PERFORMANCE, ECONOMIC BENEFIT AND LITTER QUALITY IN PENS OF BROILER CHICKENS PRODUCED ON CHANGING TIMES OF PHASE FEEDING

ANYIGOR, EMEKA AUSTIN (B. Agric. Tech., FUTO)

REG. NO.: 20184143918

A THESIS SUBMITTED TO

THE POSTGRADUATE SCHOOL

FEDERAL UNIVERSITY OF TECHNOLOGY, OWERRI, IMO STATE, NIGERIA

AUGUST 2024

PERFORMANCE, ECONOMIC BENEFIT AND LITTER QUALITY IN PENS OF BROILER CHICKENS PRODUCED ON CHANGING TIMES OF PHASE FEEDING

ANYIGOR, EMEKA AUSTIN (B. Agric. Tech., FUTO)

REG. NO.: 20184143918

A THESIS SUBMITTED TO

THE POSTGRADUATE SCHOOL

FEDERAL UNIVERSITY OF TECHNOLOGY, OWERRI, IMO STATE, NIGERIA

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE MASTER OF SCIENCE (MSc.) DEGREE IN ANIMAL NUTRITION

AUGUST 2024

CERTIFICATION

This is to certify that this study titled '**Performance, Economic Benefit and Litter Quality in Pens of Broiler Chickens Produced on Changing Times of Phase Feeding'** was carried out by **Anyigor, Emeka Austin (Reg. No.: 20184143918)** in partial fulfillment for the requirements for the award of the degree of Master of Science (M.Sc.) in Animal Nutrition in the Department of Animal Science and Technology, Federal University of Technology, Owerri.

.... **Prof. E. B. Etuk** Supervisor	18-08-2024 Date
.... **Dr. N O. Aladi** Co Supervisor	19-08-2024 Date
.... **Prof. V.M.O. Okoro** Head of Department	17/09/2024 Date
.... **Prof. (Mrs.) O. P. Onyewuchi** Dean of School of Agriculture and Agricultural Technology	17/09/24 Date
.... **Prof. (Mrs.) J. N Nwosu** Dean, Postgraduate School	.... Date
.... **Prof. D. N Onunkwo** External Examiner	13-08-2024 Date

DEDICATION

This work is dedicated to God Almighty for His amazing grace, provision and protection in this journey.

ACKNOWLEDGEMENT

My paramount gratitude goes to God Almighty, who gave me the grace to undertake and complete this study successfully. I acknowledge with immense gratitude the contributions of my Supervisor, Prof. E. B. Etuk whom God used in different ways to actualize this dream. He financially, academically, emotionally and materially motivated and encouraged me throughout this study. I pray that God, in His infinite mercy, will grant him all his heart desires. As he did to others, so shall God do to his wards. I also acknowledge with great gratitude my Co-Supervisor, Dr. N. O. Aladi for his invaluable contribution to the success of this study.

My gratitude also goes to Prof. V. M. O. Okoro. Head, Department of Animal Science and Technology; Prof. B. O. Esonu, Dean, Postgraduate School, and Prof. (Mrs.) O. P. Onyewuchi, Dean of the School of Agriculture and Agricultural Technology. I am grateful to Emeritus Prof. M. U. Iloeje and Prof. A. B. I. Udedibie for that fatherly role in my life. I acknowledge my lecturers, Prof. N. J. Okeudo, Prof. G. A. Anyanwu, Prof. I. C. Okoli, Prof. (Mrs.) U. E. Ogundu, Prof. M. C. Uchegbu, Prof. O. O Emenalom, Prof. C. T. Ezeokeke, Prof. H. O. Obikaonu, Prof. I. F. Etuk, (the immediate past Head, Department of Animal Science and Technology and my undergraduate Course Adviser) , Dr. I. P. Ogbuewu, Dr. N. J. Anyanwu, Dr. T. C. Iwuji, Dr. (Ms.) F. C. Egenuka, Dr. (Mrs.) P. C. Okere., and Dr. E. U. Ahiwe. Their contributions towards the success of this study was felt and appreciated. My thanks also go to Mr. U. N. Okehie, for his assistance during the field work component of this study.

I specially appreciate the support and encouragements of my parents, Mr. and Mrs. O. Anyigor Fidelis and my brothers, Sir. Anyigor Macfred Chinedu, Mr. Anyigor Monday C., Anyigor Anayo, Anyigor Chijioke C. and my sisters, Anyigor Lovelyn C., Anyigor Oluchi C. I thank them all.

Finally, this section will not be complete without acknowledging specially the support of Adim Ijeaku Jane (Akwaugo) she is a clear definition of a friend. What would I have done without her? To all my colleagues, who in one way or the other contributed to the success of this project, I say thank you.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Two hundred and twenty-four (224), day-old, Abor acre broiler chicks, divided into 7 groups of four replicates each on a weight equalization basis were used to determine the performance, economic benefit and litter quality in pens of broiler chickens produced on changing time of phase feeding regimes. The broiler chicken groups were randomly assigned to the following feeding regimes: T1 (control) starter (0 – 28 days), finisher (29 -42 days); T2 starter (0 -7 days), finisher (8 - 42 days); T3 starter (0 - 1 days), finisher (15 - 42 days); T4 starter (0 - 21 days), finisher (22 - 42 days); T5 starter (0 - 8 days), grower (9 - 22 days), finisher (23 - 42 days); T6 starter (0 - 10 days), grower (11 - 24 days), finisher (25 - 42 days); T7 starter (0 - 14 days), Grower (15 - 27 days), finisher (28 - 42 days) in a Completely Randomized Design experiment. The formulated starter, grower and finisher diets were determined for nutrient composition. Feed and water were offered *ad - libitum* in two trenches daily at 8.00 am and 4.00 pm. Recommended vaccination and medication schedules for commercial broiler chickens were followed. At the end of the 42-day study, the final body weight (FBW) and body weight gain (BWG), total feed intake (TFI), feed conversion ratio (FCR), protein efficiency ratio (PER), mortality were determined while nitrogen utilization was calculated using appropriate formulae. One bird closest to the mean weight was selected per replicate for carcass and internal organs weight determination. The moisture content, pH, nitrogen, and phosphorus content of the litter were determined in replicates. Data obtained were subjected to the analysis of variance and mean differences were separated. Results of the study indicated that birds on T5 recorded significantly ($p<0.05$) higher body weight and body weight gain than T1 T3, T4 and T7, but not significantly (p>05) higher than those on T2 and T6. There was no significant difference ($p>0.05$) in feed intake (FI) and FCR though those on T5 recorded numerically higher (3965.32 g) FI value and better (2.13) FCR value. Birds on T5 were more efficient (40.29.) in nitrogen efficiency utilization than others with higher retention (54.41 g), and lower intake (135.06 g) and excretion (80.65 g) values. Again, there were no significant ($p>0.05$) differences in percentage carcass and internal organ weights across the treatment groups except for those birds on T1 that recorded significantly ($p<0.05$) higher percentage of breast muscle and wings than other groups. Also, T2 recorded significantly ($p<0.05$) higher percentage of gizzard weight than the control and other groups. The birds on T1 recorded a significantly ($p<0.05$) higher percentage of liver weight than the other groups. Birds on T2, T3, T5, T6, and T7 recorded significantly ($p>0.05$) lower litter nitrogen content than T1 and T4. Also, birds on T1 and T2 recorded significantly ($p>0.05$) lower litter pH than T3, T4, T5, T6, and T7. The Phosphorus content of the litter was significantly ($p>0.05$) lower for birds on T1 and T2 than T3, T4, T5, T6, and T7. It could be concluded that a starter duration of not more than 10 days produced a better body weight, a better feed conversion ratio, improved feed intake, lower nitrogen content of litter, increased profitability, and improved litter environment while the phosphorus content of litter did not appear to be significantly influenced by the changing time of feeding starter regimes.

Keywords: Broiler chicken, changing time, phase feeding, litter

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Poultry farming has economic, social, and cultural benefits and is pivotal in animal protein to families in the developing world. It also contributes meaningfully to household food security in most tropical countries. Nigeria currently has the second-largest chicken population in Africa, estimated at 180 million birds. Over 13 million households keep livestock in their homes and receive (at least part of) their income from it (Poultry Sector Study Nigeria, 2020). Kabir *et al* (2015) indicated that family poultry farms are highly profitable and effective in livelihood improvements. Kebede, (2018) noted that the Nigerian poultry subsector contributed about 25-30% of the 35% contribution from agriculture to the National Gross Domestic Product (GDP) (Poultry Sector Study Nigeria, 2020), this translates to about 6 - 8% of total GDP. The potential of poultry to contribute to the National GDP is not in doubt being the most organized in the agricultural sector. Chicken products, like chicken meat and egg contribute about 36.5 percent of animal protein consumed in Nigeria (Kebede, 2018).

Earlier reports indicated that the poultry sector is the fastest growing agricultural sub-sector, resulting in push and pull factors (Eddington & Kashangura, 2016). The basic factor leading global animal protein demand (especially chicken) is the increased earning power of the segment of the population usually called low-income earning in the developing world facilitated by online schemes against the falling prices, urbanization, the resulting shift in consumption patterns, and fast population growth. On supply, the improvement of the broiler industry can be attributed to improved breeding, nutritional enhancement, management, processing technologies, and the increasing efficiency of chicken production (Penz & Bruno, 2011). This chicken industry in

Nigeria, however, has been undergoing challenges recently, especially in feeds and feeding. These challenges could be attributed to seasonal fluctuations in the availability and price of feeds and feed materials, creating uncertainty about the availability of ingredients and feeds to farmers. The high demand for these scarce feed ingredients especially cereals for human food and finished feeds naturally results in skyrocketing costs (Pomar, Andretta & Remus, 2021).

Feed performs a crucial role in the life of animals. It provides carbohydrates, protein, vitamins, and minerals to animals at every stage of growth. It also represents up to 65 - 75% of the overall input cost of production (Esonu, 2015 Mallick. *et al*., 2020). Similarly, environmental pollution from odour generated from poultry houses through nitrogen excretion has on its own, economic effects and contributes significantly to the greenhouse effect. (USDA/NCS, 2012; Pomar *et al*., 2021).

Amid these uncertainties, however, there are still tools that can be used to optimize feed use and poultry production in Nigeria. However, modern broiler chickens are already close to their functional limit and further improvement in industrial efficiency and meat production is constrained (Tickle, Paxton, Rankin & Jonathan, 2014). Modern broiler birds have been improved to reach a market weight of 2 kg in less than six weeks because of their genetic potential to multiply 50 times in body mass in six weeks post-hatching (Knowles *et al*., 2008; Tickl*e et al.,* 2014; Aviagen, 2020a; Cobbs, 2020). Therefore, any tool or tools, scientific or non-scientific that can be used for improvement in broiler chicken production must have the potential to improve the feed-to-gain ratio, and feed conversion ratio, reduce the cost of production and reduce environmental impact on humans and animals within the environment. This implies that any tool or tools employed to improve feed intake and utilization; to increase meat production should focus more on feed design and feed nutritional management strategies as well as bio-security programs. (USDA/NCS, 2012; Pomar *et al.*, 2021)

Most processors, hotels, and eateries require broiler chickens with a live weight of not more than 2 kg, translating into 1.1 to 1.5 kilograms of dressed weight (Messo, 2023). The nutrient recommendations for broiler chickens suggested by the National Research Council (NRC) and widely used in broiler production and feeding systems in Nigeria are the 8-week regime made up of the starter phase (0 – 4 weeks) and the finisher phase (5 – 8 weeks) (NRC, 1994; Okoli & Udedibe, 2016; Belema, Okafor, & Amakiri, 2018). These types of feed designs or feeding regimes are perhaps no more economical as modern broiler chickens have been improved to efficiently utilize diets high in protein and energy to achieve market weight in a 6-week or less rearing period (Tickle *et al.*, 2014*)*. Also, data from previous studies indicates that the multiple-phase feeding regime is better in terms of feed cost, feed utilization/efficiency, reduction in feed wastage, reduction in nitrogen excretion, improvement in production, and increased production phase cycle (Saleh, Watkins & Waldroup, 1996; Mohseni, 2008; Lesson & Summers, 2008; Anyigor & Etuk, 2018). For instance, in an experiment conducted to compare two-phase feeding (0 – 28 and 29 – 56 days) and four-phase feeding (0 – 7, 8 – 14, 15 – 42, and 43 – 56 days) regimes, Anyigor & Etuk (2018) reported that the four-phase feeding regimes produced better weight gain, FCR, less cost of production per kg of meat, reduced environmental pollution (litter quality), and high-profit margins when compared to the two-phase feeding (0 – 28 and 29 – 56 days) regime. Feed design and feeding management strategies that target the early maturity of the supplying organs at the expense of the demand organs, therefore, need to be identified. Some of the tissues that need to mature rapidly in both size and function post-hatching are the heart, intestines, and lungs (supply organs) at the expense of the breast, leg, and wings (demand organs) (Christensen, 2009).

One such tool that needs to be examined is the change in time of the phase feeding regime (Saleh *et al*., 1996; Mohsen, *et al*., 2019). A change in the timing of phase feeding regimes is a precision feeding and nutrition tool which allows not only optimal use of nutrients but also reduces costs and improves nitrogen utilization efficiency (Pomar *et al.*, 2021).

1.2 Statement of Problem

The double-phase grow-out period, which has a 4-week starter and 3 – 4-week finisher (NRC, 1994; Oyedeji, Umaigba, Okugbo,& Ekunwe, 2005), as previously recommended and practised by the majority of broiler farmers in Nigeria for several decades, is currently being challenged by the modern broiler strains, which grow out in 6 weeks or less, even in open-sided tropical housing structures, achieving 2.9 kg in 42 days of rearing (Aviagen, 2019a). This challenge stems particularly from the efficiency associated with the new strains, the high cost of feed, and the poor feed conversion ratio after six weeks (Aviagen, 2019a; Vilela *et al*., 2020). This consequently impinges on farmers' profits and increases nitrogen excretion and ammonia gas emissions (Vilela *et al.*, 2020). The cost of consistently high crude protein diets used in broiler production over a long period, for instance, impinges on the profit of farmers and contributes significantly to environmental pollution from litter, ammonia volatilization which is linked to ammonia gas emission, potassium, phosphorous, and sulphur contaminations constituting odour in the environment, wet litter, spread of infection, and even death of animals (USDA/NCS, 2012; Vilela *et al.*, 2020; Pomar *et al.*, 2021). Excess intake of nitrogen from crude protein may therefore lead to the excretion of nitrogen and wastage of nutrients.

1.3 Aim and Objectives of the Study

Aim: The main aim of this study was to determine the most efficient time to change the phase of the feeding regimes in terms of performance, economic benefit, and rearing environment via the quality of litter.

Objectives: The objectives of this study were:

- To determine the performance (growth, carcass and internal organs, protein efficiency ratio, and nitrogen utilization) of broiler chickens raised at changing times of the phase feeding regimes.
- To determine the economic benefits of broiler chickens raised on changing times of the phase feeding regimes.
- To determine the litter quality from pens of broiler chickens produced at changing time of feeding phase regimes.

1.4 Justification of the Study

The National Research Council feeding programs recommendation widely practised in Nigeria is the 8-week regime comprising a starter phase (0 – 28 days) and a finisher phase (29 – 56 days) (NRC, 1994; Belema, Okafor & Amakiri, 2018). These feeding programs are no longer economical, as modern broiler chickens have been improved to efficiently utilize diets high in protein and energy and achieve market weight in less than 6 weeks (Tickle *et al.*, 2014). The 8-week feeding regime appears too long for the nutrient level and energy requirements of modern broiler chickens, which tend to grow more rapidly, particularly as the grow-out period reduces to 6 weeks. Also, modern broiler birds have been improved to reach a market weight of 2 kg in less than six weeks because of their genetic potential, which could multiply 50 times in body mass in six weeks post-harvest (Tickle *et al.,* 2014). Similarly, the Standards Organization of Nigeria recommends a 3-phase feeding regime for broiler chickens, perhaps to take care of improvements in the strains of broiler chickens (SON, 2019).

Feed cost generally reduces when the protein content of the diet is reduced; the optimal duration in which diets are changed may therefore be of financial benefit. Exotic broiler strains, according to Tickle *et al*. (2014), have the capacity for fast growth and attain a market weight of 3 kg before 8 weeks. Changing the time of phase feeding could, therefore, help to reduce crude protein use and improve nitrogen utilization (USDA/NCS, 2012; Vilela *et al.*, 2020). Pomar *et al.* (2021) opined that the use of changing the time of phase feeding as a nutritional management strategy to reduce nitrogen excretion in broiler production may be more economical, increase production, be environmentally friendly, and produce better meat quality (Lesson and Summers, 2008; USDA/NCS, 2012). More so, the adoption of a six-week production cycle in the commonly used open-sided tropical housing system by small poultry farmers may reduce their cost of production and increase the farmers' net profit as well as increase the production cycles. This is because broiler chickens start to experience a gradual reduction in feed-to-gain ratio after 38 to 42 days during the growing period, according to the breeder's performance objective. (Aviagen, 2019b; Butler, Scanes, Rochell, Mauromoustakos, Caldas, Keen & Kidd, 2020).

Indeed, Ross 308 male broiler chickens with a growth weight of over 3 kg at 35 days have been reported in an environmentally controlled housing system *(*Abdallh *et al.*, 2020). It is therefore imperative that an efficient phase feeding regime and changing time be established to ameliorate the issues of improved nutrient utilization efficiency to enhance the rearing environment and economic advantage associated with the double phase, 8-week, 0 – 28-day starter and 29 – 56-day finisher feeding regime (NRC, 1994). Particularly as the improvement in genetic potential of modern-day broiler strains becomes prevalent.

1.5 Scope of the Study

The study was to:

- determine the nutrient composition of the different types of broiler chicken feed used for this study e.g. starter, grower, and finisher feeds.
- determine the nitrogen utilization efficiency of broiler chickens by changing the timing of the feeding regime.
- assess the performance (growth, carcass, and internal organ weights) of broiler chickens on changing time of phase feeding regimes.
- evaluate the economic benefit of raising broiler chickens by changing the timing of the feeding regime.
- determine the litter quality in pens of broiler chickens on the changing time of phase feeding regimes.

CHAPTER TWO

LITERATURE REVIEW

2.1 Nigerian Poultry Industry

Poultry farming has a significant economic, social, and cultural benefit and is pivotal in supplying animal protein to family nutrition in developing countries. Muchadeyi *et al.* (2007) pointed out that poultry production contributes meaningfully to household food security in most tropical countries, including Nigeria. Intensive (commercial) chicken production was introduced in Nigeria in 1957 and since then has developed rapidly in the last centuries, as a critical livestock business in the Nigeria economy (Sonaiya, Oguntade & Adesina, 2022). Nigeria is second largest chicken producer in Africa, estimated at 180 million birds. Over 13 million households keep livestock and receive part of their income from it (Poultry Sector Study Nigeria, 2020). Kabir *et al*. (2015) indicated that family poultry farms are highly profitable and effective in livelihood improvements. The Nigerian poultry sub-sector contributed about 25-30% of the 35% contribution from agriculture to the National Gross Domestic Product (GDP) (Poultry Sector Study Nigeria, 2020), which translates to about 6-8% of the total GDP. The potential of poultry farming to contribute to the National GDP is therefore not in doubt, being the most organized in the agricultural sector (Alemayehu, Bruno, Poole, Getachew Sonaiya, Bamidele, Adebambo, Adeyinka & Dessie, 2018).

2.1.1 Characteristics and production systems in the Nigerian poultry industry

Nigerian poultry farming and production have been a growing process. However, following the commercialization of Poultry production in 1957, when a farm that holds 500 birds is considered commercial poultry production, the sector has grown into the industrial sector. The intensification of poultry production has resulted in a paradigm shift in the Nigerian poultry sector. Currently, some farmers have a holding capacity of 1 million. Farms with 500 birds are classified as backyard or village poultry production (Amos, 2006 & Sonaiya *et al.,* 2022). Using the Food and Agricultural Organization (FAO) System; the production system in Nigeria can be grouped into three categories/ sectors (Table 2.1).

Multinational integrated farms with headquarters in the southwest are part of the integrated Industrial System; most farms have joint ventures or international franchising operations in Europe. They act as the cornerstone of the entire commercial production system. They produce day-old chicks (DOC) and own their parents' stocks (PS) and their grandparents' stocks (GPS). They have tools and equipment that are highly automated, they engage in breeding, raising, and commercial activities as well as machine automation (feed mills, incubators, and cooling facilities), and they produce all or a portion of their feed requirements. This commercial sector 2 is where most Nigerian commercial poultry farmers belong. It includes all industrial farms with 10,000 to 99 999 birds and a unique vaccination program for small-scale commercial production comprised of sectors 3 and 4. (Sonaiya *et al.,* 2022).

Table 2.1**:** Summary classification of poultry production systems

Production Sector	Main Characteristics
Sector 1 are Farmers having up to 100,000 - 1,000,000 birds or more	Integrated, industrialized enterprise with sophisticated, high-level farm biosecurity measures. Complete control over all farm inputs and outputs (e.g., breeding stock, feed mill, slaughterhouse, processing, distribution, animal health services)
Sector 2 comprises farmers with a capacity range of 10,000 - 99,999 birds	Commercial poultry production involves largely independent enterprises or contractors practicing moderate to high-level biosecurity. Distribution of poultry to slaughterhouses and to live poultry markets.
Sector 3 comprises farmers that keep 1,000 - 9,999 birds.	Commercial farms with relatively poor biosecurity. Sales are more likely to be through live poultry markets or to traders who on-sell through live bird markets. This system covers ducks and other poultry. Production may be intensive, semi-intensive, or extensive.
Have less than 1000 birds and are primarily reared in the unstandardized house.	Village or backyard. These small flocks are reared in village households. An occasional bird is sold locally, bartered, used as a gift, or occasionally sold to a poultry trader for cash.

Source: FARA (2022), FAO (2021), Sonaiya *et al*., (2022)

2. 2 Broiler Production in Nigeria

Broiler chicken production has recently received much attention and has become increasingly popular in all cities within the six (6) geopolitical zones (Sonaiya *et al*., 2022). Breeding criteria for broiler chickens include rapid growth, excellent feed efficiency, strong carcass yield, and high meat quality (Kazeem, 2019) to reach this quality, broiler chicks must be fed appropriately. Providing them with balanced meals that consistently meet their nutritional needs is the hallmark of rapid growth in broiler chicks (Ullah, Pasha, Ali, Saima, Khattak & Hayat, 2012). The primary source of poultry meat, "broilers", need high-quality feed to create meat (FAO, 2021). Broiler chicks may grow to 2 kg in just 42 days (6 weeks), which results in quick capital turnover and lower production costs (Muchenje *et al*., 2011).

2.2.1 Broiler strains in Nigeria

The most common breeds/strains of broiler chickens used in Nigeria include Ross 308, Arbor Acre, Hubbard, and Cobb, Marshall. Ibiwoye & Sola-Ojo (2021) reported differences in genetic strains of broilers available in the Nigerian market. In their report on Arbor acres, Marshall, Hubbard, and Ross 308 show distinctions in body weight and some morphometric traits (Table 2.2). Ross 308® is a robust, fast-growing, feed-efficient broiler chicken with good meat yield development for customers who require consistent performance for a broad range of products and hatcheries that produce Ross 308 in Nigeria are Sayed and Agrited (Ross manual, 2018). Arbor Acre® on the other hand is one of the poultry industry's oldest and most respected names. It is robust and efficient in feed conversion, which makes it a choice strain for meat processors, its shanks are short with broad breast muscles. Hatcheries that produce Arbor Acres in Nigeria are Amo Byng, Chi, and Fidan (Poultry Sector Study Nigeria, 2020).

Cobb® strains of broiler chicken grow efficiently and have good livability and animal welfare characteristics. Cobb's broiler genetic improvement has generated incredible advances in economic traits related to feed efficiency, fast growth, muscle quality, cardiovascular function, better skeletal strength, and more uniform body size (Cobb broiler manual, 2011). Hatcheries that produce Cobb broiler chickens in Nigeria are Zartech, Olam, Cascada, and Npg. The Marshall® is a tall strain, well desirable during the festival period due to their physical appearance. The only drawback is that Marshall does not develop as quickly as other strains.

2.2.2 Housing and equipment types for broilers

Housing and equipment design can significantly affect broiler performance, feed conversion ratio, body weight gain, and health (Kazeem, 2019). Consideration should be given to housing and equipment types to optimize growth, health, and profit. For instance, a broiler house must be built on adequately drained soil. Housing should be built to protect the poultry from harsh weather and predators. East west orientation is most appropriate for poultry house building (FAO, 2021). Usually, the farmhouse is a function of the size of production, rearing system, purpose, and financial capacity of the farmer. It is essential to make provisions for possible future expansion. Also, the distance between pen house to pen house and residential housing must be sufficient for bio-security reasons. Proper netting, ventilation, and floor spacing should be optimal to improve performance, health, welfare, and productivity and prevent rodents and pests from the house. More so, equipment like feeders, drinkers, and cooling fans must be selected to fit the house design, production size, and purpose, easy to clean, and more importantly, provide easy access to feed and water. (Kazeem, 2019).

Table 2.2**:** Broiler Strains Growth Performance

Broilers Chicken Strains	Body Weight (g)	Feed Intake (g)	Carcass Weight (g)	Eviscerated (%)	Feed Conversion Ratio
Ross 308[1]	2809.00	4739	2089.00	73.33	1.68
Arbor acre[2]	2981.00	4612	2188.00	73.41	1.55
Cobb[3]	2952.00	4760	2207.00	74.76	1.61
Hubbard[4]	2948.00	4668	2209.00	74.83	1.62

Sources: Broiler Performance Objective for Ross 308 (2019)[1], Arbor acres (2018)[2], Cobb (2023)[3]; Hubbards (2013)[4]

2.2.3 Factors affecting broiler chicken performance

Various factors impact broiler chicken performance. According to Tickle *et al*. (2014) and Ifeduba *et al.* (2020), nutrition is the most critical factor. Feed makes up a considerable portion of the overall cost of raising broilers. Broiler diets should therefore provide calories, protein, amino acids, macro and micronutrients, and essential fatty acids to promote the best growth and performance. Feed input account for 70–75% of production inputs (Kazeem, 2019). The cost of poultry products has increased because of the high price of feed and feed materials, seasonal fluctuations in available feed resources, and fierce human competition with the feed milling business. Choosing the proper feeding regime, genetic strain, rearing conditions, technologies, management, and heat control will therefore improve performance and lower mortality on farms (Aviagen, 2019a). Careful application of diet optimization to increase broiler growth performance in body weight, feed conversion ratio (FCR), protein efficiency, and welfare for sustainable food production need to be prioritized. Litter quality and product quality are a function of optimization. Some tools like phase feeding regimes, including changing the time of phase feeding regime, may be able to reduce the high cost of producing a kilogram of broiler chicken meat (USDA/NCS., 2012, Anyigor & Etuk, 2018; Mohsen *et al.*, 2019; Vilela *et al*., 2020 & Pomar *et al*., 2021). Genetic strains have also been demonstrated to impact broiler performance. Cobb 700 for instance gained 2847 g (67.79 g/day) at 42 days of age; Hubbard broiler chicken displayed a range of 2711 to 3186 g (64.55 – 75.86 g/day), whereas the Ross displayed a range of 2700 to 3136 g (86 to 97 g) (Aviagen, 2019a). Therefore, based on average daily weight increase, FCR, feed consumption, and mortality, there are significant variations between strains (Ahiwe, Apeh, Omede, Medani, Abdallh, & Iji, 2018; Kazeem, 2019).

2.2.4: Management of broiler birds

Only when excellent poultry husbandry techniques and management are used can the genetic potential of broiler chicks be realized. Commercial broilers must be well managed since it takes them only a short while to attain the marketable weight of 2.0 kg. Therefore, effective management techniques, including feeding, clean water supply, litter, lighting, and biosecurity, will aid in producing broiler chickens. In industrial farming systems, approximately 70% of broiler chickens are kept indoors, whereas less than 30% are raised outside in less intense systems with higher welfare options. Disease outbreaks can be minimized by limiting human access to the house and keeping broiler production indoors. Broiler sheds are enclosed, climate-controlled (for example, with fan ventilation), and equipped with artificial lighting in the temperate zone. (Anupam Soni, Khune, Rupal Pathak, Bobade, Neetu, Ankit, Subhrajit & Yadav, 2021).

2.2.5 Litter quality and rearing environment

The rearing environment plays a significant role in the performance of broiler chickens. House design is vital in many ways for both farmers and chickens. The objective of the house is to protect the birds against predators, infection, and adverse climate change. Broiler chickens must be raised in a protected environment to enable them to achieve their genetic potential. Litter quality, house temperature, and ventilation are some areas that need critical consideration in rearing environments for optimal broiler performance (Herkelman, 2014). Litter quality can positively and negatively impact the mortality rate, the health status of the birds, performance, and product quality (Adebayo, Abiodun, Aliyu, & Zainab, 2018). Excessive Rearing house temperature, in addition to metabolic heat, will result in heat stress. This condition can affect feed intake, weight gain, FCR, and profitability of the broiler business (Baracho, Nääs, Lima, Cordeiro, & Moura, 2019). Ventilation helps to keep the birds in their comfort zone but also helps to dry the litter by extracting excess moisture from the litter and reducing the ammonia concentration in the broiler house. This reduces the buildup of pathogenic microbes in the pen (Brink, Janssens, & Demeyer, 2022), especially during brooding. Disease outbreaks on farms can lead to reduced body weight gain (FCR), an increase in mortality in birds, and significant economic losses to farmers. According to Oyedeji, & Atteh, (2005), proper selection of genetic strains, rearing environments, technologies, management, heat control, and nutrition will help improve performance and reduce mortality on the farm.

2.2.6 Duration of growth and maturity period of broiler chickens

The growth and maturity of different broiler strains vary. The Cobb 500 strain of broiler chicken reaches its highest feed-to-gain ratio (daily body weight gain) at 36 to 42 days, while the Arbor Acre strain does so at 36 to 39 days and the Ross 308 strain does so at 39 to 42 days with live weights of 2951 g, 2981 g, and 2918 g, respectively (Ross-308 broiler performance objective, 2014). Cobb 500's daily body weight gain is 97 g at day 42, 93 g at day 49, and 83 g at day 56, with FCRs of 1.70, 1.65, and 1.69, respectively. According to Ross-308 Broilers Breeders Performance Objective (2019), Cobb-500 Broilers Breeders Performance Objective (2019).

2.2.7 Market demand and profitability level of broiler chicken

Market demand for meat-type broiler chicken is high globally (USDA, 2017). The chicken business is highly profitable irrespective of the production level (large, medium, small, and backyard scale) (Kassali, Adetomiwa, & Lasisi, 2022) because of its healthy amino acid profile and the fact that it has no religious taboos in every part of the world. The high demand for broiler chicken for meat and the short period of rearing required to reach a table weight of 2 kg of live weight make the return on investment in broiler production high (Ettah, Otu, Igiri, Juliana, Ihejiamaizu, & Victor, 2021). However, many farmers spend months raising birds and only achieve a few results when it is time to sell (Kazeem, 2019). The main cause of poor sales is not paying attention to the business's strategy and marketing aspects. Broiler chickens can eat up their profit if kept above 7 to 8 weeks of age (Arbor acre). Broilers Breeders Performance Objective, 2014).

Live Birds Market is abundant in the rural and urban areas of Nigeria. The market can be highly mixed up in rural areas with other animals. However, in urban and peri-urban areas, live bird markets are distinctly separated (Kazeem, 2019). As the primary poultry meat source, broiler chicken has high market demand and profit (Ettah *et al*., 2021). Constraints in marketing live birds include seasonality in the demand and supply of live birds, a poor road network, and a lack of credit facilities (Adeyonu *et al.*, 2021). Processed birds (frozen chicken) Markets refer to the stores in the market, supermarket, and any other place where dressed (usually frozen) chickens are sold. Imported frozen chickens (spent layers, turkey, and a few frozen broiler chickens) dominate these markets (Okojie, 2017; Ahmad, 2018), giving unhealthy competition to the local producers. However, the Federal Government's ban on imported frozen chicken and turkey in 2003 increased the incentive and net income of poultry producers in Nigeria, even though the enforcement has been unsuccessful. The amount of poultry products imported into Nigeria's market, for instance, from 2017 to 2019, was 454,000 MT (Orji & Iheonun, 2023). Nevertheless, frozen food production in the country, especially in the western part of Nigeria, is gaining popularity, attracting greater demand in several major cities and towns. The high cost of production, which in turn influences the price of live birds, inadequate infrastructure, bad roads, and the high cost of the storage facility, are the major challenges confronting processed broiler marketing in Nigeria (Adeyonu *et al*., 2021).

2.3 Broiler Chicken Feed Types

There are three basic types of poultry feed, primarily available as commercial or homemade feeds in Nigeria. However, commercial feeds are predominantly available in dry total mixture ratio (TMR) in mashes, pellets, and crumbs (Ifeduba, Achonwa, Ukwu, Ogbuewu, Etuk, & Okoli, 2020).

2.3.1 Pre-starter diets

These are diet-fed to broiler chicks from 0 to 4 or 7 days post-hatching. Young chicks have different anatomy and physiology from mature broilers. At post-hatch, the digestive system often undergoes significant alterations, transitioning from embryonic yolk absorption to feed utilization (Treviño, Alvarez-González, Perales-García, Arévalo-Galán, Uscanga-Martínez, Márquez-Couturier & Gisbert, 2011) as the intestines and pancreas expand in size (Ullah *et al.*, 2012). For the early development of broiler chicks, a highly digestible raw material with ideal nutrient levels must be provided because the young chick's digestive tract is underdeveloped. Broilers will develop more quickly and reach higher slaughter weights when given a special pre-starter diet in the early days that comprises more easily digestible basic materials (Leeson, 2008).

2.3.2 Broiler starter diet

This diet is fed to broiler chicks during the brooding phase. Establishing a healthy appetite and reaching or exceeding the desired body weight for the next seven days are the two main goals of the brooding period (0 to 10 days of age). If the targeted body weights are not attained or surpassed, the Broiler Starter diet should be provided for at least the first ten days. However, it usually continues for up to 14 days (Ross-308 performance objective, 2018). The starter phase only makes u a small fraction of the feeding length and feed cost (Arbor Arce, 2018).

2.3.3 Broiler grower diet

These are diets for broiler chickens between 3 and 5 weeks of age. When switching from starter to grower diets, there is usually a 14–16-day transition period, a change in feed type and nutrient density, and a reduction in feed intake or growth rate. It essentially contains a crude protein of 21 to 21.5%, which supports continuous growth. Depending on the feed texture or form, a grower diet may be served to prevent loss in feed intake in a crumb or mini pellet. For optimum development and meat yield, grower feed quality is essential (Gomez, Arturo, Carlos, & Emesto, 2017).

2.3.4 Broiler finisher diet

This is diet-fed broiler chicken that brooding to slaughter, after 25 days of age. At this time, there is rapid development coupled with accelerated fat deposition. Broiler chickens raised to be older than 42 days will need additional finisher diets to maximize profit (Arbor Acer, 2018). The number of diets provided to the broiler, however, depends on the production objective. The production goal and product output will be substantially impacted by the required processing carcass weight, the production time, the design of the feeding program, the targeted audience, and available finance (Aviagen, 2019a). To maximize profitability, a thorough evaluation of the type of feed program design is essential. (Ross-308 Broilers Breeders Nutrition Specifications, 2019).

2.3.5 Broiler Chicken Feeding Regime and Diet Specifications

The diet specifications for broilers in popular production and market situations are shown in Tables 2.5a, b, c, and d (Yan *et al.*, 2010). To minimize the cost of live bird production, most diet specifications may need to be modified for different markets. In addition, to live weights, other factors such as carcass score, cost of feed material, live weight at processing, carcass yield and quality, market demand for skin color, and shelf life are considered when designing nutritional specifications (Ross broiler management guide, 2018). Some breeders, the National Research Council (NRC) of the United States of America, and the Standards Organization of Nigeria's standards for broiler feed are shown in Tables 2.3a, 2.3b, and 2.3c, respectively. Arbor acre, Ross broilers, and NRC have the same feeding regime and nutritional recommendation, and as such, Ross broiler feeding and nutritional recommendation were adapted for emphasis in Table 2.3a. The nutritional specification for Cobb's broiler breeder is somewhat different from that of Aviagen's broiler nutrition specification and is presented in Table 2.3b. The Nigerian Industrial Standard (NIS) feeding specification is presented in Table 2.3c.

Table 2.3a: Broiler Chicken feeding regime and nutrient specification (Ross, Arbor Acer)

Nutrient (%)	Starter (0-10 d)	Grower (11-24 d)	Finisher 1 (25-39 d)	Finisher 2 (40 + days)
Metabolizable energy(kcal/kg)	3000.00	3100.00	3200.00	3200.00
Proteins	23.00	21.5	19.5	18.5
Lysine	1.44	1.28	1.15	1.08
Methionine + cystine	1.08	0.99	0.90	0.85
Methionine	0.58	0.54	0.44	0.44
Threonine	0.97	0.51	0.89	0.73
Valine	1.10	1.00	0.89	0.73
Arginine	1.52	1.37	1.21	1.14
Tryptophan	0.23	0.20.	0.18	0.17
Leucine	1.58	1.42	1.26	1.19
Isoleucine	0.97	0.89	0.80	0.75
Calcium	0.96	0.87	0.78	0.75
Phosphorus	0.48	0.43	0.390	0.375
Magnesium	0.05	0.50	0.05	0.50
Sodium	0.16 - 0.23	0.16 - 0.23	0.16 - 0.23	0.16 - 0.23
Potassium	0.40 - 1.00	0.40 - 0.90	0.40 - 0.90	0.40 - 0.90
Chloride	0.16 - 0.20	0.16 - 0.23	0.16 - 0.23	0.16 - 0.23

Adapted from Ross Broiler Nutrition Specification (2019c)

Table 2.3b Cobb's Broiler chicken feeding regime and nutrition specification

Nutrients (%)	Starter (0-14 d)	Grower (15-27 d)	Finisher 1 (28-38 d)	Finisher 2 (39 +days)
Metabolic energy (kcal/kg)	2977.00	3032.00	3131.00	3164.00
Proteins	21.00	20.00	19.00	18.00
Lysine	1.26	1.16	1.08	1.00
Methionine + cystine	0.94	0.87	0.83	0.78
Methionine	0.50	0.46	0.43	0.42
Threonine	0.86	0.79	0.73	0.69
Valine	0.93	0.87	0.83	0.78
Arginine	1.32	1.22	1.13	1.05
Isoleucine	0.83	0.78	0.72	0.68
Calcium	0.94	0.84	0.74	0.72
Phosphorus	0.47	0.42	0.37	0.36
Sodium	0.15	0.15	0.15	0.15
Potassium	0.60	0.60	0.60	0.60
Chloride	0.28	0.28	0.28	0.28
Linoleic Acid	1.00	1.00	1.00	1.00

Adapted from Cobb's 700 Broiler Nutrition Specification, (2012)

Table 2.3c Nigerian Industrial Standard (NIS) for Broiler Chicken feeding

Nutrients (%)	Pre-Starter (0-8 days)	Starter (9-21 days)	Finisher (22-42 days)
Metabolizable energy (kcal/kg)	3000.00	3050.00	3100.00
Proteins	22.00	20.00	18.00
Crude fat	5.00	5.00	6.00
Crude fibre	5.00	5.00	5.00
Lysine	0.00	0.00	0.00
Methionine	0.00	0.00	0.00
Glycine + serine	1.30	1.30	0.97
Histidine	0.54	0.54	0.97
Leucine	2.20	2.20	1.80
Valine	0.90	0.90	0.75
Arginine	1.30	1.30	1.02
Isoleucine	0.83	0.83	0.67
Phenylalanine	0.80	0.80	0.56
Sulphur	1.62	1.62	1.04
Calcium	1.00	1.00	0.85
Phosphorus	0.45	0.45	0.45
Manganese(mg)	60.00	30.00	30.00
Iron(mg)	80.00	60.00	60.00
Copper(mg)	5.00	4.00	4.00
Zinc (mg)	40.00	35.00	35.00
Iodine (mg).	0.40	0.40	0.40
Selenium (mg)	0.20	0.10	0.10

Adapted from Nigerian Industrial Standard for Poultry Feeds (NIS 259) (SON, 2019)

2.4 Broiler Feeding Systems

2.4.1 Broiler diets and feeding regimes

The success of the broiler business largely depends on the feed and feeding program and regime. When proper feed, diets, and feeding regimes, in addition to biosecurity, anti-vermin measures, and other management systems, are used in broiler production, broiler performance and return on investment can be high (Artwell & Edmore, 2015). There are several recommended diets and feeding regimens for broiler chickens. The recommendations of diets and feeding regimes for broiler chickens are determined by the farmer's production objective and available market (Aviagen, 2019a; SON, 2019). A sequence of diets with all the nutrients needed to sustain, grow, reproduce, and create products are used to feed broiler chickens. Different feeding techniques are used, but the most popular method is diet formulation, which combines precise amounts of the feed ingredients into a total mixed ration (TMR) that is then given to the birds (USDA/NCS, 2012). Some of the commonest diets for broilers include broiler pre-starter, starter grower, and finisher 1 and 2, and broiler breeder diets. In practice, many farmers use different feeding regimes, such as dual-phase feeding, three-phase feeding, multiple-phase feeding, sequential feeding, and restricted feeding regimes (NRC, 1994; USDA/NCS, 2012; SON, 2019).

2.4.2 Phase feeding systems for broiler chickens

Pope *et al*. (2002) defined phase feeding as altering the food during the broiler's life, including nutritional management methods in which the components and chemical makeup of diets are changed over time to match an animal's nutrient needs more closely. Phase feeding strategies, therefore, imply utilizing variations in the feed requirements of broilers during distinct stages of growth.

2.4.1a. The concept of a dual-phase feeding regime

Dual-phase feeding was designed to feed broiler chicks two (2) different kinds of chicken feed throughout their production cycle. Nevertheless, many forms of dual-phase feeding are used in the production of broiler chickens (Gajana *et al*., 2011, Ode Uwa & Etuk., 2018). The 0–4-week starter and 5–8-week finisher feeding is the dual-phase feeding variant most frequently used. Other variants include feeding 0–3-week starter and finisher diets for 4–8 weeks. Manyonga-Matingo, 2013; Artwell & Edmore, 2015; Ode Uwa & Etuk, 2018). The starter feed is usually produced from highly digestible feed material that the neonates can efficiently utilize during their first few weeks of life. The starter diet can contain high (22%–23%) crude protein levels with lower energy, and the finisher diet has lower protein levels (18%–20%) with energies of up to 3150–3200 kcal/kg (Artwell & Edmore, 2015). According to the ZPA (2012), a broiler will ingest 1kg of broiler diet during its first 0 to 21 days (3 weeks) of life and a broiler finisher diet starting on day 21. A tiny chick does not have a wholly developed GIT (Hubbard, 2013), so it needs a nutritive diet high in proteins of good quality. Most farmers in Africa, including those who produce their feeds, follow the two-phase regime (Oyedeji *et al*., 2005; Okoli |& Udedibe, 2016; Belema *et al., 2018).*

2.4.2b. The concept of a three-phase feeding regime

In three-phase feeding regimes, chicks are given a starter mash diet from 0 to 21 days, a grower diet from 22 to 42 days, and a finisher diet from 43 to slaughter age (Roberto, Arturo, Carlos, & Ernesto, 2017). The traditional NRC three-phase feeding programs have (0–21, 22–42, and 43–56 days) (NRC, 1994). However, there are several variants of the three-phase feeding regime (SON, 2019; Broilers Breeders Performance Objective, 2019; Unga, 2020). For example, Unga (2020) reported that the three-phase feeding regime with a starter phase of 0–10 days, a grower phase of 11–24 days, and a finisher phase of 25–24 days to slaughter is better in terms of feed efficiency, FCR, and profitability. Other variants include but are not limited to starters 0 to 14 days, growers 15 to 24 days, 35 and 42 days (Anyigor & Etuk., 2018), followed by a finisher diet from 43 days to slaughter. The grower phase is targeted to improve the broiler skeletal framework to support the rapid increase in weight gain. Consideration should be given when switching from one diet phase to another (Unga, 2020; Broilers Breeders' Performance Objective, 2018).

2.4.2b. The concept of four-phase feeding regimes

In this phase, a pre-starter diet, which is more easily digestible and nutritious than starter crumbles, is offered to the birds (Rosa Franco, Alberto, Javier, 'David & Ana., 2021). It is well known that body weight increases three to four times within the first week, and significant gut, muscle weight, and morphology changes are seen (Broilers Breeders Performance Objective (2018).). Meat-type broilers can achieve 97 g/day in 40 days. This achievement requires an emphasis on early-phase nutrition. Using pre-starting diets is a presumption that starter diets are less effective at supplying balanced nutrients (Rosa *et al*., 2021). Therefore, nutrient supplies are reevaluated at this neonate stage. Each additional gram of weight at age 7 corresponds to 5 g of body weight at age 49. (Leeson & Summers., 2005). The typical four-phase feeding regimes will have a pre-starter diet (0–7 days), a starter diet (8–14 days), a grower diet (15–42 days), and a finisher diet (43–56 days) (Anyigor & Etuk, 2018). Mehmood *et al*. (2014) also reported that four-phase feeding improves body weight, uniformity, and profit margin. In this phase, pre-starting crumbles, which are more easily digested and nutritious than starter crumbles are used to start the feeding in this regime. During the first week, the body weight multiplies three to four times, and significant changes are seen in the weight and morphology of the muscles, intestines, and body (Rosa, Alberto, Javier, 'David, Ana, & Ia-Ruiz, 2021). Meat-type broilers have a 40-day lifespan of 70 g/day body weight gain. Early-phase nutrition must be prioritized to achieve the genetic potential of the broiler chicks. This feeding program is used by broiler producers like Irvine's and its contract farmers and CHI Farms Ltd. in Zimbabwe and Nigeria. Better weights have been obtained with four-phase feeding systems than two- and three-phase programs, averaging 1.65 kg in 28 days (Irvines, 2011). Adopting the four phases could allow broiler chickens to fully exhibit their genetic potential (Saki *et al*., 2010). Increased feed changes had no impact on broiler chicken performance. Mohseni (2008) reported that they did enhance the protein conversion ratio and lower nitrogen excretion in a study comparing the conventional NRC three-phase feeding plan to those of five and nine phases. Artwell & Edmore (2015) nonetheless, in their studies, did not find any appreciable variations in weight gain, feed intake, or feed efficiency after dividing the conventional broiler starting period into three weekly periods (0–7, 7–14, and 14–21 days). Pope *et al.* (2002), in another study, found no differences in weight increase, feed intake, feed efficiency, or carcass composition among broilers with diets varied every other day from 42 to 60 days of age. Adopting multiple phases in the feeding regime allows broilers to fully exhibit their genetic potential (Saki *et al*., 2010). The multiple-phase feeding regime can prevent legs from breaking or birds from becoming crippled. The extra weight on the birds' hearts and lungs increases their chance of developing ascites (Hooshmand, 2006).

2.5. Broiler Chicken Performance on Different Feeding Regimes

Feeds and phase feeding regimes significantly affect broiler chicken's production efficiency and performance. Proper management of broiler chicken on the farm, including phase feeding regimes, will help to optimize production, improve FCR, body weight, and carcass quality, and reduce mortality (Mpofu, 2012; Manyonga-Mango, 2013; Artwell & Edmore, 2015).

2.5.1 Two-phase feeding regimes

According to the two-phase feeding program frequently utilized in Zimbabwe (ZPA, 2012), a broiler will ingest 1. 0 kg of the average broiler diet during its first 0 to 21 days (3 weeks) of life and a broiler finisher diet starting at 21 day. A tiny chick does not have a wholly developed gastrointestinal tract (GIT), according to Hubbard (2013), so it needs a nutritive diet high in proteins. The two-phase regimes are the ones that most farmers in Africa, including those who produce their feeds, follow (Oyedeji *et al*., 2005; Okoli & Udedibe, 2016; Belema *et al., 2018).*

2.5.2 Three-phase feeding regimes: In a three-phase feeding regime, chicks are given a starter mash diet from 0 to 21 days, a grower diet from 22 to 42 days, and a finisher diet from 56 to slaughter age (Salem, Khulel, & Al-Tamee, 2023). The traditional NRC three-phase feeding programs have (0–21, 22–42, and 43–56 days) (NRC, 1994).

2.5.3 Four-phase feeding regimes: In this phase, a pre-starter diet, which is more easily digestible and nutritious than starter crumbles, is used to start the birds (Rosa Franco, Alberto, Javier, 'David & Ana., 2021). It is well known that body weight increases three to four times within the first week, and significant gut, muscle weight, and morphology changes are seen (Broilers Breeders Performance Objective (2018).). Meat-type broilers can achieve 97 g/day in 40 days. This achievement requires an emphasis on early-phase nutrition. Using pre-starting diets is a presumption that starter diets are less effective at supplying balanced nutrients (Rosa *et al*., 2021). Therefore, nutrient supplies are reevaluated at this neonate stage. Each additional gram of weight at age 7 corresponds to 5 g of body weight at age 49 (Leeson & Summers, 2005). The topical four-phase feeding regimes are a pre-starter diet (0 – 7 days), a starter diet (8 –14 days), a grower diet (15 – 42 days), and a finisher diet (43 – 56 days). (Anyigor & Etuk, 2018). Mehmood *et al*. (2014) also reported that four-phase feeding improves body weight, uniformity, and profit margin.

2.5.4 Multiple feeding regimes

Multiple-phase feeding is a nutritional management strategy that precisely meets the age-based nutrient requirements of an animal. It includes using specific synthetic amino acids in the pre-starter diet that are high in digestibility (Gutierrez, Surbakti, Haq, Carey, & Bailey, 2008). Moss *et al*. (2021) pointed out that multiphase feeding is a nutritional strategy aimed at reducing nitrogen excretion and improving feed efficiency and feed conversion ratio (FCR). A multiphase feeding regime, such as the four-phase, optimizes diets and provides commercial broiler chickens with the nutrients they need at stages of their life cycles (Anyigor & Etuk, 2018). Matching broilers' nutritional needs at a particular growth stage with the elements in mash feed is vital for diet optimization and production efficiency (Moss *et al.*, 2021). Ferket *et al*. (2002) noted that feeding requirements are like "moving targets" because there is significant genetic variation in growth characteristics, particularly regarding protein retention. A study comparing the standard National Research Council's three-phase feeding regime (NRC, 1994) to the five and nine phases showed that increasing the number of feed changes (phases) had no effect on the performance of broiler chickens but did result in an improved protein conversion ratio and decreased nitrogen excretion (Saleh *et al.*, 1996; Mohseni, 2008).

2.6 Effect of Changing Time of Feeding Regime on Performance of Broiler Chicken

Previous studies indicated that the changing time of phase feeding regime affects performance in terms of body weight and weight gain, feed conversion ratio, feed intake, and increase profitability (Saleh, Watkins & Waldroup, 1996; Anyigor & Etuk, 2018). Changing time of phase feeding also reduces feed cost, improve feed utilization/efficiency, reduction in feed wastage, reduction in nitrogen excretion, improvement in production and increased production phase cycle (Saleh, Watkins & Waldroup, 1996; Mohseni, 2008; Lesson & Summers, 2008; Anyigor & Etuk, 2018)

For instance, in our previous experiment conducted to compare changing time of feeding in the four phase feeding regime viz: pre-starter, starter, grower and finisher: (0 - 7, 8 - 14, 15 - 42 and 43 - 56 days) regimes the result revealed that, the four phase feeding duration with shorter feeding duration produced better weight gain, FCR, less cost of production/ kg meat, reduced environmental pollution (litter quality) and high profit margins when compare to others. Modern broiler birds have been improved to reach market weight of 2 kg in less than six weeks because of its genetic potential to multiply 50 times in body mass in six weeks post hatching (Knowles *et al*., 2008; Tickl*e et al.*, 2014)

2.7 Influence of Changing Times of Phase Feeding Regime on Profitability in Broiler Chicken Production

Broiler chicken production is a highly profitable enterprise (Beg, Baqui, Sarker, & Hossain, 2011; FAO, 2013). However, the cost of feeding remains one of the most important factors affecting profitability in broiler enterprises (Ettah *et al*., 2021; Adeyonu, 2022). Feed, as a dominant input in any livestock production (FAO, 2013; Ahiwe *et al*., 2018), plays a vital role in the overall success and profitability of the enterprise. Currently, the high cost of raising broiler chickens for meat is attributed to the high cost of feeding (Adeyonu *et al*., 2021; Adeyonu, 2022) because of the rise in the price of high-quality feeds and feed materials. A feeding regime is a tool designed to affect the scarce and costly feed resources available to improve feed utilization for efficient broiler production performance in terms of body weight gain, FCR, feed cost per kg of dressed chicken, and profitability (Amy, Peter, David, Stuart, Tamsyn, & Mingan, 2021). A proper feeding regime improves broiler productivity, sustainability, and profitability.

The phase feeding regime as a nutritional management strategy was designed to provide almost precise nutrient requirements for livestock animals. The phase feeding regime is an excellent way to control feed intake and body weight. Mehmood, Sahota, Akram, Javed, Hussain, Sharif, Haroon, & Jatoi (2013) noted that the phase feeding regime positively impacts live body weight, feed consumption, feed conversion, and, in turn, net income and profitability. A study comparing the traditional NRC three-phase feeding plan to the five and nine phases revealed that more feed changes did not influence broiler chicken performance. However, they did improve the protein conversion ratio and lower nitrogen excretion (Mohseni, 2008; Moss *et al*., 2021). A phase feeding regime is a nutritional management strategy to improve feed efficiency. Improvements in feed utilization efficiency generally will increase profitability.

2.7.1. Effect of phase feeding regimes on the profitability of broiler chicken Enterprises

The phase feeding regime as a nutritional management strategy was designed to provide almost precise nutrient requirements for livestock animals. The phase feeding regime is an excellent way to control feed intake and body weight. Mehmood, Sahota, Akram, Javed, Hussain, Sharif, Haroon, & Jatoi (2013) noted that the phase feeding regime positively impacts live body weight, feed consumption, feed conversion, and, in turn, net income and profitability. A study comparing the traditional NRC three-phase feeding plan to the five and nine phases revealed that more feed changes did not influence broiler chicken performance. However, they did improve the protein conversion ratio and lower nitrogen excretion (Mohseni, 2008; Moss *et al*., 2021). A phase feeding regime is a nutritional management strategy to improve feed efficiency. An improvement in feed efficiency will generally increase profitability.

2.8 Feeding Regimes and the Litter Environment of Broiler Chickens

2.8.1 Environmental implications of feeding regimes in poultry production

Feeding regimes are one of the strategies to address these challenges in poultry production (Malomo *et al*., 2018). A feeding regime as a system designed for efficiency in nutrient utilisation in the feed by poultry has both positive and negative consequences for the environment. During rearing activities on the farm, feed and water spill out, and birds excrete. This may contain many nutrients when mixed with litter material, which can increase the moisture content of litters, generate foul odors, and incubate pathogenic bacteria if adequate ventilation is not available (Mitroi *et al*., 2021, Smits *et al*., 2021). Poultry excretions have high uric acid concentrations, usually modified into urea by an aerobic breakdown. Urease, embodied in fecal waste, may easily change urea nitrogen into extremely volatile ammonia, which is then easily spread into the surrounding air (Belloir *et al,* 2017). High temperatures, pH, low wind speed, urease activity, and a vast surface area for emissions facilitate the volatilization of ammonia in poultry manure. Up to 18 – 41% of fecal nitrogen could be lost in the environment if no steps are taken to improve the nutrient excretion of ammonia and other nitrogenous compounds (Malomo *et al*., 2018). Nutritional management, like feeding regimes, has shown a significant reduction in the environmental impact of nitrogen excretion in poultry production (Mohseni, 2008; Gutierrez *et al*., 2008; Manyonga-Mango, 2013; Artwell |& Edmore, 2015).

2.8.2 Effect of feeding regime on litter quality in broiler pens

Concerns for the environment-related ammonia (NH_3) emissions are becoming more problematic. The transformation of nitrogen (N) excreted by chickens into NH_3 puts the environment (pen house), the farmer's, and the animal's health at risk. The impact of reducing excretion on broiler production through phase feeding regimes on litter quality, N uptake, and ammonia concentrations in the poultry pen house cannot be overemphasized (Beker *et al*., 2004; Miles *et al*., 2004; Webb *et al*., 2005; Carter & Kim, 2013). During brooding, the diets fed to chicks are highly rich in dietary crude protein, and the potential for feed and water waste is equally high (Brink, Janssens, & Demeyer, 2022). The wasted feed and water, when mixed with litter materials in the pen house, can cause wet litter. This condition favours the growth and multiplication of pathogenic bacteria within the poultry pen house. In additionally, the worsening litter quality is associated with excreted nitrogen (N), which raises the amount of NH_3 and moisture content in the litter and contributes to foot and hock lesions in broilers (Bilgili *et al*., 2009; Shepherd & Fairchild, 2010; Nagaraj, *et al*., 2007, De Jong *et al*., 2014; Dunlop *et al*., 2016; Swiatkiewicz, *et al*., 2017). The excess ammonia in the brooding poultry pen can choke, leading to a reduction in the immune system of the chicks, making the chicks vulnerable to infection, which causes the chicks to be sick (Anderson, *et al*., 2021). This condition has contributed significantly to the poor performance of broiler chicks and the high mortality during and after brooding (Brink *et al*., 2022).

Phase-feeding regimes positively impact the quality of the litter and the welfare of the birds. They also cause a decrease in NH_3 concentrations that are measured at the litter level. By improving the indoor climate, it is possible to limit the generation and volatilization of NH_3, which positively influences not only the pen house environment but also the producer and the chickens (Brink *et al*., 2022). Studies indicated that a source-based feeding strategy decreased N excretion in broilers, resulting in a decrease in the N content of the litter and an improvement in the litter's quality (Belloir *et al*., 2017; Shao *et al*., 2018; Lemme *et al.*, 2019; Van Harn *et al*., 2019). According to Belloir *et al*. (2017), N excretion decreased by 13% for each percentage point drop in dietary crude protein. One of these source-based feeding strategies in broiler production is phase feeding. It holds promise not only to reduce nutrient excretion and nutrient utilization but also to reduce the overall cost of production, improve performance, increase net income, and improve the rearing environment (Gutierrez et *al*., 2008; Van Emous, Winkel, & Aarnink, 2019).

2.8.3. Effect of feeding regime on other pollutants in broiler pens

The feeding regime has a significant effect on pollutants in the broiler pen. Generally, poultry excretion contains many nutrients (Ifeduba *et al*., 2020). The components of broiler manure include but are not limited to, bacteria, moisture, total carbon, total nitrogen, ammonium nitrate (NH4-N), nitrate nitrogen (NO3-N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sodium (Na), manganese (Mn), iron (Fe), copper (Cu), and zinc (Zn) (Belloir *et al*., 2017 and Smits *et a*l., 2021). These compounds and elements negatively affect the environment, crops, water bodies, and animals. Such, Pál, Strifler, Horváth, Koltay, Rawash, & Dublecz. (2021). High nutrient pollutants, footpad dermatitis, processing declines, and condemnations could result from excessive litter moisture (Hunter *et al*., 2017). Phoshorus is one of the nutrients under the most scrutiny regarding the environment. Poultry species and pigs lack the phytase enzymes needed to digest phosphorous in the form of phytic acid in their diets (Carter & Kim, 2013). Consequently, most of the phosphorus in typical diets is excreted through feces. Reducing phosphorus excretion and concentration in poultry droppings and pig dung can be avoided by not overfeeding phosphorus or using highly digestible sources of dietary phosohrus (Powers & Angel, 2008). Phosphate (P_2O_5) results from the manure's surface runoff or from the water-soluble forms' leaching that causes the eutrophication of open waterways, resulting in water body contamination. Increasing mineral levels in diets can increase nutrient excretion (Carter & Kim, 2013).

Greenhouse gases such as carbon dioxide (CO_2), methane (CH4), and nitrous oxide are pollutants that broilers can emit during rearing activity, which contribute significantly to greenhouse gases (GHGs) and pollution of surface water and groundwater (with NO3 and NH4) (Mitroi *et al*., 2021).

Methane emissions are flammable and about 28 times more potent than carbon dioxide. It is made from the organic matter decomposing in manure stored without oxygen. Nitrous oxide (N_2O) is 265 times more harmful than CO_2 as a pollutant. It is a byproduct of the anaerobic fermentation of NO_3 in animal waste applied to soils with low oxygen levels and the nitrification of (NH_4^+) into (NO_3^-). Also, hydrogen sulphide (H_2S) odour from storage and manure affects the broiler's performance (Méda, Hassouna, Aubert, Robin, & Dourmad, 2011).

CHAPTER THREE

MATERIALS AND METHOD

3.1 Sites of the Experiment

These feeding trial components of the study were carried out in the Poultry Unit of the School of Agricultural and Agricultural Technology (SAAT) Teaching and Research Farm, Federal University of Technology, Owerri, Imo State, Southeast Nigeria. The experimental diets were produced at Fidelity Feed Mills Ltd., Egbu, Owerri North LGA. The laboratory analysis component of the study was also carried out at the Precision Food and Feed Analysis Laboratory, Ibadan, Oyo State, Nigeria. Imo State lies between latitude 5.5720122' North and longitude 7.0588219' East. Owerri, the capital of Imo State, is in the southeastern agroecological zone of Nigeria. The annual rainfall, temperature range, and relative humidity are 234.25 mm, 23.71 ºC (74.68 ºF), 32.93 ºC (91.27 ºF), and 76.67%, respectively. Dry season duration (i.e., months with less than 65 mm of rainfall) is 3 months (January, February, and March) (Ncei, 2022.).

3.2 Source of Experimental Materials

3.2.1. Experimental birds

Two hundred and twenty-four (224), unsexed, day-old Arbor acre broiler chicks for this study were procured from a reputable commercial distributor in Owerri, Imo State.

3.2.2: Feed ingredients

Feed materials for the experimental diets were procured from another reputable commercial distributor in Owerri. The materials include yellow maize, soybean meal, palm kernel cake, fish meal, bone meal, oyster shell, salt, vitamin and mineral premixes, lysine, and methionine.

3.3 Experimental Diets and Analysis

Experimental starter, grower, and finisher broiler diets were formulated for the broiler feeding phases. The gross composition and calculated compositions are presented in Table 3.1. The formulated experimental broiler chick diets were produced in mash form. The nutrients and gross energy composition of the diets were determined through proximate analysis using bomb calorimeters (AOAC, 2019). Also, the metabolizable energy (ME) of the diets for poultry was calculated using the equation by El Hag, (2022).

The ME for poultry was calculated with the proximate composition of the diets using the equation by ME (P) =1.549 + 0.0102 CP + 0.0275 EE + 0.0148 NFE + 0.0034 CF. Where ME = metabolisable energy of poultry; CP = crude protein, EE = ether extract, NFE = nitrogen-free extract (carbohydrate), and CF = crude fiber.

Again, the amino acids of the diets for poultry were determined through mass spectrometry and calculated using the equation by Marino, Iammarino, Santillo, Muscarella, Caroprese, & Albenzio, (2010).

The amino acid of the diets was calculated using the equation,

$$\text{Amino Acid Concentration} = \frac{\text{Absorbance of sample x Concentration of Standard solution}}{\text{Absorbance of Standard Solution}}$$

Table 3.1. Gross composition and calculated nutrient content of experimental broiler chicken diets

Ingredients	Broiler chicken diets		
	Starter	Grower	Finisher
Maize	50.00	57.00	62.70
Soybean meal	27.5	28.5	27.8
Palm kernel cake	11.00	8.5	4.00
Fish meal	8.00	3.00	2.5
Bone meal	1.50	1.5	1.5
Vitamin/mineral	0.25*	0.25**	0.25***
Salt	0.25	0.25	0.25
Oyster shell	1.00	1.00	0.25
Lysine	0.25	0.25	0.25
Methionine	0.25	0.25	0.25
Total	100.00	100.00	100.00
Calculated nutrient composition of experimental boiler diets (%)			
Metabolized energy (kcal/kg)	3048.30	3101.10	3206.71
Crude protein	23.12	20.47	19.04
Ether Extract	6.89	6.84	7.85
Ash (%)	3.64	2.76	3.08
Crude fiber	4.24	4.14	3.52
Calcium	1.25	1.10	1.07
Phosphorus	0.96	0.89	0.87
Sodium	0.11	0.11	0.11
Chloride	0.15	0.15	0.15
Lysine	2.01	1.92	1.94
Methionine	0.68	0.56	0.63

***Micro-mix® broiler starter vitamin/mineral premix contains 2.5 kg:** Vitamin A, 12,500,000.00I.U.; vitamin D3, 2,500,000.00 I.U.; vitamin E, 40,000.00 mg; vitamin K3, 2,000.00 mg; Vitamin B1, 3,000.00 mg; Vitamin B2, 5,500.00 mg; niacin, 55,000.00 mg; calcium pantothenate, 11,500.00 mg; vitamin B6; 5,000.00 mg; vitamin B12, 25 mg; chlorine chloride, 500,000.00 mg; folic acid, 1,000.00 mg; biotin, 80,000.00 mg; manganese, 120,000.00 mg; iron, 100,000.00 mg; zinc, 80,000.00 mg; copper, 8,500.00 mg; iodine, 1,500.00 mg; cobalt, 300.00 mg; selenium, 120.00 mg; and antioxidant, 120,000.00 mg.

****Micro-mix® broiler grower vitamin/mineral premix contains 2.5 kg**: Vitamin A, 10,000,000 I.U.; vitamin D3, 2,000,000 I.U.; vitamin E, 20,000.00mg; vitamin K3, 2,000.00mg; Vitamin B1, 3,000.00mg; Vitamin B2, 5,000.00mg; niacin, 45,000.00 mg; calcium pantothenate, 10,000.00 mg; vitamin B6; 4,000.00 mg; vitamin B12, 20 mg; chlorine chloride, 300,000.00 mg; folic acid, 1,000.00 mg; biotin, 80,000.00 mg; manganese, 120,000.00 mg; iron, 80,000.00 mg; zinc, 80,000.00 mg; copper, 8,500.00 mg; iodine, 1,500.00 mg; cobalt, 300.00 mg; selenium, 120.00 mg; and antioxidant, 120,000.00 mg.

*****Micro-mix® broiler finisher vitamin/mineral premix contains 2.5 kg**: Vitamin A, 8,000,000 I.U.; vitamin D3, 150,000 I.U.; vitamin E, 15,000.00 mg; vitamin K3, 1,000.00 mg; Vitamin B1, 2,000.00 mg; Vitamin B2, 3,000.00 mg; niacin, 35,000.00 mg; calcium pantothenate, 8,000.00 mg; vitamin B6; 3,000.00 mg; vitamin B12, 20 mg; chlorine chloride, 200,000.00 mg; folic acid, 1,000.00 mg; biotin, 60,000.00 mg; manganese, 90,000.00 mg; iron, 60,000.00 mg; zinc, 60,000.00 mg; copper, 6,500.00 mg; iodine, 1000.00 mg; cobalt, 250.00 mg; selenium, 90.00 mg; and antioxidant, 90,000.00 mg

3.4 Experimental Design and Management of Experimental Birds

Two hundred and twenty-four (224) unsexed, day-old Abor-acre broiler chicks were divided into seven groups of 32 birds each. Each group was further subdivided into four replicates of 8 birds on an equal-weight basis. Each replicate was housed in a compartment measuring 1.6 m x 1.0 m in an open-sided poultry house. The experimental broiler chick groups were randomly assigned to the seven experimental broiler feeding regimes as treatments (Table 3.2) in a completely randomized design (CRD) experiment. Brooding of chicks was ensured using stoves and lanterns within the first 2–3 weeks. Feed and water were offered *ad libitum* in two tranches at the same time daily (8.00 a.m. and 4.00 p.m.). Recommended vaccination and medication schedules were followed throughout the experimental period. The feeding trial lasted 42 days.

Table 3.2: Experimental treatment regimes

Feeding Phases	Changing time of phase feeding (days)						
	T1 Control	T2	T3	T4	T5	T6	T7
Starter phase	0 - 28	0 - 7	0 - 14	0 - 21	0 - 8	0 - 10	0 -14
Grower phase	-	-	-	-	9 - 21	11 -24	15 - 27
Finisher phase	29 - 42	8 - 42	15 - 42	22 - 42	22 - 42	25 - 42	28 - 42
Sources	Variants of the traditional two-phase feeding regime				SON (2019)	Aviagen (2019c),NRC (1994)	Cobb500 (2000)

3.5 Data Collection

3.5.1 Growth performance

The birds were weighed in replicates on the first day of the experiment and weekly thereafter to obtain the initial body weights and weekly body weight gains, respectively. Feed intake was determined by weighing the feed offered and the leftovers the next morning. These data were used to calculate the feed conversion ratio (FCR) and feed cost per kg of body weight gain.

3.5.2 Protein efficiency ratio and nitrogen utilization

Protein efficiency ratio, nitrogen intake, excretion, retention, efficiency, and excretion per body weight gain were calculated as follows:

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

Nitrogen intake (Nintake) (g): This was calculated by multiplying the total feed intake (FI) of the pen by the crude protein (CP) content of the diet and dividing by 6.25 (equation 1).

Whole-body nitrogen retention (Nret.) (g): This was estimated according to equation (2) by multiplying the total body weight (BW) gain of the pen by a constant value for whole-body nitrogen content (Nbody = 29 g/kg) (ITAVI, 2013). Aletor *et al. (*2000), and Bregendahl *et al.* (2002) showed that whole-body nitrogen content was not affected by a reduction in dietary CP content, even when dietary CP is limiting.

Total efficiency of nitrogen retention (Nitrogen efficiency (%)): This was calculated using equation 3. **Total nitrogen excretion (Nitrogen excretion (g)):** This was calculated by obtaining the difference between N. intake and N. ret (equation 4). **Total nitrogen expressed per kg of body weight gain (BWG) (Nexc/BWG) (g/kg BWG):** This was calculated using equation (5) to allow comparison between treatments and experiments:

Nitrogen intake (N.intake) = FI x CP diet ÷ 6.25................................... Equation (1)

Nitrogen retention (N.ret.) = N. body x (BW gain/1000)........................ Equation (2)

Nitrogen efficiency (N.eff.) = 100 times N.ret / N intake………………Equation (3)

Nitrogen excretion (N.exc.) is calculated as the difference between nitrogen intake and nitrogen retention. ……………….Equation (4)

Nitrogen excretion/body weight gain (Nexc/BWG) = Nexc/BWG x 1000..Equation (5). (ITAVI, 2013 and Belloir *et al.*, 2017).

3.5.3 Carcass and internal organ weight determination

Carcass and internal organ weights were determined at the end of the feeding trial. One bird whose weight was closest to the mean of each treatment was selected per replicate, starved overnight, and slaughtered by cutting the jugular vein, bled, eviscerated, and primal cut obtained after removing the head, neck, shank, and abdominal fat as described by Aladi (2016). Dressing percentages were obtained as outlined by Burson (2001). The organ weights (liver, spleen, proventriculus, gizzard, duodenum, ileum, and jejunum; cecum; large intestines; heart; and pancreas) were weighed using a sensitive electronic scale and the values recorded. The carcass weights were obtained by removing the head, neck, shanks, and abdominal fat after the bleeding, plucking, and evisceration of the chickens.

3.5.4 Determination of the profitability of changing the time of phase feeding Regimes

Feed cost/kg (₦) was multiplied by the total feed consumed to determine the cost of feed consumed. The cost of feed consumed was subtracted from the cost of live birds per kg (N) to determine the net gain without considering the other fixed costs, which were considered like all the treatments.

3.5.5 Determination of the Litter Quality in Pens of Broiler Chickens on Changing Time of Phase Feeding

Samples of litter were obtained from selected spots (3 per replicate), bulked per replicate, and stored in airtight containers for laboratory analysis of litter quality parameters. Parameters that are defined include (i) moisture content, (ii) PH, (iii) nitrogen content, and (iv) phosphorus.

The nitrogen and moisture content of the litter were calculated after the analysis using the following equation:

$$\% \text{ moisture content} = \frac{(W0 + W1) - (W0 + W)}{W_1} \times 100$$

Where:

WO = weight of the empty porcelain crucibles

W1 = weigh 1.00g of sample

W2 = weight of the porcelain crucibles and content

$$\% \text{ Nitrogen} = \frac{(T - B) \times N \times 14.007 \times 100 \times 10 \times 6.25}{W\,(mg)}$$

Or

$$\% \text{ Nitrogen} = \frac{(T - B) \times N \times 14.007 \times 100 \times 10 \times 6.25}{W\,(g) \times 1000}$$

$$gN/L = \frac{(T-B) \times N \times 14.007}{\text{Volume sample (ml)}}$$

Where:

W = sample weight (g)

T = Titration volume of sample (ml)

B = Titration volume of blank (ml)

N = Normality of acid to 4 decimal places

10 = Volume taken for distillation from the diluted digest

1000 = Converting the weight of the sample from g to mg

gN/l = Gram Nitrogen per Litre

14.007 = Molecular weight of nitrogen

gN/L = Gram of nitrogen per liter (if the liquid is analyzed)

6.25 = Conversion Factor from Nitrogen to Protein (AOAC, 1996).

3.6: Statistical Analysis of Data

The means of the collected data were subjected to a one-way analysis of variance (ANOVA) using R. Core Team (2023). Significantly different means were separated using Duncan's New Multiple Range Test (DMRT).

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Determined Nutrient Composition of Experimental Broiler Diets

The determined nutrient composition of the experimental broiler chicken diets (starter, grower and finisher) is presented in Tables 4.1, 4.2 and 4.3.

4.1.1 Determined proximate, gross energy, and calculated metabolizable energy Composition of experimental broiler diets

The gross energy (GE) composition of the experimental broiler starter, grower, and finisher diets was similar to the calculated values and the recommendations of the Standards Organization of Nigeria (SON, 2019). The ME expectedly increased from the starter and peaked at the finisher diet. The crude protein was reduced consistently from starter to finisher diets; this pattern agrees with the recommendation of some nutrients in feed for broiler chickens (SON, 2019).

4.1.2 Determined mineral composition of experimental broiler diets

The calcium, phosphorus, magnesium, and other minerals were reduced consistently from starter to finisher diets; this pattern agrees with the recommendation of some nutrients in feed for broilers (SON, 2019).

4.1.3 Determined amino acid compositions of experimental broiler diets

The amino acid composition of the experimental diets. There were variations in the values obtained from the recommendations of SON (2019). However, most of the values were within a tolerable range.

Table 4.1: Determined proximate and calculated metabolizable energy of experimental broiler chicken diets

Nutrients (%)	Broiler chicken diets		
	Starter	Grower	Finisher
Moisture	11.33	13.49	14.26
Gross energy (Kcal/kg)	3061.43	3211.06	33226.65
Metabolizable energy (Kcal/kg)	2980.00	2990.00	3000.00
Crude protein (CP)	21.21	20. 18	18.78
Ether extract (EE)	3.39	4.88	5.68
Crude fibre	6.21	5.42	5.68
Nitrogen-free extract (NFE)	70.80	75.83	76.04
Ash	9.72	7.18	8.08

Table 4.2. Determined mineral composition of experimental broiler diets

Minerals (%)	Broiler chicken diets		
	Starter diet	Grower diet	Finisher diet
Calcium	2.08	1.90	1.86
Sodium	0.24	0.22	0.21
Phosphorus	0.33	0.32	0.31
Manganese (mg/kg)	72.33	70.82	66.76
Copper (mg/kg)	4.46	4.37	4.88
Zinc (mg/kg)	32.38	31.89	31.96

Table 4.3. Determined amino acid composition of experimental broiler chicken diets

Amino acids (mg/100g)	Broiler chicken diets		
	Starter Diet	Grower Diet	Finisher Diet
Cystine	0.46	0.43	0.37
Threonine	1.10	1.06	1.03
Methionine	0.57	0.65	0.69
Tyrosine	1.28	1.33	1.35
Phenylalanine	1.89	1.86	2.07
Leucine	2.97	3.05	2.94
Isoleucine	1.59	1.62	1.42
Tryptophane	0.19	0.24	0.21
Valine	1.86	1.90	1.83
Lysine	0. 96	0.68	0.74
Aspartic acid	3.87	3.92	3.01
Glutamic acid	3.03	3.89	3.99
Serine	2.13	2.06	1.99
Glycine	1.80	1.75	1.92
Proline	1.74	1.84	1.79
Alanine	1.86	2.03	2.09
Histidine	0.91	0.79	0.88
Arginine	2.12	2.06	1.88

4.2 Performance of Broiler Chickens at Changing Times of Phase Feeding

The performance of broiler chickens on changing times of phase feeding is presented in Table 4.3, while the weekly performance of broiler chickens on changing times of phase feeding is presented in Figures 4.1 to 4.4.

4.2.1 Final body weight and body weight gain: The results of the study showed that the final body weight and body weight gain of the experimental birds placed on changing times of phase feeding in T_5 and T_6 were significantly ($p<0.05$) higher than the values obtained for birds on the control (T_1), T_2, T_3, T4, and T_7. Birds on T5, which consumed a starter diet for 0–8 days, recorded the highest body weight gain and final body weights. On a weekly basis, the analyzed data shows that during the experimental period, the mean body weight and body weight gain were not affected by the changing time of phase feeding regimes from 0 to 35 days. However, at ages 36 to 42, T5, which were placed on feeding regimes (0 to 8, 9 to 21, and 22 to 42 d), showed significantly ($p<0.05$) higher live weight and weight gain when compared to other treatment groups. The reason could be that reducing the starter feeding duration from 28 or 21 days to 8 days, introducing the grower phase up to 14 days, and feeding the finisher phase for 21 days may have matched the protein energy ratio, resulting in more efficient protein digestion, absorption, and utilization. This result demonstrates the assertion by Moss *et al*. (2021) that matching broilers' nutritional needs at a particular growth stage with the elements in mash feed is vital for diet optimization and production efficiency. Results obtained also agree with reports that changing times of phase feeding improved body weight and body weight gain in broiler chickens (Muchenje e*t al*., 2011; Sahota *et al*., 2012; Mehmood *et al*., 2015).

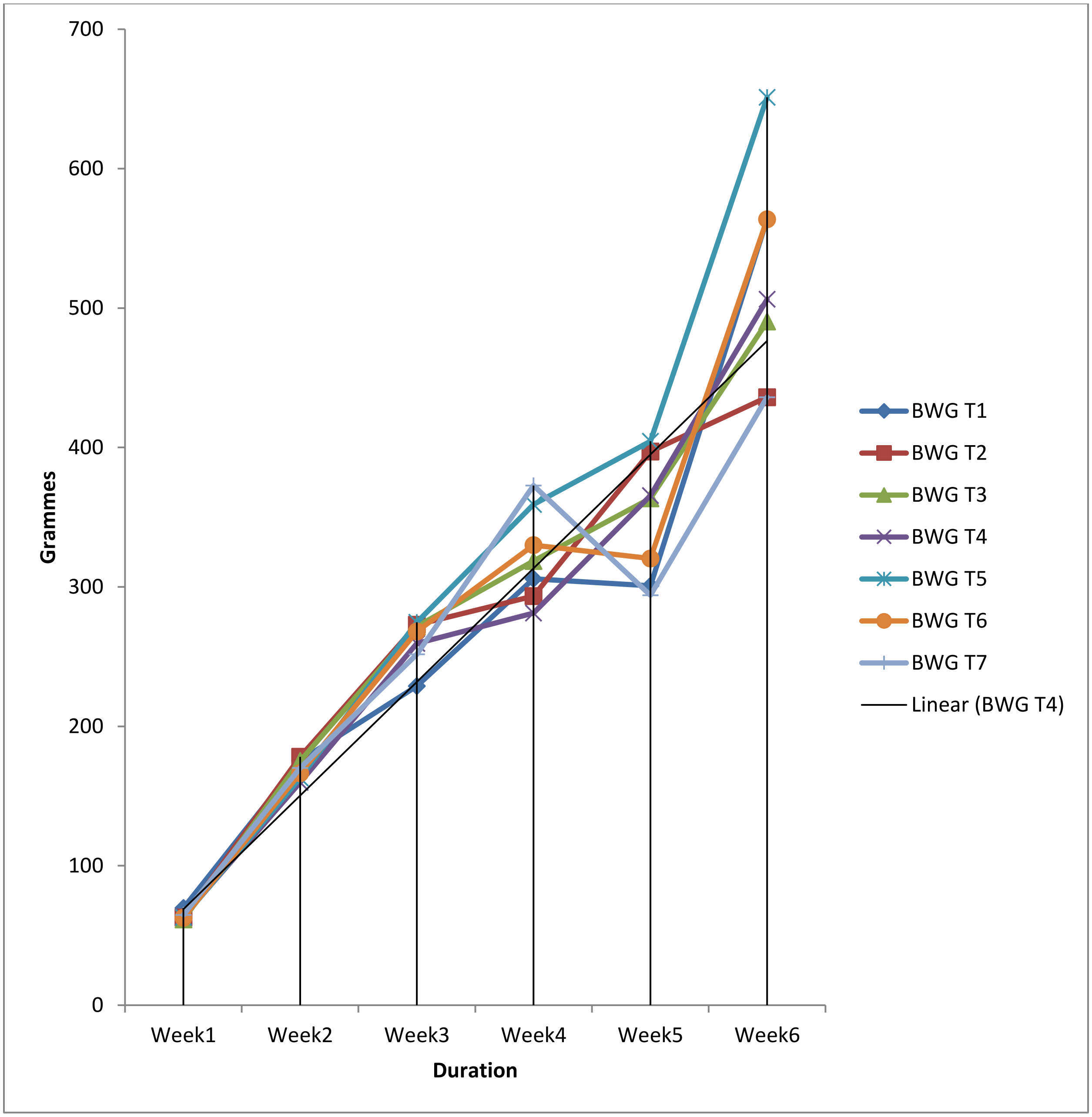

Fig. 4.1. Weekly body weight gain

4.2.2 Feed intake

Feed intake in all the groups was comparable ($p > 0.05$). The total feed intake of the birds on T_5 was, however, numerically higher (1696.59 g) than those on other treatment groups, while birds on T1 (control) produced the numerically lowest (1605.40 g) feed intake. Feed intake increased with an increase in the number of phases. Again, when weekly feed intake was analyzed, the result of the mean weekly feed intake revealed that at week 1, the feed intake was statistically the same. However, at 2nd and 3rd weeks, T2 and T5, which had shorter starter duration (0 to 7 days) and 0 to 8 days, respectively, recorded significantly ($p > 0.05$) lower feed intake when compared with other treatment groups. It appears that the feed intake followed the same trend as the body weight gains in some of the treatments (Fig. 4.2). The lower feed intake may have been because of higher energy in the grower and finisher diets, respectively. It also explains the fact that animals eat to meet their energy requirements. This result is in line with the findings of Muchenje e***t al***. (2011) and Mehmood ***et al*****.** (2015), who reported that an increase in the number of phases in a feeding regime produced a slight increase in feed intake.

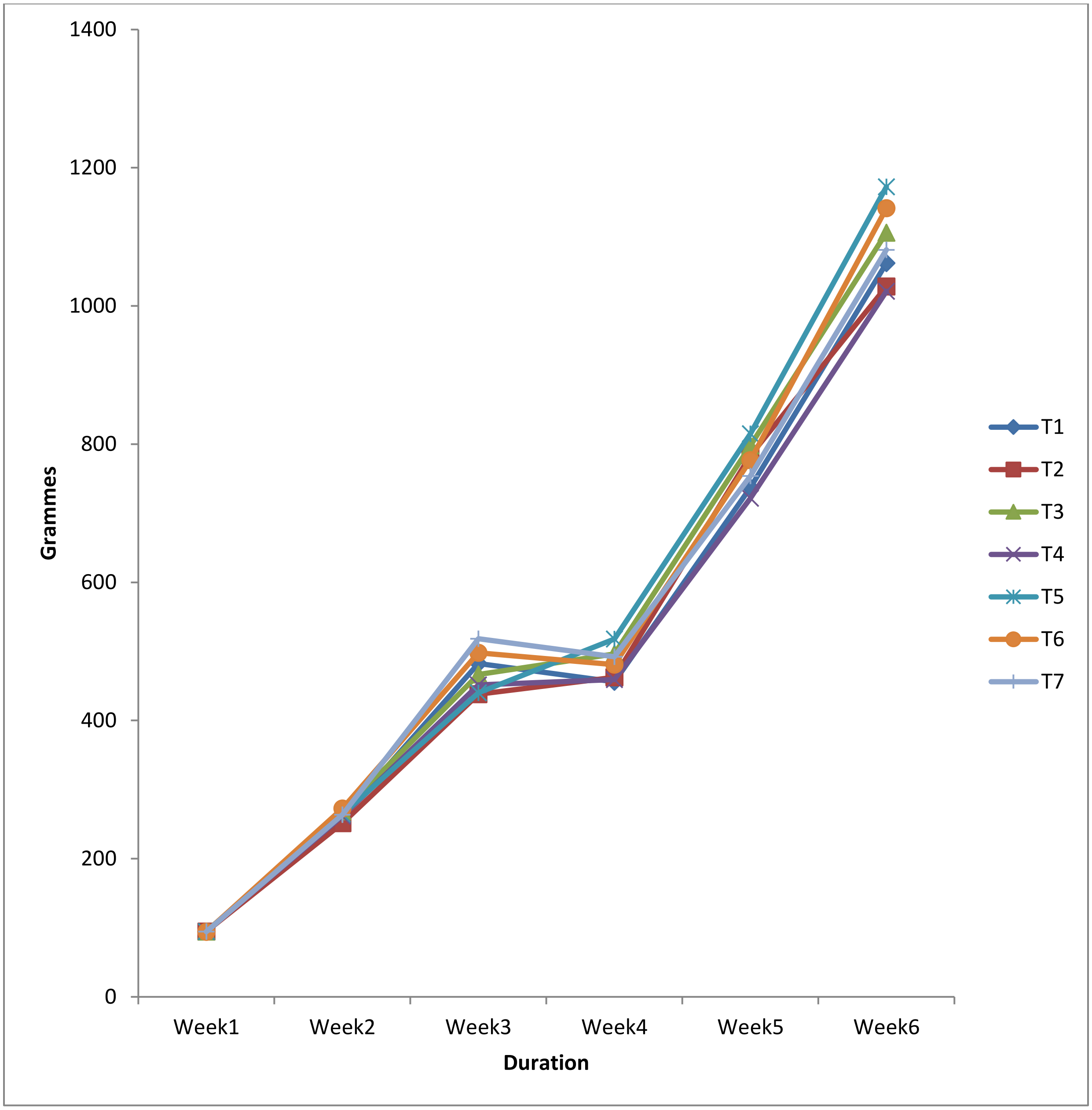

Fig. 4.2: Weekly Feed Intake

4.2.3 Feed conversion ratio

The data obtained from this study showed that there were no significant ($p<0.05$) differences in feed conversion ratio (FCR). Birds in T5, however, produced a numerically better (2.13) feed conversion ratio than those in other groups. These results are in line with the report that changing the time of phase feeding has no negative impact on the feed conversion ratio. (Gajana ***et al*.,** 2011; Al-Neem ***et al*.,** 2015; Tony & Fayed, 2015; Artwell & Edmore, 2015). There were some similarities in the FCR pattern within the first three weeks; this changed as the birds aged, especially in the 5th and 6th weeks of the treatments (Fig. 4.3).

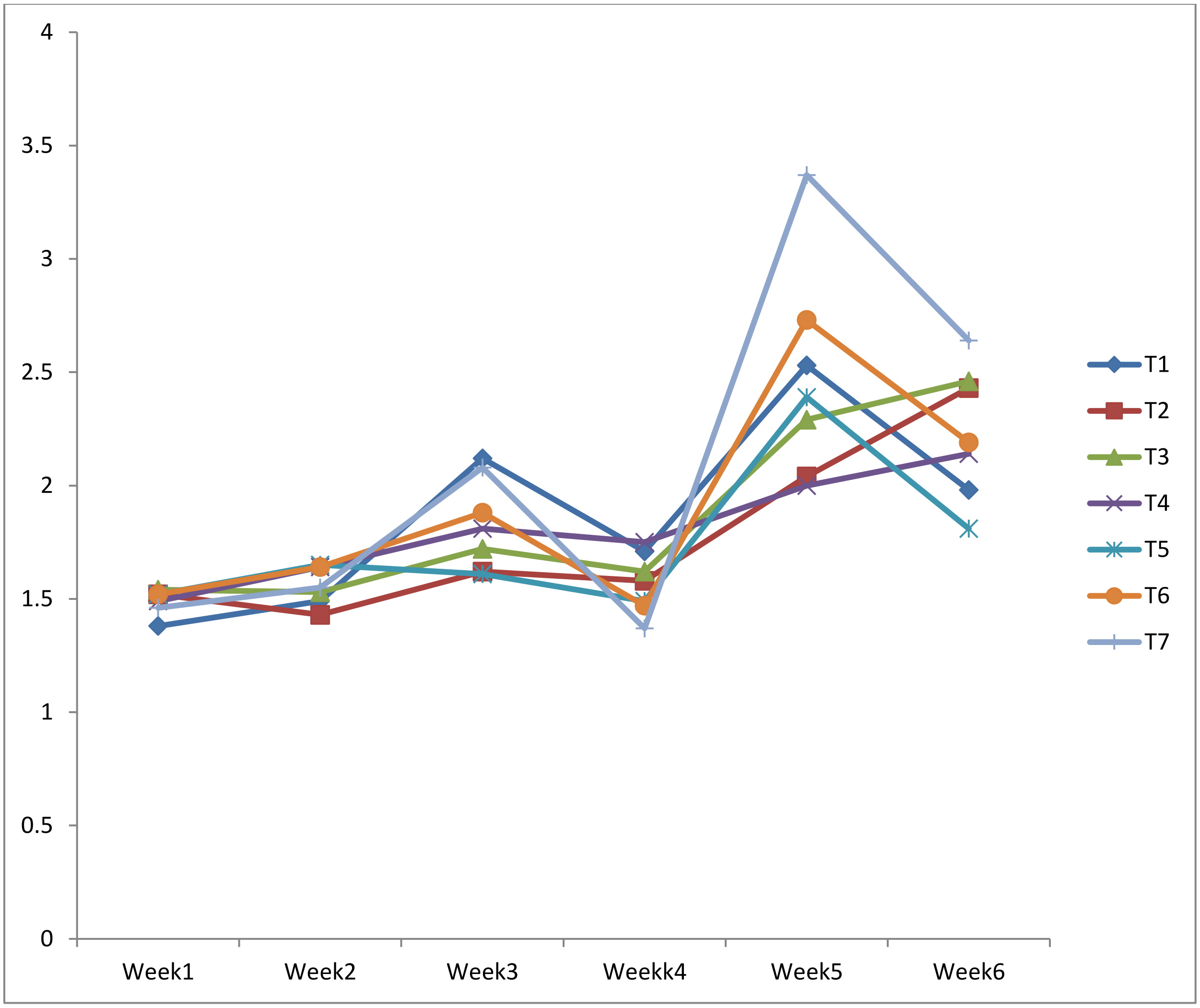

Fig4.3: Weekly Feed Conversion Ratio

Table 4.4: Performance of broiler chickens raised on changing the time of phase feeding regimes.

Parameters	Changing times of phase feeding (days)							SEM
	T1 Control	T2	T3	T4	T5	T6	T7	
Starter phase	0 - 28	0 - 7	0 - 14	0 - 21	0 - 8	0 - 10	0 - 14	
Grower phase					9 - 21	11 - 24	15 - 27	
Finisher phase	29 - 42	8 - 42	15 - 42	22 - 42	22 - 42	25 - 42	28 - 42	
Initial body weight (g)	38.82	38.84	38.56	38.84	39.10	39.13	39.03	0.08
Final body weight (g)	1644.20[b]	1702. 20[ab]	1680.70[b]	1635.90[b]	1915.30[a]	1735.70[ab]	1634.60[b]	30.46
Body weight gain (g)	1605.40[b]	1663. 36[b]	1642.20[b]	1597.14[b]	1876.25[a]	1696.59[ab]	1595.60[b]	30.44
Feed intake (g)	3559.68	3670.24	3876.01	3611.68	3965.32	3916.53	3844.82	54.80
Feed conversion ratio	2.22	2.21	2.37	2.27	2.13	2.31	2.44	0.04
Feed cost per kg (₦)	349.76	349.76	349.76	349.76	349.98	349.98	349.98	0.22
Feed cost/kg body weight gain (₦)	790.96	780.53	808.54	786.17	727.85	792.45	843.42	15.29
Feed cost savings per kg of live weight (%)	0.00	0.61	-1.05	0.29	3.30	-0.09	-3.21	-
Mortality (%)	0.75[ab]	0.50[ab]	0.50[ab]	0.50[ab]	0.50[ab]	0.00[b]	1.00[a]	0.096

[ab] Means within a row with different superscripts are significantly ($p<0.05$) different.

4.2.4 Feed cost per kg of body weight gain (₦) and feed cost savings per kg of body weight gain (%)

The feed cost per kg of body weight gain was not significantly ($p > 0.05$) different across the treatment groups. However, birds in the T5 treatment group recorded the lowest (₦727.85) feed cost per kg body weight gain, resulting in 3.30% feed cost savings per kg body weight gain, while birds in the T7 treatment group recorded the highest (₦843.42) value. Saharei (2013) noted that feed cost, nitrogen (₦) excretion, and carcass quality of broiler chickens were reduced when the crude protein contents of diets were reduced. The weekly feed cost per kg body weight gain shown in Fig. 4.4a indicated a relatively high value among birds on T7, especially in weeks 5 and 6. This high feed intake might have resulted in negative feed cost savings (-3.21%), as shown in Fig. 4.5b. Mallick ***et al***. (2020) reported that feed costs represent 65–75% of the total cost of broiler chicken production.

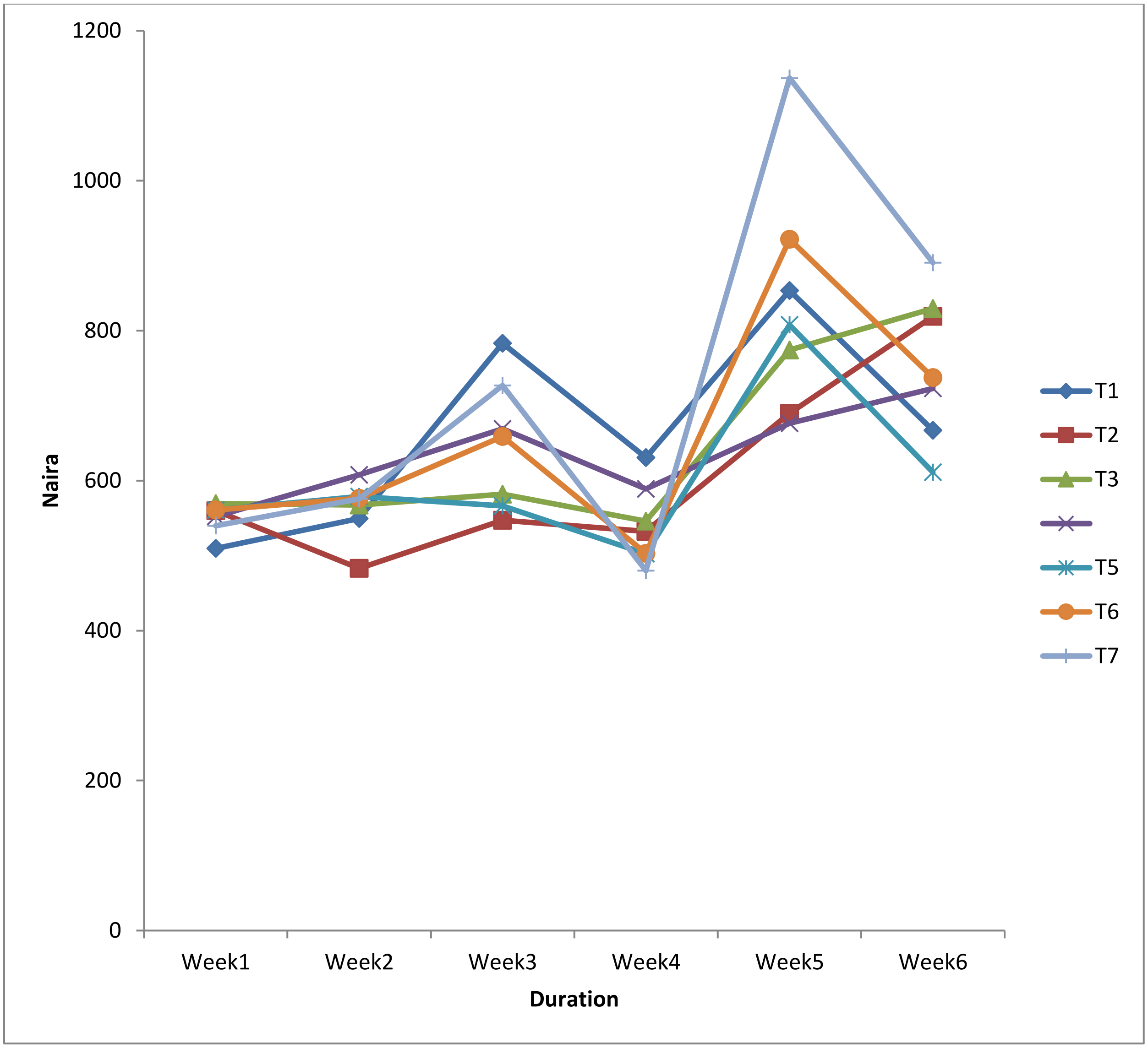

Fig. 4.4 Weekly feed cost per kg body weight gain

4.2.5 Mortality

Mortality ranged from 0.00 to 1.00% among the groups, with birds on T6 recording no mortality and those on T7 recording the highest value (1.00%). According to Ahsan, (2003), mortality in broiler chickens is caused by several factors, including genetics, nutrition, toxins, poor brooder management, and relaxed biosecurity measures. The mortality recorded in this study was, however, well below the recommended level, according to Aviagen (2019a).

4.3 Protein Efficiency Ratio and Calculated Nitrogen Utilization of Broiler Chickens with Changing Time of Phase Feeding Regime

The protein efficiency ratio and calculated nutrient utilization of broiler chickens with changing time of phase feeding are presented in Table 4.4 and Figures 4.5 – 4.9.

4.3.1 Protein Efficiency Ratio (PER)

The results obtained from this study (Table 4.4) showed significant ($p<0.05$) differences in the PER among the treatment groups. Even though birds in T5 produced a statistically higher (2.97) value than other groups, the mean weekly PER revealed that, as the bird grows older, the PER declines across the groups (Fig. 4.5), especially in the fifth and sixth weeks of age, except in a few instances. It, however, agrees with the report that lowering dietary CP levels in broiler chicken production resulted in an increase in total protein intake and an increase in PER (Kamran ***et al.,*** 2008). This might possibly explain why birds with shorter starter durations (T2 and T5) recorded a higher PER than other groups.

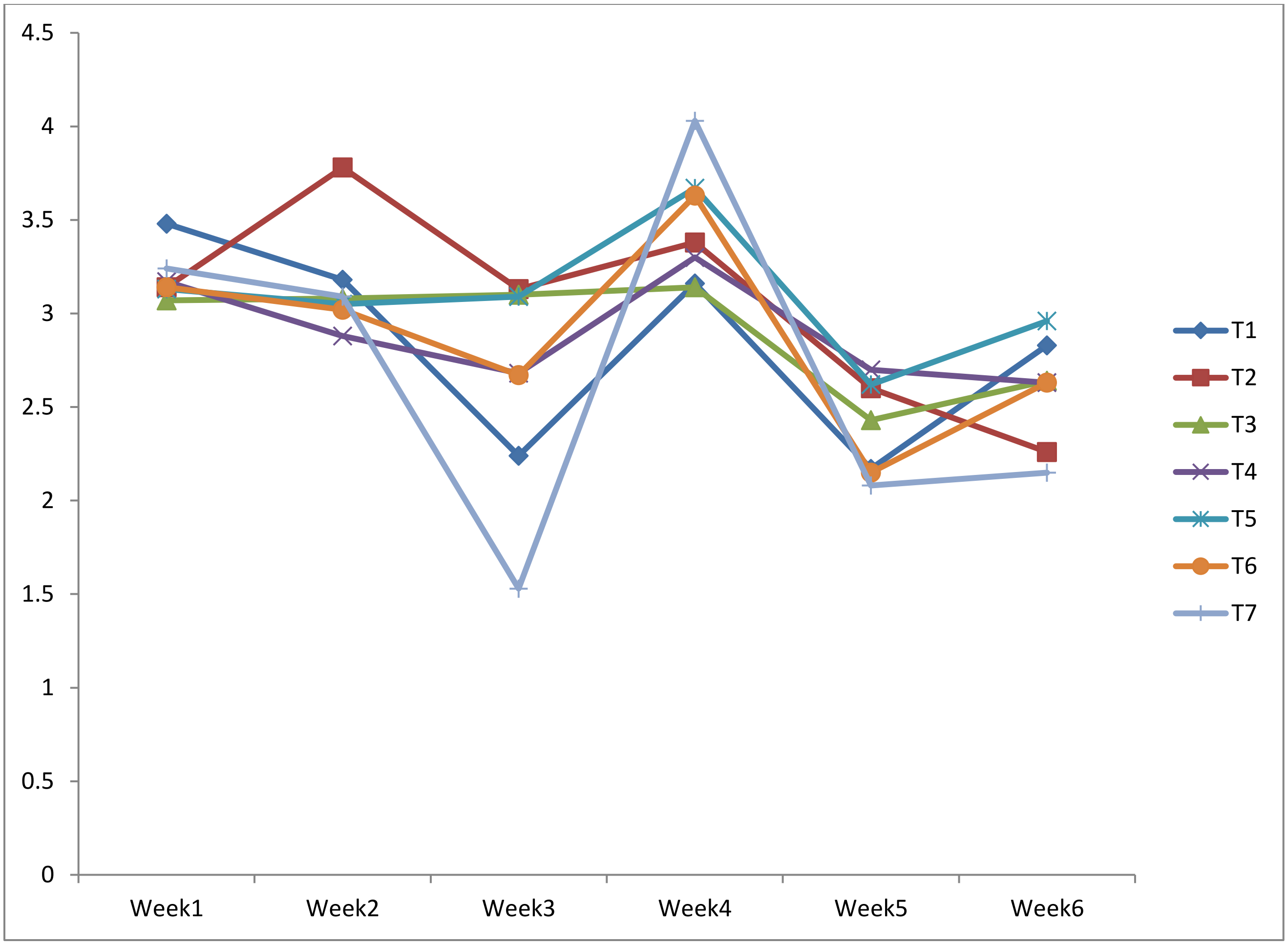

Fig. 4.5 **Protein efficiency ratio**

4.3. 2. Nitrogen utilization

Nitrogen utilization of broiler chickens with changing times of phase feeding regimes is presented in Table 4.4, while the weekly values are presented in Figures 4.6 – 4.9. The nitrogen utilization parameters calculated include nitrogen intake (Nintake), nitrogen retention (Nret.), and nitrogen excretion (Nexc.). Nitrogen excretion per kg body weight gain (Nexc/kg BWG) and nitrogen efficiency (Neff.).

The statistical analysis shows significant differences ($p<0.05$) in the parameters across different feeding regimes. This indicates that the phase feeding regimes have a substantial impact on nitrogen utilization in broiler chickens. For example, the Protein Efficiency Ratio (PER) varies significantly among the different feeding regimes, with T5 (2.98) and T2 (2.88) recording highest PER, indicating more efficient protein utilization in these groups. In the same vein, nitrogen Intake (Nintake) varied significantly ($p<0.05$) with T1 (control) and T4 recording the highest nitrogen intake, with values of 140.51 g and 140.35 g, respectively. T5 had the lowest nitrogen intake of 135.06 g. However, despite the lower intake, T5 showed high efficiency validating (Belloir *et al*., 2017) who reported better utilization of the consumed nitrogen when dietary crude protein is reduced. Also, Nitrogen Excretion (Nexc.) were lowest in T5 (80.65 g), and highest in T1 (control) at 94.16 g indicating reduced nitrogen waste. Nitrogen Excretion per kg Body Weight Gain (Nexc/kg BWG) followed the same trend as Nitrogen Excretion (Nexc.). There were significant differences ($p<0.05$) among the treatment group in Nitrogen Retention (Nret.) with the highest nitrogen retention observed in T5 (54.41 g), indicating that a larger portion of the consumed nitrogen was used for growth, while the lowest retention in T7 (46.20 g), suggested less efficient nitrogen utilization for growth. Nitrogen Efficiency (Neff.) followed similar trend with Nitrogen Retention with T5 showing the highest nitrogen efficiency (40.29%), meaning a significant portion of consumed nitrogen was retained. This means that feeding regimes like T5, with an early switch from starter to grower phase (0 - 8 days starter, 9 - 21 days grower, and 22 - 42 days finisher), optimize nitrogen utilization (Anyigor & Etuk, 2018) This will results in lower nitrogen waste and higher nitrogen retention and efficiency thereby minimizing environmental pollution from poultry farms, and enhance the profitability of broiler production.

.

Table 4.5: Cumulative nitrogen utilization of broiler chickens at changing times of phase Feeding regimes

Parameters	Changing times of phase feeding regimes (days)							SEM
	T1 Control	T2	T3	T4	T5	T6	T7	
Starter phase	0 - 28	0 - 7	0 - 14	0 - 21	0 – 8	0 - 10	0 - 14	
Grower phase					9 – 21	11 - 24	15 - 27	
Finisher phase	29 - 42	8 - 42	15 - 42	22 - 42	22 - 42	25 - 42	28 - 42	
Protein efficiency ratio	2.60^{b}	2.88^{a}	2.67^{b}	2.37^{c}	2.98^{a}	2.70^{b}	2.35^{c}	0.052
Nitrogen intake (g)	140.51^{a}	135.55^{f}	138.69^{c}	140.35^{b}	135.06^{g}	135.84^{e}	136.95^{d}	0.473
Nitrogen excretion (g)	94.16	87.31	91.07	94.03	80.65	86.64	90.68	4.307
Nitrogen excretion/body weight gain (g/kg BWG)	0.06	0.05	0.06	0.06	0.04	0.05	0.06	0.003
Nitrogen retention (g)	46.56^{e}	48.24^{c}	47.62^{d}	46.32^{f}	54.41^{a}	49.20^{b}	46.20^{g}	0.598
Nitrogen efficiency (%)	33.14^{cd}	35.59^{b}	34.34^{c}	33.00^{d}	40.29^{a}	36.21^{b}	33.79^{c}	0.574

^{abcdefg} Means within a row with different superscripts are significantly ($p<0.05$) different.

4.3.2a Nitrogen Intake

The results showed that the nitrogen intake of the experimental birds placed at changing times of phase feeding was significantly (p<0.05) different among the treatment groups. Birds on T5 and T2, however, produced the lowest cumulative nitrogen intake (135.06 g and 15.55 g, respectively) within the 42-day duration**.** The higher feed intake of birds on three phases of phase feeding did not negatively influence the nitrogen intake of the birds but rather pointed to the possibility that changing times of the phase feeding regime could affect the nitrogen intake of broiler chickens. Again, the nutrient intake of poultry is affected by both the nutrient composition of the diet and the feed intake. Such ***et al*.** (2021) also report that feeding low-protein diets decreased the total nitrogen and uric acid contents**.**

4.3.2b: Nitrogen Excretion

Nitrogen excretion shows the amount of nitrogen that is unutilized by the birds. The more nitrogen is retained in the animal body, the less nitrogen will be excreted into the environment (Anggraeni ***et al*.,** 2020). The calculated nitrogen excretion of broiler chicken produced on changing time of phase feeding regimes was similar (p > 0.05) among the groups. However, birds on (T5, T6, and T2), which had the shortest duration of starter diet (0 –7, 0 – 8, 0 – 10 days) and the lowest nitrogen intake (153.06 g and 135.5 g), also excreted the least amount (80.65 g and 87.31 g), respectively, within the 42-day duration of the study.

4.3.2c Nitrogen retention

The nitrogen retention of the experimental birds placed on changing times of phase feeding was significantly (p<0.05) higher in birds on T5 and T6 than in other groups. Birds on T5 and T6 produced the highest nitrogen retention values of 54.41 g and 49.20 g, respectively (Such ***et al*.,** 2021). They were on the three-phase feeding regime; in addition, the starter phase duration was

10 days maximum. According to Sibbald and Wolynetz (1985) and Anggraeni ***et al.*** (2020), nitrogen retention is the difference between the value of feed nitrogen intake and the value of nitrogen excreted after correction with the value of endogenous nitrogen excretion. Increased nitrogen retention indicates nitrogen is utilized by the bodies of animals (Anggraeni ***et al.***, 2020). Such ***et al***. (2021) also report that feeding low-protein diets decreased the total nitrogen and uric acid contents.

4.3.2d Nitrogen excretion per kg body weight gain

The total nitrogen excretion per kg body weight gain of broiler chicken produced on changing time of phase feeding regimes was similar (p > 0.05) among birds. Birds on T5, T6, and T2 had the shortest starter phase duration (0 – 7, 0 – 8, and 0 – 10 days,) which appears to indicate that the shorter the starter broiler phase duration, the lower the quantity of nitrogen excreted per kg body weight gain. This is in line with Belloir ***et al.*** (2017), who reported that nitrogen excretion per kg of BW gained decreased with the reduced CP content of the diet based on age, which is the main objective of changing the time of phase feeding regimes.

4.3.2e Nitrogen efficiency

The calculated nitrogen efficiency of broiler chicken produced on changing time of phase feeding regimes was significantly (p<0.05) higher in T5 than in other groups. However, the nitrogen efficiency appears to be influenced by the duration of the starter phase in both the two- and three-phase feeding regimes. Birds on T5 had a nitrogen efficiency of 40.29. Birds on the control (T1) recorded the least efficiency value (33.14). (Kamran ***et al.,*** 2008).

4.4 Carcass and Internal Organ Characteristics of Broiler Chickens Produced on Changing Time of Phase Feeding Regimes

4.4.1 Carcass characteristics of broiler chickens produced at a different time of phase Feeding

The carcass weight characteristics of the experimental broiler chickens are shown in Table 4.5. There was no significant difference observed in the percentage carcass weight, but birds on T5 produced the highest (66.75%) value while T4 produced the least (63.66%). Again, there were no significant differences in the thigh and wing values of the experimental birds. This result agrees with the findings of Salem ***et al.*** (2023) that feeding regime phases had no significant effect on the carcass and leg weight of broiler chickens. On the other hand, the breast, drumstick, and back of the carcass were significantly ($p<0.05$) different among a few of the groups, though no discernible patterns were observed. Most of the values of the parameters in the groups were, however, comparable ($p > 0.05$). Bellier ***et al.*** (2017) and Salem ***et al.*** (2023) reported that changing the feeding phase did not have a significant difference on some of the carcass cuts.

Table 4.5 Carcass weight characteristics of broiler chickens produced on changing time of phase feeding regimes

Parameters (% live weight)	Control	Changing time of phase feeding						
	T1	T2	T3	T4	T5	T6	T7	SEM
Starter duration (Days)	0-28d	0 -7d	0 -14d	0 -21d	0 -8d	0 -10d	0 -14d	
Grower duration (Days)					9 -21d	11 -24d	15 -27d	
Finisher duration (Days)	29 -42d	8 -42d	15 -42d	22 -42d	22 -42d	25 -42d	28 -42d	
Live weight (g)	1644.20^{b}	1702.20^{ab}	1680.70^{b}	1635.90^{b}	1915.30^{a}	1735.70^{ab}	1634.60^{b}	30.46
Carcass weight (g)	1643.70	1701.70	1680.20	1639.40	1914.80	1735.20	1634.10	29.38
Dressing percentage	66.28	64.60	65.03	63.66	66.75	64.65	63.90	0.46
Cut parts (% carcass weight)								
Breast	43.80^{ab}	43.25^{ab}	44.07^{a}	44.60^{a}	40.72^{b}	43.82^{ab}	41.70^{ab}	0.43
Thigh	30.49	30.74	31.05	30.82	29.55	31.01	30.23	0.32
Wings	6.45	6.55	6.02	6.05	6.02	6.50	6.30	0.08
Drum stick	2.83^{ab}	3.20^{a}	2.62^{b}	3.12^{ab}	3.06^{ab}	3.17^{ab}	2.76^{ab}	0.08
Back	3.92^{ab}	3.71^{abc}	3.12^{c}	4.01^{a}	3.27^{bc}	3.34^{bc}	3.57^{abc}	0.10

^{abc} Means within a row with different superscripts are significantly ($p<0.05$) different.

4.4.2 Internal organ weights of broiler chickens on changing time of phase feeding Regime

Data obtained from the internal organs revealed that the weights of full and empty gizzards in T2 were significantly ($p<0.05$) higher than those of T3 and T7. Birds on T3 and T7 had comparable ($p > 0.05$) values to T1, T4, T5, and T6. Tony and Fayed (2015) reported no significant difference in the gizzard of broiler chicken raised on the modified duration of feeding starter and grower diets to broiler chicken. However, there was no significant difference between the two phase-feeding and three-phase feeding regimes. The liver weights of birds on T1 were significantly ($p<0.05$) higher than those on T2, T3, and T6, but comparable ($p>0.05$) to those on T2, T4, and T7. However, the liver values of birds on T2, T3, and T5 were comparable ($p > 0.05$). Birds on T1 produced the highest liver value (2.61%). Tony and Fayed (2015) and Artwell and Edmore (2015) reported no significant difference in the liver of broiler chickens raised on the modified duration of feeding starter and grower diets to broiler chickens. Again, the weight of the heart and intestine showed similarity ($p > 0.05$) among the treatment groups, which agreed with the report of Artwell and Edmore (2015) that the carcass, liver, heart, head, and intestine weights of broiler chickens were raised on different phase feeding regimes.

Table 4.7: Internal organ and intestinal weight characteristics of broiler chickens raised at changing times of phase feeding

Parameters (% live weight)	Changing the timing of phase feeding regimes (days)							SEM
	T1 Control	T2	T3	T4	T5	T6	T7	
Starter phase	0-28	0 - 7	0 – 14	0 - 21	0 - 8	0 - 10	0 - 14	
Grower phase	-	-	-	-	9 - 21	11 - 24	15 - 27	
Finisher phase	29 -42	8 - 42	15 – 42	22 - 42	22 - 42	25 - 42	28 - 42	
Full gizzard	2.71^{ab}	3.07^{a}	2.50^{b}	2.84^{ab}	2.94^{ab}	2.91^{ab}	2.60^{b}	0.063
Empty gizzard	1.88^{ab}	2.06^{a}	1.70^{b}	1.98^{ab}	2.03^{ab}	2.05^{a}	1.77^{ab}	0.045
Liver	2.60^{a}	2.40^{abc}	2.03^{c}	2.54^{ab}	2.18^{bc}	2.16^{c}	2.29^{abc}	0.057
Heart	0.58	0.58	0.58	0.52	0.46	0.49	0.60	0.025
Intestine	5.30	5.23	4.02	4.51	4.47	4.63	4.80	0.181

$^{ab\ c}$**Means** within a row with different superscripts are significantly (P<0.05) different.

4.5 Income and Profitability of Broiler Chickens Produced on Changing Times of Phase Feeding Regimes

4.5.1 Total variable cost of raising broiler chickens on changing times of phase feeding

The total variable (input) cost and revenue (income) data of broiler chickens at changing times of phase feeding per bird is presented in Table 4.7. The total variable (input) cost ranged from ₦2545.64 for birds on T1 to ₦2688.39 for those on T5. This largely reflected the pattern of feed intake and the cost of feed consumed. The cost of feed consumed was lowest for birds in treatment T_1 and highest for those in treatment T5. This could have resulted from changes in feeding regimes and multiple feed regimes that split the starting phase with the grower phase broiler finisher feeding period, as reported by Muchenje e***t al***. (2011) and Mehmood ***et al*.** (2015).

Again, feed costs contributed 46.39–49.09% of the cost of producing broiler chicken in this study. Birds on T5 produced the highest revenue **(₦** 4232.41), while those on the control (T1), T7, T4, and T1 produced the lowest values (₦ 3614.87, **₦ 3618.73,** and **₦ 3635.99**), respectively. Net income and estimated profitability also followed a similar trend, with the highest estimated profitability of 33.21% produced by birds on T5 and the least (22.97%) produced by birds in treatments T7, T4, and T1. These results agree with Oyedeji ***et al*.** (2005), who stressed that feeding varying levels of protein and energy will positively impact livability and increase the live weight of broilers, which will consequently result in the profitability of broiler farming.

Table 4.8: Income and profitability of broilers raised on changing time of phase feeding regimes

Parameters (₦)	Changing the time of phase feeding regimes (days)							
	T1	T2	T3	T4	T5	T6	T7	
	Control							SEM
Starter phase	0 - 28	0 - 7	0 - 14	0 - 21	0 - 8	0 - 10	0 - 14	
Grower phase	-	-	-	-	9 - 21	11 - 24	15 - 27	
Finisher phase	29 - 42	8 - 42	15 - 42	22 - 42	22 - 42	25 - 42	28 - 42	
Day-old chicks	420.00	420.00	420.00	420.00	420.00	420.00	420.00	0.000
Total feed cost	1245.03	1283.70	1355.67	1263.22	1387.78	1370.71	1345.61	11.722
Drugs and vaccines	150.25	150.25	150.25	150.25	150.25	150.25	150.25	0.000
Charcoal	145.09	145.09	145.09	145.09	145.09	145.09	145.09	0.000
Litter materials	225.00	225.00	225.00	225.00	225.00	225.00	225.00	0.000
Lighting	175. 00	175. 00	175. 00	175. 00	175. 00	175. 00	175. 00	0.000
Disinfectant	17.86	17.86	17.86	17.86	17.86	17.86	17.86	0.000
Labour cost	167.41	167.41	167.41	167.41	167.41	167.41	167.41	0.000
Total variable cost (A)	**2545.64**	**2584.31**	**2656.28**	**2563.83**	**2688.39**	**2671.32**	**2646.22**	11.722
Feed cost (% of variable cost)	**48.91**	**49.67**	**51.04**	**49.27**	**51.62**	**51.31**	**50.85**	0.223
Output and Revenue								
Final body weight (kg)	1.64	1.70	1.68	1.64	1.92	1.74	1.64	0.021
Price/kg Body Weight	2200.00	2200.00	2200.00	2200.00	2200.00	2200.00	2200.00	0.000
Manure (₦)	18.75	18.75	18.75	18.75	18.75	18.75	18.75	0.000
Total revenue (B)	**3635.99^{b}**	**3763. 59^{b}**	**3716.29^{b}**	**3618.73^{b}**	**4232.41^{a}**	**3837.29^{b}**	**3614.87^{b}**	49.018
Net income (B-A)	**951.95^{b}**	**1040.58^{b}**	**921.61^{b}**	**916.50^{b}**	**1405.62^{a}**	**1028.57^{b}**	**830.25^{b}**	38.724
Est.% profit	**26.18^{bc}**	**27.65^{ab}**	**24.80^{d}**	**25.33^{c}**	**33.21^{a}**	**26.80^{b}**	**22.97^{d}**	0.671

^{abcd}: Means within a row with different superscripts differ significantly (P<0.05).

*Capital input costs were not considered.

4.6. Quality of Litter in Pens of Broiler Chicken Produced on Changing Time of Phase Feeding Regimes

The litter quality of the experimental broiler chicken produced at different times of phase feeding is presented in Table 4.8.

4.6.1 Litter pH

Data from the litter samples revealed that birds on T4 and T7 produced significantly ($p<0.05$) higher pH values (more alkaline) than others. Birds on T1 (control) recorded the lowest pH value, with 7 points. These results are in line with Brink ***et al.*** (2022), who reported that phase feeding lowers nitrogen excretion and ammonia volatilization, leading to an improved pH level in the litter.

4.6.2 Litter moisture

Birds on T1 (control) produced significantly ($p<0.05$) higher (22.14%) moisture in the litter than other groups, with those on T5 producing the lowest (9.82%) value. The moisture content of the litter, however, varied inconsistently, though birds on changing times of phase feeding with longer exposure to a high crude protein diet did appear to produce higher values. This result agrees with Belloir ***et al***. (2017), who reported that nitrogen and moisture content decreased slightly when dietary CP content was reduced.

4.5.3 Litter nitrogen

The litter nitrogen levels of broiler chickens on T1 and T4 were significantly ($p<0.05$) higher than those in other groups. As reported for litter moisture, a longer period of exposure of broiler chickens to high crude protein diets results in high litter nitrogen (Belloir ***et al.,*** 2017). This might indicate higher efficiency of nitrogen utilization by broilers on the short and modified starter phase feeding duration, and the introduction of the grower phase may have led to improvements in nitrogen utilization. Brink ***et al.*** (2022) similarly reported that changing the time phase reduces nitrogen and improves litter quality.

4.5.4 Litter Phosphorus

The phosphorus content of the litter was significantly ($p<0.05$) higher in T7 and T5 than in other groups. Birds on T2 produced the least (0.88%) quantity of litter phosphorus, which was, however, similar ($p > 0.05$) to the 0.91 obtained for those on the control (T1). In the same vein, the litter phosphorus of birds on T1 and T2 was significantly ($p > 0.05$) lower than that on T3 and T4. The result indicates that splitting the starter and introducing the grower phase significantly ($p<0.05$) increased P excretion. This contradicts Nahm (2003), who concluded that phase feeding, which implies dietary changes per phase, is a good strategy for reducing phosphorus excretion and improving litter quality.

Table 4.9: Quality of litter in pens of broiler chicken produced on changing time of phase feeding regimes

Litter Parameters	Controlling the time of phase feeding regimes (days)							SEM
	T1	T2	T3	T4	T5	T6	T7	
Starter phase	0-28	0 -7	0 -14	0 - 21	0 - 8	0 - 10	0 - 14	
Grower phase	-	-	-	-	9 - 21	11 - 24	15 - 27	
Finisher phase	29 -42	8 -42	15 -42	22 - 42	22 - 42	25 - 42	28 - 42	
pH	7.17^{d}	7.19^{d}	7.33^{c}	7.81^{a}	7.55^{b}	7.53^{bc}	7.87^{a}	0.0618
Moisture (%)	22.14^{a}	14.69^{cd}	14.82^{cd}	13.91^{d}	15.83^{bc}	9.82^{e}	16.56^{b}	0.7797
Nitrogen (%)	5.74^{a}	4.65^{b}	4.66^{b}	5.72^{a}	4.96^{b}	4.80^{b}	5.12^{b}	0.1104
Phosphorus (%)	0.90^{d}	0.88^{d}	0.91^{c}	0.91^{c}	0.96^{a}	0.94^{b}	0.97^{a}	0.0069

$^{\mathbf{abcd}}$ Means within a row with different superscripts are significantly ($p<0.05$) different.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study investigated the impact of changing the time of phase feeding regimes on the performance, nitrogen utilization, carcass and organ weight characteristics, economic benefits, and litter quality of broiler chickens. The following conclusions were drawn.

- The starter phase duration of not more than 10 days, as reflected in T2 (0 – 7 days), T5 (0 – 8 days), and T6 (0 – 10 days), produced higher final body weight, body weight gain, feed conversion ratio, improved feed intake, a decrease in total protein intake, and an increase in protein efficiency ratio compared to other treatments. Birds on T5 (0 – 8 days starter, 9 – 21 days grower, and 22 – 42 days finisher), however, produced the best indices in the performance parameters evaluated.
- Nitrogen utilization parameters such as nitrogen intake, nitrogen excretion, nitrogen retention, and nitrogen efficiency of broiler chickens followed a similar trend with the performance parameters. Birds with a shorter duration of the starter phase were more efficient in nitrogen utilization.
- The changing times of phase feeding did not show any discernible pattern in the carcass and internal organ characteristics, except that there were significant differences in drumstick and breast muscle of birds in T4 when compared to other groups. Birds on T5, however, recorded the highest carcass weight.
- Again, birds on T5 (0 – 8 days starter, 9 – 21 day grower, and 22 – 42 day finisher) recorded the highest (33.21%) estimated profit margin

- The litter quality parameters, like moisture and nitrogen, produced the same pattern in this study.

5.2 Recommendations

Based on these findings, it is recommended that:

- Broiler chicken producers consider implementing a phase feeding regime like T5 (0 – 8 day starter, 9 –21 day grower, and 22 – 42 day finisher) for the three-phase regime and T2 (0 – 7 d starter and 8 –4 2 d finisher) for the two-phase feeding regime with an early switch to a higher energy diet. This approach can lead to improved performance in live body weight, weight gain, feed conversion ratio, improved feed intake, increased protein efficiency ratio, nitrogen utilization, some carcass cuts, profitability, and litter quality.
- Further research should be explored to determine the long-term effects of the recommended feeding regimes on broiler health, meat quality, and overall sustainability.

5.3 Contributions to Knowledge

This study has established that

- Broiler chickens with shorter starter phase durations (7 – 10 days) produced higher body weight, body weight gain, a better feed conversion ratio, a higher protein efficiency ratio, compared to those with longer starter phase durations. These findings contribute to the understanding of optimal feeding strategies for broiler chicken production.
- Broiler chickens with a shorter starter phase duration produced higher net income and estimated profitability.

- The improved performance of broiler chickens on shorter starter phase durations had a positive effect on litter quality parameters like pH, moisture, nitrogen, and phosphorus content.
- This study affirmed the effectiveness of the recommended Nigerian Industrial Standard for broiler chicken feeding (SON, 2019) compared to others.

REFERENCES

Adeyonu A. G., Okunola A., Alao M. E., Oyawoye E. O., & Okonkwo C. E. (2021). An assessment of the broiler value chain in Nigeria. ***Open Agriculture***, 6(1), 296–307. https://doi.org/10.1515/opag 2020-0168

Adeyonu, A. G., & Odozi, J. C. (2022). What are the drivers of profitability of broiler farms in the north-central and south-west Geo-political zones of Nigeria? *SAGE Open*, *12*(1), 215824402110710. doi:10.1177/21582440211071076

Ahiwe, E. U., Omede, A. A., Abdallh, M. B., & Iji, P. A. (2018). Managing dietary energy intake by broiler chickens to reduce production costs and improve product quality. In *Animal Husbandry and Nutrition*. doi:10.5772/intechopen.76972

Ahmad, R.W. (2018). Poultry meat was smuggled to Nigeria in 2017. Daily Trust. Retrieved on January 23, 2024, from https://www.dailytrust.com.ng/.u

Ahsan, U. H. (2003). Lecture note on sanitation and disinfection. Department of Poultry Husbandry. University of Agriculture, Faisalabad, Pakistan.

Aladi, N. O. (2016). Studies on Dietary Fermented Mixture of Cassava and Palm Kernel Cake on Carcass Characteristics of Broilers and Pigs. PhD Thesis. Federal University of Technology, Owerri, Nigeria, p. 109.

Alemayehu, T., Bruno, J., Poole, J., Getachew, F., Sonaiya, E. B., Bamidele, O., Adebambo, O., Adeyinka, I.A., and Dessie, T. 2018. Household baseline data in Nigeria: Monitoring delivery of chicken genetic gains. ILRI Research Report 47. Nairobi, Kenya: International Livestock Research Institute (ILRI)..

All About Poultry (2020). Poultry Hub Australia. Retrieved January 29, 2024, from Poultry Hub Australia website: https://www.poultryhub.org/all-about-poultry

Al-Neemi, H. (2015). Male and Female Broiler Growth Performance, Carcass Traits, and Economic Indicators Influenced by Feeding Programs (Regimes) of Diets. *International Journal of Applied Biology and Pharmaceutical Technology*, Volume-7, Issue-1, P. 125 Available online at www.ijabpt.com

Amos, T. T. (2006). Analysis of backyard poultry production in Ondo State, Nigeria. Int. J. ***Poultry Science***. 5 (3), 247–250.

Amy, F. M., Peter, V. C., David, J. C., Stuart, J. W., Tamsyn, M. C., & Mingan, C. (2021). Precision feeding and precision nutrition: a paradigm shift in broiler feed formulation. ***Animal Bioscience*** 34 (3): 354–362, March 2021 https://doi.org/10.5713/ab.21.0034 pISSN 2765-0189 eISSN 2765-023

Anderson, K., Moore, P. A., Jr, Martin, J., & Ashworth, A. J. (2021). Evaluation of a novel poultry litter amendment on greenhouse gas emissions. *Atmosphere*, *12*(5), 563. doi:10.3390/atmos12050563

Anggraeni, A. S., Suryani, A. E., Sofyan, A., Sakti, A. A., Istiqomah, L., Karimy, M. F., & Darma, I. N. G. (2020). Nutrient digestibility of broiler chicken fed diets supplemented with probiotics phytase-producing. *IOP Conference Series. Earth and Environmental Science*, *462*(1), 012003. doi:10.1088/1755-1315/462/1/012003

Anupam Soni, V.N. Khune, N.S., Rupal Pathak, M.D. Bobade, A.D., Neetu S., Ankit K., Subhrajit D., & Yadav S.K. (2021). Broiler Management, an English monthly magazine

Anyigor, E. A., & Etuk, E. B. (2018). Determine optimal four-phase feeding regimes in a 56-day broiler production period. Proc. 43rd Annual Conference of the Nigerian Society of Animal Production. March 18th–22nd, 2018 at the Federal University of Technology, Owerri, Pp. 283

AOAC (1996) Official Method of Analysis of the Association of Official Analytical Chemists. AOAC International, Arlington.

AOAC (2019). Standard method performance requirements (SMPRs) for quantitation of cannabinoids in cannabis concentrates https://griegler-aoac-org.cld.bz/2019-AOAC-CASP-Book/94/#zoom=z

Artwell, M., & Edmore, M. (2015). Comparison of Broiler Chicken Performance on Different Phase Feeding Programs. Department of Agriculture, Zimbabwe Open University, Harare, Zimbabwe Volume 4 Issue 6. Available at www.ijird.com

Aviagen (2018a) Arbor Acres Plus Broiler Nutrition Specifications (All Plant Protein-Based Feeds) https://aviagen.com/assets/Tech_Center/AA_Broiler/AABroilerHandbook2018-EN.pdf

Aviagen (2018b). Ross Broiler Management Handbook. https://en.aviagen.com/assets/Tech_Center/Ross Broiler/Ross-BroilerHandbook2018-EN.pdf. Accessed June 2021.

Aviagen (2019a) Ross 308/Ross 308 FF Broiler: Performance Objectives, 2019. http://sorooshe-roshd.com/wp-content/uploads/pdf/Ross308-308FF-BroilerPO2019-EN.pdf

Aviagen (2019b) Ross Nutrition Specifications. http://en.aviagen.com/assets/Tech_Center/Ross_Broiler/RossBroilerNutritionSpecs2019-EN.pdf. accessed January 2022.

Aviagen (2019c). Breeders' Nutrition Information. Retrieved from @ www.aviagen.com on June 2021

Baracho, M. S., Nääs, I. A., Lima, N. D. S., Cordeiro, A. F. S., & Moura, D. J. (2019). Factors affecting broiler production: A meta-analysis. *Revista Brasileira de Ciencia Avicola*, *21*(3). doi:10.1590/1806-9061-2019-1052

Beg, M. A. H., Baqui, M. A., Sarker, N. R., & Hossain, M. M. (2011). Effect of stocking density and feeding regime on performance of broiler chicken in summer season. *International Journal of Poultry Science, 10*(5), 365–375. doi:10.3923/ijps.2011.365.375

Beker, A. S .L. Vanhooser, J. H. Swartzlander, & R.G. Teeter, 2004. Atmospheric ammonia concentration effects on broiler growth and performance. *J. Applied Poultry Science* 13:5-9.

Belema, B., Okafor, S.N., Okey, G.A. & Akalio, AO, (2018) Effects of the graded levels of cholecalciferol (Vitamin D3) on the heamatological characteristics and serum enzymes of broilers in the hot humid southern Nigeria.

Belloir, P., Méda, B., Lambert, W., Corrent, E., Juin, H., Lessire, M., & Tesseraud, S. (2017). Reducing the CP content in broiler feeds: impact on animal performance, meat quality and nitrogen utilization. *Animal: An International Journal of Animal Bioscience*, *11*(11), 1881–1889. doi:10.1017/s1751731117000660

Bilgili, S. F., Hess, J. B., Blake, J. P., Macklin, K. S., Saenmahayak, B., & Sibley, J. L. (2009). Influence of bedding material on footpad dermatitis in broiler chickens. *The Journal of Applied Poultry Research*, *18*(3), 583–589. doi:10.3382/japr.2009-00023

Bregendahl, K., Sell, J. L & Zimmerman, D. R. (2002). Effect of low-protein diets on growth performance and body composition of broiler chicks. *Poultry Science* 81, 1156–1167.

Brink, M., Janssens, G. P. J., Demeyer, P., Bağci, Ö. & Delezie, E. (2022). Reduction of dietary crude protein and feed form: Impact on broiler litter quality, ammonia concentrations, excreta composition, performance, welfare, and meat quality. *Animal Nutrition (Zhongguo Xu Mu Shou Yi Xue Hui)*, *9*, 291–303. doi:10.1016/j.aninu.2021.12.009

Butler, L. D., Scanes, C. G., Rochell, S. J., Mauromoustakos, A., Caldas, J. V., Keen, C. A., & Kidd, M. T. (2020). Cobb MV × Cobb 700 broiler responses to eight varying levels of amino acid density with emphasis on digestible lysine. *The Journal of Applied Poultry Research*, *29*(1), 34–47. doi:10.1016/j.japr.2019.12.002

Carter, S. D., & Kim, H. (2013). Technologies to reduce environmental impact of animal wastes associated with feeding for maximum productivity. *Animal Frontiers*, *3*(3), 42–47. doi:10.2527/af.2013-0023

Chang'a, E. P., Abdallh, M. E., Ahiwe, E. U., Mbaga, S., Zhu, Z. Y., Fru-Nji, F., & Iji, P. A. (2020). Replacement value of cassava for maize in broiler chicken diets supplemented with enzymes. *Asian-Australasian Journal of Animal Sciences*, *33*(7), 1126–1137. doi:10.5713/ajas.19.0263

Christensen, V. L. (2009). Development during the First Seven Days Post-hatching. *Avian Biology Research*, *2*(1–2), 27–33. doi:10.3184/175815509x430417

Cobb, C. G. (2023). *The project manager's guide to mastering Agile: Principles and practices for an adaptive approach*. John Wiley & Sons.

Cobb broiler manual, (2011). Management Guide. Retrieved on January, 2021…..from Cobb: //www//https w.cobb-vantress.com/assets/5c7576a214/.

Cobb's (2020). Cobb's Broiler management and supplement guide. Available at https://www.cobb-vantress.com/assets/5c7576a214/Broiler-guide-R1.pdf

De Jong, I. C, Gunnink H, & Van Harn, J. (2014). Wet litter induces footpad dermatitis and reduces overall welfare, technical performance, and carcass yield. Broiler chickens. *Journal of Applied Poultry Research* 23: 51-58.

Dunlop, M. W., Moss, A. F., Groves, P. J., Wilkinson, S. J., Stuetz, R. M., & Selle, P. H. (2016). The multidimensional causal factors of 'wet litter' in chicken-meat production. *The Science of the Total Environment*, *562*, 766–776. doi:10.1016/j.scitotenv.2016.03.147

El Hag, M. (2022). Re: What is the best equation to estimate metabolizable energy of poultry feeds? Available at https://www.researchgate.net/post/What_is_the_best_equation_to_estimate_metabolizable_energy_of_poultry_feeds2/62c42cb4e9ec89523b560c10

Esonu, B. O. (2015). Animal nutrition and feeding: A functional approach (3rd ed). Hudson-Jude, Nigeria. ISBN 978-34075-7

Ettah, O. I., Igiri, J. A., & Ihejiamaizu, V. C. (2021). Profitability of broiler production in Cross River State, Nigeria. *Global Journal of Agricultural Sciences*, *20*(1), 35–40. doi:10.4314/gjass.v20i1.5

FAO (2013). Poultry feed availability and nutrition in developing countries. Velmurugu Ravindran, Monogastric Research Centre, Institute of Food, Nutrition and Human Health, Massey University, Palmerston North, New Zealand https://www.fao.org/3/i3531e/i3531e06.pdf

FAO (2021). Country Programming Framework for Nigeria 2018–2022. Abuja https://www.fao.org/documents/card/en/c/CB2969EN

FARA (2022). Emphasizing the need for unified and Forum for Agricultural Research in Africa (**FARA**)

Ferket, P. R., Van Heugten, E., Van Kempen, T. A. & Angel, D. R. (2002). Nutritional strategies to reduce environmental emissions from non-ruminants Journal of Animal Science 80: 168- 182.

Gajana, C. S., Nkukwana, T. T., Chimonyo, M. & Muchenje, V. (2011). Effect of altering the starter and finisher dietary phases on growth performance of broilers. *African Journal of Biotechnology* 10(64): 14203 -14208.

Gororo, E., & Kashangura, M. T. (2016). Broiler production in an urban and peri-urban area of Zimbabwe. *Development Southern Africa*, *33*(1), 99–112. doi:10.1080/0376835x.2015.1113123

Gutierrez, O., Surbakti, N., Haq, A., Carey, J. B., & Bailey, C. A. (2008). Effect of continuous multiphase feeding schedules on nitrogen excretion and broiler performance. *The Journal of Applied Poultry Research*, *17*(4), 463–470. doi:10.3382/japr.2008-00015

Herkelman, K. (2014). Wenger feeds knowledge centre. Management of ammonia levels in poultry houses. https://wengerfeeds.wordpress.com/category/broilers/

Hooshmand, M. (2006). Effect of Early Feeding Programs on Broiler Performance. Int. J. Poult. Sci. 5(12): 1140-1143.

Hooshmand, M. (2006). Effect of Early Feeding Programs on Broiler Performance. *International Journal of Poultry Science* 5(12): 1140-1143.

Hubbard. (2013). Management guide for Broiler. Hubbard L. L. C., Duluth GA 30096 – 30105.

Hunter, J. M., Anders, S. A., Crowe, T., Korver, D. R., & Bench, C. J. (2017). Practical assessment and management of foot pad dermatitis in commercial broiler chickens: A Field Study. *The Journal of Applied Poultry Research*, *26*(4), 593–604. doi:10.3382/japr/pfx019

Ibiwoye D.I. & Sola-Ojo FE. (2021). Multivariate Analysis of Four Strains of Broiler Chickens at Four Weeks of Age Genet. *Biodiversity Journal*, 5 (2); 53-62

Ifeduba, A.V., Achonwa, C. C., Ukwu, C. P., Ogbuewu, I. P, Etuk, E. B. &. Okoli, I. C., (2020). Commercial Intensive Poultry Production in Tropical Environments with Particular

Reference to Nigerian Poultry Industry. *World Rural Observations* 202; 12(3): 67 -84. doi:10.7537/marsweo120320.06

ITAVI (2013). Estimation des rejets d'azote, phosphore, potassium, calcium, cuivre, zinc par les élevages avicoles. Mise à jour des références CORPEN-Volailles de 2006. Institut Technique de l'Aviculture, Paris, France.

Irvine's E. (2011). Retrieved from http://www.wattagnet.com/Poultry.aspx accessed on 08/10/2017

Kabir, M.S., Asaduzzaman, M. & Dev, D.S. (2015). Livelihood improvement through family poultry farming in Mymensingh district. *Journal of Bangladesh Agricultural University*, 13(2): 247–256.

Kamran Z., Muhammad S., Mahr-un-Nisaa, Mukhtar A. N., Tariq M., Tanveer A., Masroor E. B. and Mirza M. H. M. (2008). Effect of low levels of dietary protein on growth, protein utilisation and body composition of broiler chicks from one to twenty-six days of age. Institute of Animal Nutrition and Feed Technology, University of Agriculture, Faisalabad, Pakistan.

Kassali, R., Adetomiwa, K., & Lasisi, A. L. (2022). Competitiveness of broiler production in Nigeria: A policy analysis matrix approach. *Heliyon*, *8*(5), e09298. doi:10.1016/j.heliyon.2022.e09298

Kazeem, O. B., (2019). Broiler chicken production and management. Institute of food security, environmental resource and agricultural research, federal university of agriculture, abeokuta. Lecture note.

Kebede, F. G. (2018). *Household baseline data in Nigeria: Monitoring delivery of chicken genetic gains*. doi:10.13140/RG.2.2.11924.35209

Knowles, T. G., Kestin, S. C., Haslam, S. M., Brown, S. N., Green, L. E., Butterworth, A Nicol, C. J. (2008). Leg disorders in broiler chickens: prevalence, risk factors and prevention. *PloS One*, *3*(2), e & Mamadou Ba (2022). Commercial poultry success stories in sub-Saharan Africa Senegal Case Study. FARA Research Report 6 (04): Pp 47

Leeson, S. (2008). Predictions for commercial poultry nutrition. *Journal of Applied Poultry Research.* 17: 315-322.

Leeson, S. & Summers, J.D. (2005) Commercial Poultry Nutrition. Third Edition, Nottingham University Press, Nottingham, U.K. p.

Lemme, A., Hiller, P., Klahsen, M., Taube, V., Stegemann, J., & Simon, I. (2019). Reduction of dietary protein in broiler diets not only red*rnal of Operations and Strategic Planning*, *3*(1), 31–57. doi:10.1177/2516600x19896910

Mallick, P., Muduli, K., Biswal, J. N., & Pumwa, J. (2020). Broiler poultry feed cost optimization using linear programming technique. *Jou*Malomo, G. A., Bolu, S. A., Madugu, A. S., & Usman, Z. S. (2018). Nitrogen emissions and mitigation strategies in chicken production. In *Animal Husbandry and Nutrition*. doi:10.5772/intechopen.74966

Malomo, G. A., Bolu, S. A., Madugu, A. S., & Usman, Z. S. (2018). Nitrogen emissions and mitigation strategies in chicken production. In *Animal Husbandry and Nutrition*. doi:10.5772/intechopen.74966

Manyonga-Matingo, R. (2013): Broiler production in Zimbabwe. *Farmers Journal*. 6 (4) 33-42.

Marino, R., Iammarino, M., Santillo, A., Muscarella, M., Caroprese, M., & Albenzio, M. (2010). Technical note: Rapid method for determination of amino acids in milk. *Journal of Dairy Science*, *93*(6), 2367–2370. doi:10.3168/jds.2009-3017

Méda, B., Hassouna, M., Aubert, C., Robin, P. & Dourmad, J. Y. (2011). Influence of rearing conditions and manure management practices on ammonia and greenhouse gas emissions from poultry houses. *World's Poultry Science Journal* 67: 441– 456.

Mehmood, S, Sahota, A. W, Akram, M., Javed, K ., Hussain J*, Sharif, H.*,. Haroon, S*& Jatoi, A. S.** (2013). Influence of feed restriction regimes on the growth performance of broilers with different initial weight categories. *Journal of Animal Plant Science* 23(6):1522-1526

Mehmood, S., Sahots, A.W., Akam, M., Javed, K., Hussain, J., Shaheen, M. S., Abbas, Y, Jatoi & A. Iqbal (2014). Growth performance and economic appraisal of phase feeding at different stocking densities in sexed broilers. Livestock Production Science 31: 75–94.

Messo, W. (2023). Ten reasons your broilers are not adding weight. Poultry Blog Articles. https://www.kenchic.com/farm-centre/10-reasons-your-broilers-are-not-adding-weight. Retrieved January 6, 2023.

Miles, D. M., Branton, S. L., & Lott, B. D. (2004). Atmospheric ammonia is detrimental to the performance of modern commercial broilers. *Poultry Science*, *83*(10), 1650–1654. doi:10.1093/ps/83.10.1650

Mohamed S. S, Rafea M. K & Nawaf G. A, (2023). Effect of Feeding Broilers with Three Different Regimens on Performance and Carcass Characteristics. Animal Production Department, College of Agriculture and Forestry, University of Mosul, Mosul, Iraq. .

Mohsen, F., Mehrdad, M., Omid, G.N., Saveewonlop, S., Rattanatabtimtong, Y., Ruangpanit, O.S. & Attamangkune, S. (2019). Effects of different phase-feeding programs with different feed forms on broiler growth performance, carcass traits and intestinal morphology. *International Journal of Poultry Science*. 18: p. 181-186.

Mohseni, H. (2008) Phase feeding of broiler chicken. MSc Thesis. Tarbiat Modaress University, Tehran, I.R. Iran, 14115-336

Muchadeyi, F. C., Eding, H., Wollny, C. B. A., Groeneveld, E., Makuza, S. M., Shamseldin, R., Simianer, H., & Weigend, S. (2007). Absence of population sub-structuring in Zimbabwe chicken ecotypes inferred using microsatellite analysis. *Animal Genetics* 38:332-339.

Muchenje1 V, Gajana1, C. S., Nkukwana1 T. T, & Chmonyo2 M. (2011). Effect of altering the starter and finisher dietary phases on growth performance of broilers. African Journal of Biotechnology Vol. 10(64), pp. 14203-14208.

Nagaraj, M., C. A. P. Wilson, J. B. Hess, and S. F. Bilgili. 2007. Effect of high protein and all vegetable diets on the incidence and severity of pododermatitis in broiler chickens. J. Appl. Poult. Res. 16:304-312

Nahm, K. H. (2003). Evaluation of the nitrogen content in poultry manure. *World's Poultry Science Journal*, *59*(1), 77–88. doi:10.1079/wps20030004

Ncei, M. I. (2022.). Annual 2022 global climate report. Retrieved 25 February 2024, from https://www.ncei.noaa.gov/access/monitoring/monthly-report/global/202213

Nigerian Industrial Standard for Poultry Feeds (NIS 259) (SON, 2019); Nigerian Industrial Standard on methods of Sampling and Analysis of Animal Feeds and Feedstuffs NIS 173:19-83

NRC (1994) Nutrient Requirements of Poultry. 9th Rev. Edition. National Research Council, Natl. Acad. Press, Washington, DC.

Ode-Uwa, I. J. &. Etuk, E.B (2018). Performance of Broilers on Variants of the Dual- Phase Feeding Regime. Proc. 43rd Annual Conference of the Nigerian Society for Animal Production, March 18th – 22nd 2018, FUT Owerri 1464- 1466.

Okojie, J. (2017). Nigeria's poultry industry and high rate of smuggling. Retrieved from https://www.businessdayonline.com/exclusives/analysis-sub/backpage/article/.

Okoli, I. C. & Udebibe, A.B.I. (2016). The science and technology of cassava utilization in poultry feeding preceding of a NIPFERD workshop on knowledge transfer towards cost effective poultry feeds production from processed cassava products to improve the productivity of small-scale farmers in Nigeria.

Orji, I & Iheonun, C. (2023). The huge domestic production gap, the implacable appetite for poultry meat, and persistent demand offer a vast array of opportunities for private investments in the poultry market in Nigeria. Insight note a kwakol research publication | tenth edition 2023 https://assets-global.website files.com/618a9de0f5ee92b306a4c52d/65807689e473274bb618bbae_INSIGHT%20NOTE%20-%20Nigeria%E2%80%99s%20Poultry%20Market%20eCopy.pdf

Oyedeji, J. O. & Atteh, J.O. (2005) Response of broilers to feeding manipulations. International Journal of Poultry Science 35: 677–685.

Penz, A. M. (Jr) & Bruno, D.G. (2011): Challenges Facing the Global Poultry Industry to 2020.

Pomar, C., Andretta I & Remus A (2021). Feeding Strategies to Reduce Nutrient Losses and Improve the Sustainability of Growing Pigs. Front. Vet. Sci. 8:742220. doi: 10.3389/fvets.2021.74222

Pope, T. & Emmert, T. J (2002). Impact of Phase-Feeding on the Growth performance of broilers subjected to high environmental temperatures. Poultry Science 81: 504–511.

Poultry Sector Study Nigeria, (2020). Poultry Sector Study Nigeria Retrieved from https://www.rvo.nl/sites/default/files/2020/10/Poultry-Sector-Study-Nigeria.pdf on May 23, 2021.

Powers W, Angel R., (2008). A review of the capacity for nutritional strategies to address environmental challenges in poultry production. Poult Sci 2008; 87:1929-38.

R Core Team (2023) R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna.
https://www.R-project.org/

Roberto, S. G., Arturo, C. C., Carlos, L. C, Ernesto, Á. G.(2017) . Evaluation of three feeding programs for broilers based on sorghum-soybean diets with different protein percentages. 1 Danisco Animal Nutrition, Industrial Vallejo, México DF; 2 Centro de Enseñanza, Investigación y Extensión en Producción Avícola de la Facultad de Medicina Veterinaria y Zootecnia de la Universidad Nacional Autónoma de México, Salvador Díaz Mirón, Zapotitlán, México, DF; 3 Departamento de Producción Animal Aves de la Facultad de Medicina Veterinaria y Zootecnia de la Universidad Nacional Autónoma de México,

Rose 308 broiler performance objective (2014). Ross 308 Broiler Management Guide and Nutrition Supplement, Alabama, USA.
https://images.proultry.com/files/company/1759/Ross_PM3_Broiler_PO_2014_EN.pdf

Roxana Mitroi1,, Oana Stoian1 , Cristina Ileana Covaliu1 , and Dragoş Manea2, (2021). ; Pollutants resulting from intensive poultry farming activities and their impact on the environmenhttps://doi.org/10.1051/e3sconf/202128603018

Saharei, M. (2013): Improvement of production efficiency and carcass quality through feed restriction programs in broiler

Sahota, A.W., Mehmood, S., Akram, M., Jatoi, A. S. & Javed, K. (2012). Phase feeding programs influence growth performance, breast yield and economics in sexed broiler chickens. Book of proceedings, National Sci. Conf. "Agriculture and food security issues in global environmental perspectives" The University of Poonch, Rawalakot, Azad Jammu and Kashmir, Pp. 280.

Saki, A. A., Momeni, M., Tabatabaei, M. M., Ahmadi, A., Rahmati, M. M. H., Matin, H. R. H., & Janjan, A. (2010). Effect of feeding programs on broilers Cobb and Arbor Acres plus performance. International Journal of Poultry Science, *9*(8), 795–800. doi:10.3923/ijps.2010.795.800

Saleh, E. A., Watkins, S. E. & Waldroup, P. W. (1996). Changing the time of starter, grower and finisher diets for broilers 1: Birds grown to 1kg. Journal of Applied Poultry Research 5: pp. 269 – 275.

Salem, M. S., Khulel, R. M., & Al-Tamee, N. G. (2023). Effect of feeding broilers with three different regimens on performance and carcass characteristics.

IOP Conference Series. Earth and Environmental Science, *1158*(5), 052024. doi:10.1088/1755-1315/1158/5/052024

Shao, D., Shen, Y., Zhao, X., Wang, Q., Hu, Y., Shi, S., & Tong, H. (2018). Low-protein diets with balanced amino acids reduce nitrogen excretion and foot pad dermatitis without affecting the growth performance and meat quality of free-range yellow broilers. Italian Journal of Animal Science, *17*(3), 698–705. doi:10.1080/1828051x.2017.1400414

Shepherd, E. M., & Fairchild, B. D. (2010). Footpad dermatitis in poultry. *Poultry Science*, *89*(10), 2043–2051. doi:10.3382/ps.2010-00770

Sibbald, I. R., & Wolynetz, M. S. (1985). Relationships between estimates of bioavailable energy made with adult cockerels and chicks: Effects of feed intake and nitrogen retention. *Poultry Science*, *64*(1), 127–138. doi:10.3382/ps.0640127

Smits, C. H. M., Li, D., Patience, J.F. and den Hartog, L.A. 2021. Animal nutrition strategies and options to reduce the use of antimicrobials in animal production. FAO Animal Production and Health Paper No. 184. Rome, FAO. https://doi.org/10.4060/cb5524en

SON (2019). Nigerian Industrial Standard (NIS 259: 2019): Standard for Poultry Feeds (ICS 65.120). Pp. 9 -16.

Sonaiya, E. B, Oguntade, E. A. and Adesina A. A. (2022). Commercial Poultry Success Stories in Nigeria: Drivers, Challenges, and Lessons. FARA Research Report 6 (11): Pp. 51.

Such, N., Pál, L., Strifler, P., Horváth, B., Koltay, I. A., Rawash, M. A., Dublecz, K. (2021). Effect of feeding low protein diets on the production traits and the nitrogen composition of excreta of broiler chickens. *Agriculture*, *11*(8), 781. doi:10.3390/agriculture11080781

Swiatkiewicz, S., Arczewska-Wlosek, A., & Jozefiak, D. (2017). The nutrition of poultry as a factor affecting litter quality and foot pad dermatitis – an updated review. Journal of Animal Physiology and Animal Nutrition, 101(5), e14–e20. doi:10.1111/jpn.12630

Tickle, P. G., Paxton, H., Rankin, J. W., Hutchinson, J. R., & Codd, J. R. (2014). Anatomical and biomechanical traits of broiler chickens across ontogeny. Part I. Anatomy of the musculoskeletal respiratory apparatus and changes in organ size. *PeerJ*, *2*, e432. doi:10.7717/peerj.432

Tony. M.A. and Fayed. R.H., (2015 Impact of starter and grower diets' duration on the performance of broiler chicks. https://www.researchgate.net/publication/273870646

Treviño, L., Alvarez-González, C. A., Perales-García, N., Arévalo-Galán, L., Uscanga-Martínez, A., Márquez-Couturier, G., Gisbert, E. (2011). A histological study of the organogenesis of the digestive system in bay snook Petenia splendida Günther, 1862 from hatching to the juvenile stage. *Zeitschrift Für Angewandte Ichthyologie [Journal of Applied Ichthyology], 27*(1), 73–82. doi:10.1111/j.1439-0426.2010.01608.x

Ullah, M. S., Pasha, T. N., Ali, Z., Saima, F., Khattak, F. M. and Hayat, Z. (2012). Effects of different pre-starter diets on broiler performance, gastrointestinal tract morphometry and carcass yield. *J. Anim. Plant Sci*. 22:570-575.

Unga (2020) Broilers feeding regime on a 3-phase diet, Unga Farm Care (EA) Ltd. https://www.standardmedia.co.ke/farmkenya/market/...

United States Department of Agriculture USDA (2017). Livestock and Poultry: World Markets and Trade. Foreign Agricultural Service, April 2017. 2017 International Long-Term Projections to 2026, USDA Economic Research Service, March 2017. https://www.ers.usda.gov/webdocs/DataFiles/51280/BL-2017-SU-All-2014-2026.xlsx?v=42824

USDA/NCS (2012). Nutrient Management Technical Note No 8. United States Department of Agriculture Natural Resources Conservation Service Retrieved from https://directives.sc.egov.usda.gov/31266.wba

van Emous, R. A., Winkel, A., & Aarnink, A. J. A. (2019). Effects of dietary crude protein levels on ammonia emission, litter and manure composition, N losses, and water intake in broiler breeders. *Poultry Science, 98*(12), 6618–6625. doi:10.3382/ps/pez508 van Harn, J., Dijkslag, M. A., & van Krimpen, M. M. (2019). Effect of low protein diets supplemented with free amino acids on growth performance, slaughter yield, litter quality, and footpad lesions of male broilers. *Poultry Science*, *98*(10), 4868–4877. doi:10.3382/ps/pez229

Vilela, M. D. O., Gates, R. S., Souza, C. D. F., Teles Junior, C. G. de S., & Sousa, F. C. (2020). Nitrogen transformation stages into ammonia in broiler production: sources, deposition, transformation and emission to environment. *Dyna*, *87*(214), 221–228. doi:10.15446/dyna.v87n214.83318

Webb, J. S, Menzi, H, Pain, B. F., Misselbrook, T. H., Dammgen, U, Hendriks, H, & D € ohler, H. € (2005): Managing ammonia emissions from livestock production in Europe.

Yan, F., Coto, C., Wang, Z., Cerrate, S., Watkins, S. E., & Waldroup, P. W. (2010). Comparison of nutrient recommendations for broilers. *International Journal of Poultry Science*, *9*(11), 1006–1014. doi:10.3923/ijps.2010.1006.1014

ZAPA, (2012) Joint interpretation of AER/FGF and ZPA/SHH over time and space underlies hairy2 expression in the chick limb