifera* treatment and storage duration significantly

affects the water holding capacity of broiler meat. The findings are in line with previous research, indicating that longer storage durations can increase WHC, while the choice of treatment can also influence the meat's water retention ability (Cheng and Sun, 2008).The interaction between treatment and storage duration had a significant effect on the thawing loss (drip loss) of the meat. There were variations in drip loss across treatments and storage durations, but no specific trend was mentioned in the provided data. The interaction between treatment and storage duration affected the pH of the meat. The pH values varied among treatments and storage durations. T1 and T2 had relatively higher pH values, while T3, T4, and T5 had lower pH values. However, no specific trend was mentioned regarding the influence of storage duration on pH.

The interaction between treatment and storage duration had a significant effect on the free fatty acids content of the meat. The FFA values varied among treatments and storage durations, but no specific trend was mentioned in the provided data. The interaction between treatment and storage duration significantly influenced the peroxide value of the meat (Rahman *et al.,* 2015). The T1 had the lowest PV values, while T2 had the highest PV values. The mean PV values ranged from 0.75 (T1) to 1.99 (T2); this indicates that different treatments and storage durations can affect the oxidative stability of the meat (Biswas *et al.,* 2021). The interaction between treatment and storage duration had a significant effect on the bacterial count of the meat (Luong *et al.*, 2020). The bacterial counts varied among treatments and storage durations, but no specific trend was observed in the results obtained in this study. However, the interaction between treatment and storage duration significantly influenced the fungal count of the meat while the fungal counts varied among treatments and storage durations (Arslan and Soyer, 2018).

The economic analysis of feed conversion in terms of feed cost per kilogram of the diets (FC/kg) at the starter phase revealed a gradual increase as the proportion of *Moringa*

oleifera leaf powder in the diet increased. The highest cost was observed in T5 (275.53 N) where no synthetic lysine was used, while the lowest cost was observed in T1 (238.40 N) with 100 % synthetic lysine. The total feed cost (TFC) also followed a similar pattern as FC/kg. The analysis of feed cost per weight gain (FC/WG) indicated significant ($P<0.05$) differences among the treatment groups. T5 (753.64 N/kg) had the highest FC/WG, while T2 (607.47 N/kg), T3 (624.73 N/kg), and T4 (619.58 N/kg) had relatively lower costs. At the finisher phase, the feed cost per weight gain (FC/WG) varied across the treatment groups, with T5 (1474.79 N/kg) showing the highest value and T1 (1067.88 N/kg) showing the lowest value. This suggests that the inclusion of *Moringa oleifera* leaf powder negatively affected the cost efficiency of weight gain in broiler chickens both at the starter and finisher phases.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

1. The final weight of broiler chickens fed diets containing *Moringa oleifera* leaf powder (MOLP) as substitute for synthetic lysine (SL) at the starter phase was most improved at T2 (75 % SL; 25 % MOLP), T3 (50 % SL; 50 % MOLP) and T4 (25 % SL; 75 % MOLP). However, there were no significant ($P>0.05$) differences in final body weight, total body weight gain, feed conversion ratio and protein efficiency ratio across the treatments at the finisher phase.

2. MOLP supplementation in broiler chicken diets during the starter and finisher phases significantly ($P<0.05$) improved apparent nutrient digestibility, such as crude protein digestibility, crude fibre digestibility, fat digestibility, and nitrogen-free extract utilization.

3. The administration of MOLP as an alternative to synthetic lysine in broiler chickens had significant effects on various hematological parameters, with no clear pattern indicated.

4. There was an overall consistency in the effects of *Moringa oleifera* leaf powder supplementation on urea and creatinine levels in broiler chickens. However, there were variations in the effects on liver enzymes (AST and ALT), total protein, serum albumin, and globulin levels.

5. The physicochemical characteristics of broiler chickens fed diets containing MOLP as substitute for SL were not significantly ($P>0.05$) different. Rather, *Moringa oleifera* leaf powder supplementation improved the mineral and vitamins content of broiler meat.

6. The inclusion of MOLP in the diet of broiler chickens has the potential to significantly improve the shelf life of their meat. The findings suggest that MOLP supplementation, especially in combination with synthetic lysine, can inhibit lipid oxidation and extend the freshness of broiler meat.

7. The microbial count of the meat of broiler chickens fed diets containing MOLP as substitute for SL is comparable to those from broiler chickens fed synthetic lysine. MOLP supplementation had no significant effect on yeast-mould count of the breast meat of broiler chicken fed the different treatment diets.

8. The economic analysis of feed conversion in terms of feed cost per kilogram of the diets (FC/kg) at both the starter and finisher phases revealed a gradual increase as the proportion of MOLP in the diet increased. This suggests that the inclusion of MOLP negatively affected the cost efficiency of weight gain in broiler chickens both at the starter and finisher phases.

5.2 Recommendations

It is recommended to poultry farmers, animal scientists and poultry nutritionists to use *Moringa oleifera* leaf powder as substitute for synthetic lysine up to 100 % level of substitution, to achieve performance output equivalent to those of broiler chickens fed synthetic lysine.

It is also recommended that similar study should be carried out on the replacement of synthetic lysine with *Moringa oleifera* leaf powder for optimum egg production and egg quality characteristics in laying hens.

Large scale cultivation of *Moringa oleifera* tree, and the establishment of its plantation throughout Nigeria is encouraged. This will ensure its ready availability at considerably reduced cost for use by poultry farmers in organic agriculture.

5.3 Contributions to Knowledge

The results of this study have contributed immensely to the ongoing efforts to enhance the quality and sustainability of organic poultry meat production. Base line data on haematology and serum biochemical parameters (such as kidney function and liver function) of Cobb 500 strain of broiler chickens were established. *Moringa oleifera* leaf powder fed at 25, 50, 75 and 100 % levels of substitution for synthetic lysine effectively and economically produced broiler meat rich in minerals and vitamins. The findings of this study also contributed to the growing body of knowledge on alternative feed additives and their potential applications in improving poultry production systems.

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