COMPARATIVE STUDY OF THREE STRAINS OF BROILER CHICKENS USING GROWTH TRAITS, BIOCHEMICAL PROFILE AND MATHEMATICAL MODELS

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DECLARATION

I declare that the work in this dissertation entitled ‘‘**COMPARATIVE STUDY OF THREE STRAINS OF BROILER CHICKENS USING GROWTH TRAITS, BIOCHEMICAL PROFILE AND MATHEMATICAL MODELS’’** has been performed by me in the Department of Animal Science under the supervision of Dr. M. Kabir and Dr. A.O. Iyiola-Tunji. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at any University.

Makka Nuhu	----------------------------	--------------------
	Signature	Date

CERTIFICATION

This dissertation titled **"COMPARATIVE STUDY OF THREE STRAINS OF BROILER CHICKENS USING GROWTH TRAITS, BIOCHEMICAL PROFILE AND MATHEMATICAL MODELS"** meets the regulations governing the award of Master of Science in Animal Science of Ahmadu Bello University, Zaria and is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This dissertation is specially dedicated to my family.

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ABSTRACT

This study was conducted to compare three strains (Arbor Acre, Marshal and Ross) of broiler chickens using growth traits, biochemical profile and mathematical models (Gompertz, Logistics and Simple linear regressions) with the view of identifying the best strain and the most suitable model for fitting growth curve in broilers. A total of 225 birds (75 per strain) were used. The traits recorded at 2, 4, 6 and 8 weeks of age were body weight, shank length (SL), thigh length (TL), body length (BL) and breast width (BRW) while the traits recorded at 4 and 8 weeks for biochemical profile were glucose (GLU), urea, creatinine (CRE), albumin (ALB) and total protein (TP). At the end of 8 weeks of age, 27 birds from 3 treatments, (9 birds per treatment) were used for carcass traits analysis. The carcass traits measured were carcass weight (CW), breast weight (BRW), thigh weight (TW), drum stick weight (DS), shank weight (SW), gizzard (GZ) and liver. Statistical analysis was done using General linear model procedure of Statistical Analysis System and Python programming interface. The mean body weights obtained at 2, 4, 6, and 8 weeks of age for Arbor acre, Ross and Marshal were 168.40, 494.52, 1085.14 and 1458.96g, 172.14, 505.40, 1044 and 1377g and 145.64, 401.65, 946.58 and 1272.06g, respectively. SL obtained at 2, 4, 6, and 8 weeks of age for Arbor acre, Ross and Marshal were 6.71, 9.42, 13.15, and 14.59cm, 7.24, 10.34, 13.08, and 14.13cm and 7.07, 9.45, 12.19 and 13.72cm, respectively. BRW obtained at 2, 4, 6, and 8 weeks of age for Arbor acre, Ross and Marshal were 13.12, 16.86, 25.04 and 27.49cm, 13.86, 20.71, 23.68 and 27.10cm, 13.22, 17.81, 23.68 and 25.70cm respectively. Similarly, TL obtained at 2, 4, 6, and 8 weeks of age for Arbor acre, Ross and Marshal were 4.95, 6.33, 9.13 and 9.85cm, 5.00, 6.83, 9.26 and 9.34cm and 4.62, 6.22, 8.38, and 8.52cm, respectively. Lastly, BL obtained at 2, 4, 6, and 8 weeks of age for Arbor acre, Ross and Marshal were 24.17, 32.21, 45.81 and 52.92, 26.16, 35.01, 45.45 and 51.97cm, 24.17, 32.54, 44.67 and 50.27cm, respectively. Effect of strain on blood

biochemical traits were not significant (P>0.05) between the three strains. Similarly, effect of strain on carcass traits were not significant (P>0.05) except for drumsticks weight (DS) which no significant (P>0.05) effect between Ross and Arbor acre with corresponding values of 161.33±6.15g and 145.66±6.15g respectively while Arbor acre and Marshal (140.33±5.77) also had no significant (P>0.05) effect. Correlation coefficients between body weight (g) and body linear measurement (cm) traits were moderate to highly significant (P<0.01) for all the strains at age 2, 4, 6 and 8 weeks. Blood biochemical traits had low positive to high negative associations with other traits of all the strains at 4 and 8 weeks of age. Carcass weight had positive and highly significant (P<0.01) associations with BRW (0.92), TW (0.84) and DS (0.97) in Arbor acre. Similarly corresponding values of BRW (0.82), TW (0.86) and DS (0.76) were recorded for Ross while BRW (0.94), TW (0.98), DS (0.91) were recorded for Marshal. Ross and Arbor acre used for this study showed a good difference for body weight than Marshal strain. The comparison of growth curves using mathematical models in this study showed that, based on the leading key indicators of low Mean square errors (MSE), high coefficient of determination and high correlation coefficients, simple linear regression (SLR) was more appropriate to describe growth pattern of Arbor acre, Ross and Marshal strains compared to Gompertz (GOM) and Logistics (LOG).

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

In many developing countries of the world including Nigeria, the broiler industry plays a major role in supplying the population with meat which is highly nutritious and popularly consumed (Ukwu, 2004). The broiler chicken in Nigeria had served as the major source of protein for the population. Despite their economic importance, poultry production is affected by environmental factors among which include temperature, humidity and nutrition (Orunmuyi, 2006). Evaluation of performance of broiler strains is carried out using various indices, such as growth traits (body weight and body linear -measurement). Ebangi and Ibe (1994) reported that body linear measurement have heritable basis and have been identified to play a major role in the subsequent carcass yield of broiler strains.

A range of techniques are available to gain information about broiler mass and body conformation. Some of these techniques use simple and inexpensive equipment, while others required sophisticated and expensive equipment (Kabir *et al*., 2010a). The most direct way to determine broiler's mass is to weigh it using digital weighing scale. However, under some circumstances, a scale may not be available. An alternative is to measure a body part and relate the measurement to the body weight. Shank length, thigh length, breast width are some body parts that are commonly measured and related to body weight in poultry (Nwagu *et al.,* 2009; Kabir *et al.,* 2010b).

Breeders of meat-type chickens over the years introduced the use of mathematical models such as Gompertz, Logistics, Artificial Neural Network (ANN), Wood, Richards, Von Bertalanffy, France, Monomolecular and Lopez models as a means of visualizing growth pattern of individual or group of farm animal overtime, and subsequently use equations generated to predict the expected weight of individual or group of farm animals at a specific age (Turgar and Selahiti 1991; Patra *et al.,* 2002; Cetin *et al.,* 2007).

1.1.1 Poultry Breeding

From the early 20th century, the breeding of chickens for meat and egg has experienced significant changes in methods of selection, industry, market structure and traits demanded for due to the consumption of poultry meat and eggs that has increased steadily (Aggrey *et al.*, 2003). It has moved from a combined total of 117 million tonnes in 2001 to 147 million tonnes in 2011(EGWPT, 2011) of the current total, 13% is produced from turkeys, ducks or poultry species other than chickens. Although unique issues for other strains exist, development in their breeding has in general been parallel to those of chickens.

The greatest potential for poultry consumption remains in the tropics, where per capita egg and meat consumption levels are increasing (Aggrey *et al.*, 2003). Several traits of importance comes to mind, chief amongst which breeders must select for, body weight, shank length, thigh length among a host of others. However, future developments in the breeding of chickens will be governed by the same factors that have determined developments in the past but with one important difference: the ‘chicken itself’ is likely to play its own role when it presents the limits of its biological capabilities. It has been speculated that genetic progress at the present rate and for the current main traits will be possible for a limited period of less than two decades (Crawford, 1990). Areas of speculation for the future impact of main determinants include: industry developments; consumer demands; breeding technologies; and biological constraints.

The distributions of indigenous poultry out number that of other livestock and they are the only species that can be kept by the poorer section of the population in the rural areas. Gueye (2000) reported that they represent about 98% of the total poultry numbers kept in Africa. In Malawi, they constitute 83% (Judith and Gondwe, 2004) Nigeria 80% of 120 million poultry birds (Fayeye *et al.,* 2005). Despite their popularity and potentials, Ajayi *et al.* (2008) pointed out that rural poultry are rarely accorded primary consideration in economic development activities. However, rural farmers often regard this sector as secondary to other livestock and crop farming activities.

1.2 Justification

Live body weight at market age is known to be the most important traits in determining profit from broiler enterprise (Mistra and Mohapatra, 1995). Poultry breeders have tried to establish the relationships that exist between biochemical traits, body weight and body conformation traits as this information reflects on the growth and development of the broiler birds (Adenowo and Omoniyi, 2004; Kabir and Olufemi, 2013; Kabir *et al*., 2010a). Breeders of meat- type chickens have become interested in adult body weight, the trend being towards a big bodied weight at early age in order to attract better price at market (FDLPCS, 1992).

Growth models are the most adequate means of describing the growth patterns and adequately predicting body weight or body parts of broiler strains by summarizing the information in few parameters that may be interpreted biologically (Turgar and Selahiti, 1991). Generally, growth of broiler can be explained by changes in weight, length and volume of the body during certain period of time. Analysis of these changes have been done mostly by mathematical non-linear models (Turgar and Selahiti, 1991). Growth curves models have been used by several researchers. For such as; Gompertz model in Japanese quail and turkey (Anthony *et al.*,1991), in fowl and ducks (Knizetova *et al.*, 1991) and geese, white and brown Japanese quail (Sezer and Tarhan, 2005). Gompertz and Richards model in heavy white male and female turkey (Heidari *et al.*, 2011) and Artificial Neural Network (ANN) model in male and female partridges (Cetin *et al.*, 2007). Lastly, Logistics and Artificial Neural Network (ANN) model was used in predicting egg production of White leghorn hen (Savegnago *et al.*, 2011). There are few published studies on the use of growth models such Gompertz, Logistics and Simple linear regression in determining growth curves as well as predicting body weight at the inclining phase of growth in Arbor acre, Ross and Marshal broiler strains.

1.3 Hypotheses

This research is designed to test the following hypotheses:

H_o: Strain has no effect on growth traits (body weight and body linear measurement), biochemical profile and carcass traits of broiler chicken.

H_A: Strain has effect on growth traits (body weight and body linear measurement), biochemical profile and carcass traits of broiler chicken.

$H_{o:}$ Growth curves of three strains (Arbor acre, Ross and Marshal) of broiler chickens were similar

$H_{A:}$ Growth curves of three strains (Arbor acre, Ross and Marshal) of broiler chickens were different

1.4 Objectives

I. To determine the effect of strain on some growth traits (body weight and body linear measurement), biochemical profile and carcass traits.

II. To determine the relationship between growth traits (body weight and body linear measurement) serum biochemical profile and carcass traits of Arbor acre, Ross and Marshal broiler strains.

III. To compare body weight curve of Arbor acre, Ross and Marshal strains using Gompertz, Logistic and simple linear regression models so as to identify the best suited model that describes growth in Arbor acre, Ross and Marshal broiler strains.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 History of Chickens

The origin of the domestic chicken (*Gallus gallus domesticus L.*) has been documented by Darwin (1968). Archaeological remains of domestic chicken are found in 16 Neolithic sites along the Yellow River in Northeast China as well as in the Indus Valley. Because some of these remains date back to 8,000 years ago, domestication must have been undertaken at least since that time. Previous molecular studies suggested a single domestic origin in Southeast Asia (Thailand) (Liu *et al*., 2004); At least six distinct maternal genetic lineages have now been identified (Cuc *et al.,* 2011); suggesting more than one domestication centre. Four living species of genus Gallus are known: red junglefowl (*Gallus gallus*), La Fayette's junglefowl (*Gallus lafayettei*), gray junglefowl (*Gallus sonnerati*), and green junglefowl (*Gallus varius*), that differ by their morphological aspect and geographical distribution in Asia.

Gallus gallus is the closest to domestic chickens by its morphological traits and gives fertile offspring after crossing with domestic chickens, whereas matings between domestic chickens and any of the other three wild species yields very poor hatchability and chick survival. This Red jungle fowl exhibits a strong sexual dimorphism with males having red fleshy wattles. This chicken is most widely distributed over the Southeast Asia (Liu *et al*., 2004). *Gallus lafayettei* morphologically resembles the red junglefowl, with an orange brown breast feathers, having purple spot on the top of the neck and a yellow spot on the comb. It is found in Sri Lanka. *Gallus sonnerati* has grey plumage and can be found distributed from southwest to central India. *Gallus varius* is found only on the island of Java and its immediate vicinity of Bali and Lombok (Cuc *et* *al.*, 2011). It is characterized by several peculiarities including a wattle with three different colours (red, yellow and blue) and plumage with a greenish tinge. *Gallus gallus* (Animal diversity web, University of Michigan ©),*Gallus lafayettei* (www.hlasek.com – lubomir hlasek ©), *Gallus sonnerati* (Nidhin G. Poothully ©), *Gallus varius* (Lars Petersson ©). According to archaeological findings and literature from the early 20th century, it is thought that chickens reached Europe along two main trading routes: a northern route through China and Russia and a southern route through Persia and Greece (Crawford, 1990). An alternative scenario reports that the two routes started from Iran, one via the Mediterranean Sea, and the other via the Black Sea. The Mediterranean type of chicken is considered to be the most ancestral type of the European domestic chickens. Records from Greek mythology support the fact that chicken reached Greece by 700 BC. Poultry keeping was well developed under the Romans, who utilised chickens as a food source and also used them for leisure, religion and divination (Raach-Moujahed *et al.*, 2011).

2.2 Avian Species and Chicken Strains

Chickens represent an important category (63% of all avian strains) and the oldest type of poultry (FAO, 2007). Chicken strains are divided according to type and are classified into: layers (used exclusively for eggs production), broilers (production of chicken meat), dual purpose strains (meat and eggs), fighting strains and ornamental strains. The most important strains in the development of modern egg laying strains include the White Leghorn, New Hampshire and Plymouth Rock were developed only in the second half of the nineteenth century in the developed countries, commercial synthetic strains dominate the production of meat and eggs, while local strains are marginalized and restricted to the hobby sector. In the developing countries local strains still play a major important role; and in some cases make up 70-80 % of the chicken population (Guèye, 2000; FAO, 2007). Chicken types found in the hobby sector may look very different from each other, but that does not necessarily mean they are genetically very diverse (Cuc *et al.*, 2011). The same may be true for some of the indigenous strains in developing countries (FAO, 2007).

2.3 Commercial Broiler Breeders

Breeding companies have the responsibility to manage their genetic resources to deliver stock of predictable performance at high health standards (Mckay, 2009). McKay (2009) further added that population sizes must be sufficient to avoid breeding inbreeding and ensure that the genetic variation is maintained to sustain long-term selection response. The most important developments in genetics since the late 1980s have been in the ability of breeding programs to deliver predictable and coordinated changes in multiple traits. Major investments are now being made to further improve the relevance and accuracy of the measurements made. This will allow more efficient and accurate selection to make further progress in many traits (McKay, 2009).

Genetic improvement in pigs and poultry is now almost wholly in the hands of specialized breeding companies whose business is the art of genetic improvement and the supply of improved breeding stock (Silva *et al.,* 2007). The evolution of this process has taken decades and in the case of broiler chickens, it is now that, the number of primary poultry breeding companies globally has reduced to less than ten (10) through the process of mergers and acquisition (Sullivan *et al.,* 2009). Presently, three (3) companies supply over 90% of the global parent stock requirement (Sullivan *et al.,* 2009). Breeding broilers for over half of the world puts a lot of responsibilities on the shoulder of any one company. The global leader include:

1. **Aviagen®**- Aviagen group is the world leading poultry strainer, developing products to meet the needs of the commercial broiler and turkey industries. Formed in 1999, the company now combines poultry breeding resources and expertise across its brand portfolio, which include Ross, Arbor Acre, Lohman Indian River, CWT farms and Nicholas (Aviagen, 2013)
2. **Hubbard** – Grimaud company started from the small flock of chicken with which Ira and Oliver Hubbard began the business in 1921 (EGWPT, 2011). Hubbard has grown to be one of the major international broiler breeding companies in the world. The poultry industry has seen remarkable changes during the past 90 years, with dramatic results for the benefit of humankind. It provides solutions that focus on the economic performance, health and well-being of breeding stock. Hubbard specializes in state-of-the art selection programs to improve the performance of pure lines, and offers a range of products that respond to current and future needs of the broiler industry (McKay, 2009). It has a longstanding experience in breeding, developing and marketing breeding stock for both conventional and alternative markets. Hubbard operates its selection programs in three (3) different centers in North America, Europe, along with its own production sites in America, Europe and Brazil (Manager, 2012). However, ultra-yield's genetic potential is maximized at the heavier weight (2.8 - 4.0 kg) where the highest meat yield can be harvested by the processors looking for the maximum value de-boned chicken meat from each carcass.
3. **Marshall** – The founders of Marshall, brothers Elias and Richard D'Souza, started their career in the poultry industry with modest beginning in 1961 in Nasik, India (EGWPT, 2011). 200-birds backyard farm was the first step in learning about raising and farming

poultry for meat and eggs. In the years and decades that followed, the founders went on to play a pivotal role in the development of the poultry industry in India. Marshall is one of the very few basic poultry breeding companies in Asia. In a short period of time, Marshall broiler strains have firmly established themselves as leaders in efficient chicken meat production taking intensive commercial broiler growing to a whole new level of productivity. Marshall breeding program includes a good mix of classical population genetic and tools available through the advances in molecular genetics and collaborative research with universities. Poultry breeding companies generally have a pyramid structure (FAO, 2007). A general structure for broiler breeders is shown below. What differs is the efficiency of the primary strainer at the top of the pyramid in setting relevant breeding goals and achieving the targets that result in the development of suitable products for their clients (Olori, 2009).

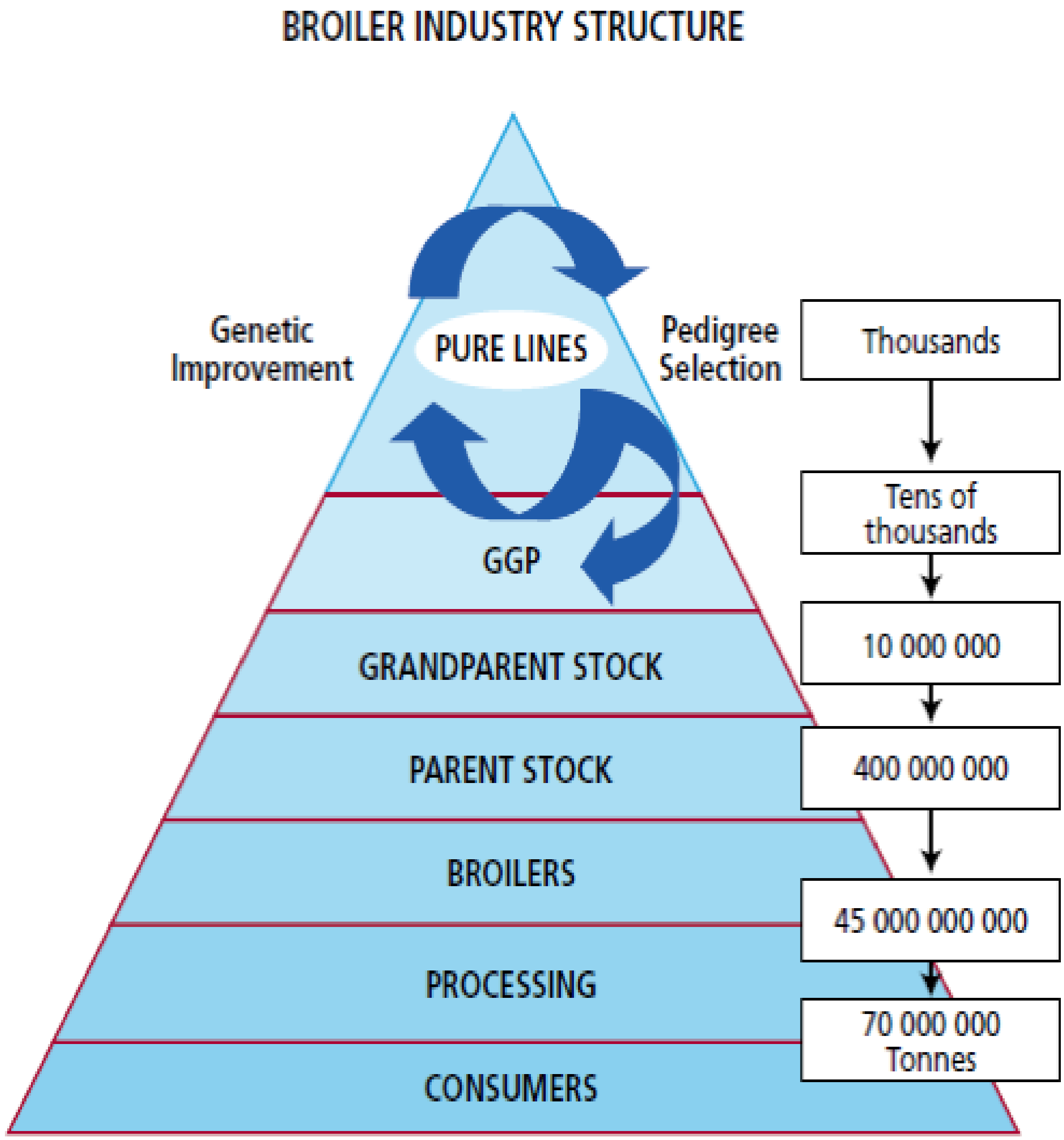

Figure 2. 1.Broiler industry structure. ***Source:*** **McKay, 2008**

2.4 Growth Curve / Model in Poultry

The choice of growth function for precise description of broiler growth is an important first step towards better prediction of broiler performance. The function of body weight or body composition weight related to age could describe growth of broiler. The term" growth function" denotes an analytical function written as a single equation: W= F(T), where W is organic mass, example weight and F is final weight, T is time (Hruby *et al.*, 1996).

The term growth curve usually evokes the image of sigmoid curve depicting a lifetime sequence of measure of size often body weight (Oni, 1997). Various attempts at mathematically describing the growth of animals has been made over the centuries (Dina, 2006). With the advent of modern computers and the ability to rapidly manipulate complex formulas, the accuracy and utility of growth models have significantly improved (Harlow and Ivey, 2005). Models should not be complex in computation and should be easy for any scientist with basic knowledge of regression to use (Akpa, 1999). Coefficient of determination (R^2) measures the amount of variability accounted for by the fitted models. The adequacy of a model is by high R^2 value, while low values indicate inadequacies. An R^2 value of 70% and above indicate a good measure of fitness (Olorunju, 1991). The ability to predict growth pattern of broiler chicken will aid selection, production planning and economic decision making. Therefore, the model that is able to make the most accurate prediction when compare to the actual values will be more reliable and will be an asset to both farmer and breeder (Oni, 1997).

2.4.1 Linear models

A variety of growth functions including logistic, Gompertz, Richards, Michaelis-Menten, logistic nonlinear mixed effect, spine regression, exponential, and log linear models, Simple and

Multiple linear regression have been reported as models for consideration in poultry production (Turgar and Selahiti, 1991; Patra *et al.*, 2002; Cetin *et al.*, 2007; Ntirampeba *et al.*,2014). These growth functions have been commonly used to estimate the optimum growth, nutrient responses and time required to produce birds of desired weights. Normally, the functional form of the growth function used for final weight or mature size is determined as a function of time or age of the bird. Lopez *et al.* (2000) recommended a Michaelis-Menten-type equation to model growth in a wide variety of animals because it described diminishing returns behavior. Aggrey (2002) suggested using the Logistic, Gompertz and Richards models rather than spine linear regression model in chickens because the models showed better fitting and concluded that Gompertz model was the best for describing broiler chicken growth. Beiki *et al.* (2012) demonstrated that the Richards model was the best in Japanese quail and the Gompertz model fitted better than the Logistic with a set of data in poultry. Aggrey (2009) applied the Logistic model with nonlinear mixed effects to model growth in Japanese quail. The model accounted for the variation between measurement units and heteroscedasticity.

Zuidhof (2005) evaluated 8 dynamic nonlinear broiler carcass and carcass part yield models for predicting weights of carcass parts with maximal accuracy and minimal bias. This consist of four sigmoidal (S) nonlinear models (Gompertz, Richards, and Lopez) which were used to describe carcass part weight as a function of age, three diminishing returns (DR) models (Lopez, Mitscherlich, and log linear), and a log-linear proportional yield (PY) model, which were used to describe carcass part yield and weight, respectively. He studied parameters for nonlinear equations that could be used to predict carcass part weights of broilers at different processing ages up to 112 days. The study was conducted to develop strain-specific mathematical descriptions of carcass part yields of males and females from 6 commercial strain crosses in order to support decisions about the selection of strains and marketing weights. He found that the Richards model, with inflexion points that can vary depending on age, gender, strain and species, were better to predict carcass part weights as a function of age when compared with the Gompertz model, with fixed points of inflexion. This knowledge can be used in order to optimize broiler production economic and processing decisions.

Hruby *et al*., (1996) studied the fit of the Gompertz, logistic and polynomial functions to body protein composition of male broilers as a function of age (week). The Gompertz function was the best fit according to residuals and coefficients of determination during the 19 week broiler study. Hancock *et al.* (1995) evaluated the differences between six commercial broiler strains and two sexes on potential growth, nutrient and environment requirements using Gompertz model to describe their growth potential up to 11 weeks of age. They found that the rates of growth among strains and sexes were significantly different, while the rates of maturing were not significantly different neither among strains nor sexes. Duan-Yai *et al.* (1999) applied the Gompertz model to describe the growth curves of males and females of a single strain of broilers. The model was used to determine weight as a function of time. The total requirement of protein or AA was stated as the sum of the separate requirements for maintenance and the growth of protein, assuming the retentions of lipid, ash and water have no protein requirement.

2.5 Growth and its Implication on Poultry Production

In biology, growth can be defined as the changes throughout life accompanied by the utilization of materials, and leading to an increase in volume, size, or shape of an organism (Aggrey, 2002; Aggrey *et al.*, 2003). These changes can be monitored by measurements of body weight at regular intervals and summarized by mathematical equations fitted to growth curves.

Biologically, interpretable growth parameters can reduce the variation caused by the environment and random events (Aggrey, 2002; Aggrey *et al.*, 2003).

Growth is the single most important phenotype for evaluating the productivity of livestock species. It helps in evaluating the efficiency of management and optimum managerial practices that will sustain gain at optimum level with least cost, since feed cost decreases with increasing growth rate (Aboul-Seoud, 2008). Growth is an all-encompassing term which when studied in detail reveals an array of traits which could be selected for or against in any research work (Aggrey *et al.,* 2003; Narinc *et al.,* 2010)

Since the essential trait used in breeding programs to increase poultry meat production is the live weight of the bird; growth evaluation, live weight at fixed ages, growth curve and live weight gains are traits that are also evaluated. Growth curves revealing time-dependent non-linear changes of the body or organ weights of this animals show that there are additive and non-additive genetic variations between strains, lines and individuals in terms of growth curve parameters (Akbas and Oguz, 1998).

Growth traits such as body weight and body weight gain are affected by genetic and non-genetic factors (Aboul-Seoud, 2008). Specific growth parameters have been summarized for large variety of birds thus spawning the formulation of many hypothesis concerning variable growth rates among species. This hypothesis may be classified into three groups. The first implies that variation in growth rates may be related directly to the environment. The second suggests that variation in growth rates represent the effect of parent's ability to feed and satisfy all the young produced. The third suggests that variations in growth rate are results of constraints imposed on anatomy and physiology of the bird (Ricklefs, 1985).

Ricklefs (1985) as cited by Narinc *et al*. (2010) showed that the major improvement due to selection for growth has occurred during the first two weeks post hatch expressed as relative or exponential growth rate. Growth may be viewed in different ways as: absolute growth rate, relative growth rate and cumulative growth rate in time (Aggrey *et al.,* 2003).

The absolute growth rate may be defined as the weight increment per unit of time

$$(W2 - W1) / (T2 - T1)$$

In which (W2 – W1) is the weight increment in time interval (T2 – T1). This formula represents the average absolute growth rate or average daily gain.

The relative growth rate as defined by Aggrey *et al.* (2003) is the absolute growth rate divided by the initial weight according to the following formula:

$$(W2 - W1) / (W1)$$

Where: W1 = the weight at the beginning and W2 = the weight at the end of the period.

The cumulative growth could be represented by the curve of weight against time and is often described by mathematical growth functions (Narinc *et al.*, 2010).

2.6 Growth Performance Traits

In Nigeria, there are many reports on growth performance traits for broiler chickens. The reports of Adeyinka *et al.* (2004), Adeyinka *et al.* (2006) and (Kabir *et al.*(2010a) suggested the need to generate these growth rate for any future improvement efforts. Udeh (2015) obtained significant strain differences on broiler birds' weight and body linear measurement. There is evidence that there are genetic differences in growth rate between strains and the changes in weight ranking may be critical in the age ranged eight (8) to twelve (12) weeks (Deeb and Lamont, 2000). The development of suitable strains of broiler chickens for the tropical environment is a research interest which has engaged the attention of a number of poultry geneticists and breeders for the past two decades (Narinc *et al.,* 2010).

2.6.1 Body weight

The live body weight of any animal is an important variable that determines the market value of that animal. The exact time at which the animal is ready for slaughter can be accessed on the basis of its body weight and general development (Akanno *et al.,* 2007). Amao *et al.,* (2011) obtained final body weight of Ross, Anak and Marshall broiler chicken as 2445.32±60.02, 2340.75±39.04 and 2100.21±61.23g, respectively. Adeyinka *et al.* (2006) also recorded body weights of naked necked broiler chickens at day old, 2, 4, 6, and 8 weeks as 37.22±0.32, 210.46±1.97, 744.33±4.31, 1,351.3±7.91 and 2,428.1±14.61g respectively. Udeh and Ogbu, (2011) also reported 1.88± 0.04, 1.65±0.03 and 1.81±0.03 for Arbor acre, Marshal and Ross strains at 8 weeks of age respectively. Mammo and Sultan (2010) obtained the average live weight of Hubbard strain as 1,554.0±90.4.8 at 8 weeks of age. Ojedapo (2013) reported the final weights of Marshall Broiler strain as 374.78±30.87, 785.63±22.57, 1525.08±86.51 and 1981.34±37.76g. Afolayan *et al.* (2012) also recorded daily weight gain of Ross from 6 to 9 weeks for treatments T1, T2, T3, T4, T5, T6 and T7 as 52.83, 53.23, 45.69, 38.97, 37.34, 31.07 and 28.34 g/bird/day respectively. They also reported final weight for Ross strain from 6 to 9 weeks as 2310.01, 2308.81, 2160.01, 2016.43, 1984.64, 1852.86 and 1795.71 g/bird for the respective treatments. Udeh *et al.* (2011) reported superiority of Ross strain in final body weight (1.890g) at 8 week over to Arbor acre (1.880g), Anak (1.855) and Marshall (1.654g)

2.6.2 Shank length

Udeh *et al.*(2011) observed that shank length differed between strains with 7.80±0.05, 7.64±0.06 and 7.54±0.06cm for Arbor acre, Marshall and Ross respectively. Nosike (2014) reported Shank length ranged between 8.10cm and 9.20cm with a mean of 8.58cm for Nigerian local chicken. This mean shank length was higher than the value (6.60cm) reported by Momoh and Kershima (2008) for female local chickens. This was also true for local chickens in Edo State where Okpeku *et al.* (2003) reported that males recorded higher values 9.52 ± 0.32cm than the females 8.99 ± 0.64cm. Aderonke (2010) reported 4.7±0.05, 6.4±0.08, 7.9±0.10 and 10.8±0.39cm for shank length in Hubbard broiler strain at 2, 4, 5, and 8 week of age, respectively. Essien and Adeyemi (1999) oservations that shank length increased with age and differed among broiler strains, agree with reports of Okon *et al.* (1997).

2.6.3 Thigh length

Ojedapo (2013) obtained thigh length of 6.10cm in ecotypes local strains of chickens at 18 weeks. Udeh and Ogbu (2011) however reported higher thigh length 17.16±0.06, 17.39±0.08 and 15.25±0.04 cm for Arbor acre, Marshall and Ross respectively. Egena *et al.* (2014) reported 11.01cm shank length for indigenous Nigerian chicken at 18 weeks of age.

2.6.4 Breast width

Rondelli *et al.* (2003), Zhao *et al.* (2009) and Taha *et al.* (2012) observed that strains differed in breast width at different ages. Their findings corroborate those of Okon *et al.* (1997) who reported that age was the major determinant of growth and physiological development in chicks. Ajayi and Ejiofor (2009) also reported significant effect of genotype on breast width. Aderonke (2010) reported 18.9±0.17, 25.9±0.29, 35.5±0.31 and 39.9±0.05cm for breast width in Hubbard broiler strain at 2, 4, 5, and 8 week of age respectively, Udeh and Ogbu (2011) reported

10.53±0.05, 12.93±0.05, 9.60±0.06 for Arbor acre, Marshall and Ross strain at 8 week respectively. Okon *et al.* (1996) recorded a range of 15.59±0.08 to 37.08±0.24 from 3-12 weeks of age. Essien and Adeyemi (1999) reported that breast width increased with age from 1 to 8 weeks in Lohman Brown and Anak broiler strains.

2.6.5 Body length

Okon *et al*. (1996) observed that body length increased with age and recorded a range of 10.23 ± 0.12 to 25.0 ± 0.21cm from 3 to 12 weeks of age in Lohmann Brown broiler chickens with 51.71%, 26.93% , 26.90% increase between (3-6 weeks), (6-9 weeks) and (9-12 weeks) respectively. Adedeji *et al.* (2008) observed that body length differed with sex as seen in pure and crossbred progeny of chicken in a derived savannah environment with males being higher in lengths than females. Similarly, age differences in body lengths were observed by Sola-Ojo *et al.* (2008) among chickens of 6-20 weeks. Udeh and Ogbu (2011) reported significant strains differences in body lengths between Arbor acre (32.79±0.15), Marshall (31.30±0.16) and Ross (37.12±0.07) strains agree with earlier reports by Okpeku *et al*. (2003) on local chickens of Edo state. Essien and Adeyemi (1999) also reported that, from 1 week to7 weeks of age body length increased from 16.01± 0.11 to 40.26± 0.47cm in Lohmann brown while, in Anak broiler strain, a range of 16.10 ±0.12 to 41.08±0.37cm was obtained. Okpeku *et al*. (2003) obtained body length of 34.16 ± 2.82 and 34.11 ± 2.72cm for males and females, respectively in matured local chickens of Edo state.

2.6.6 Correlations

Udeh and Ogbu (2011) reported correlations coefficient of body weight and body measurements of the three strains of broiler chicken ranging from -0.05-0.76, -0.02-0.56 and -0.28- 0.60 in Arbor Acre, Marshal and Ross strains respectively. The relationships between body weight and most of the body measurements were positive and non-significant ($p>0.05$) in the three strains of broilers. They observed highly significant ($p<0.01$) positive correlations for shank length and breast width (0.62), thigh length and breast width (0.66), thigh length and wing length (0.64) and breast width and wing length (0.76) in Arbor Acre broiler. While in Marshal, the reported significant ($p<0.05$) positive relationships for shank length and body width (0.56), shank length and wing length (0.50) and body width and wing length (0.47). Similarly, in Ross strain, significant ($p<0.05$) positive relationships were observed for thigh length and wing length (0.54), shank length and wing length (0.55) and body width and breast width (0.50). The authors reported that positive and significant correlations among the body measurements observed in the three strains of broilers indicate high prediction of body weight in the broiler chickens. This is because an increase in any of the body measurement will invariably lead to a corresponding increase in the body weight of the chickens (Ajayi *et al*., 2008). Similarly, Yahaya *et al.* (2012) reported correlations coefficients of 0.916, 0.894, 0.861, 0.897, 0.977 and 0.963 were obtained between body weight and neck length, shank length, thigh length, keel length, breast width and back length for Hubbard strain, while for Arboracre strain the correlation values of 0.967, 0.974, 0.882, 0.935, 0.981 and 0.969, respectively was obtained between body weight and neck length, shank length, thigh length, keel length breast width and back length all indicating a strong positive relationship. This means that an improvement in the body weight might lead to an improvement in other parameter.

Sanda *et al*. (2014) reported correlation coefficients of body weight and linear body measurements of breast girth, shank length, thigh length and wing span in Arbor Acre, Marshall and Ross to range from 0.77 to 0.97, 0.77 to 0.98 and 0.79 to 0.96, respectively. They reported that the relationships between the body weight and linear body measurements were positively correlated and highly significant ($p>0.05$) in the three broiler strains. Suggested that positive correlations among the body measurements observed in the three strains of broilers indicate high predictability among the variables.

2.7 Biochemical Blood Components of Broiler Chickens

Blood is a complex fluid containing a large variety of dissolved suspended inorganic and organic substances or specialized circulating tissues and cells suspended in the intercellular fluid substance (Polat *et al.,* 2011). Blood circulates in the arteries, veins and capillaries of man and animals and Its primary function is to transport oxygen from respiratory organs to body cells distributing nutrients and enzymes to cells and carrying away waste products thereby maintaining homeostasis of the internal environment (Nworgu *et al.,* 2007).

The various functions of blood are made possible by the individual and collective actions of its constituents – the biochemical and haematological components. Generally, both the biochemical and haematological blood components are influenced by the quantity and quality of feed, age and disease (Akinmutimi, 2004). Biochemical components are sensitive to elements or factors present in the feed (Akinmutimi, 2004), including elements of toxicity. They can also be used to monitor stress markers. Blood chemistry studies are usually undertaken to establish the diagnostic baselines of blood characteristics for routine management practices of farm animals (Obikaonu *et al*., 2011; Etuk *et al.*, 2012)

Over the years many researchers have focused their genetic studies on improving only economic traits. This improvement of physiological parameters is negatively associated with some aspects of immunological performance in poultry and has led to undesirable effects as reported by Yunis *et al.* (2000) and Cheema *et al.* (2003). A broader perspective of improved and efficient genetic study has emerged because, selection, breeding and genetic improvement have a marked effect on characteristics of the blood biochemistry; as researchers utilize the biochemical parameters of the blood as markers in livestock species to enhance productivity and reproductive performance (Nguyen and Tran, 2003). Abdi-Hachesoo *et al.* (2011) noted that genetic resources such as creatinine, total protein, total Albumin, serum proteins, cholesterol, glucose level and bilirubin have been established as genetic markers in farm animals.

2.7.1 Creatinine

Creatinine, a biomarker of protein metabolism derived from phosphocreatine in muscle is normally low in chickens, its high level is associated with high level of muscle activity (Ibrahim *et al.,* 2012). The kidney maintains the blood creatinine in a normal range of 0.3 to 1.8mg/dl (Vasile *et al.,* 2013). Lower values an indication of low muscular wastage, might be possibly caused by inadequacy of protein in diet for the animal to utilize. Polat *et al.* (2011) reported 1.12-1.22mg/dl creatinine in Arbor acre, Bowes *et al.* (1989) reported creatinine level of 0.44±2.9 mg/dl to 0.52±5.7mg/dl for male broiler chicken, 0.44±9.0mg/dl to 0.52±6.7 for female broiler chicken while male leghorn chicken ranges from 0.45±2.7mg/dl to 0.50±8.6mg/dl. The low level of creatinine was associated low creatinine -dehydrating mechanism. Domesticus *et al.,* (2013) reported creatinine level of Cobb, Cockerel, Fayoumi, Rhode Island Red and Sonali (derived from Rhode Island Red and Fayoumi) to be 0.60±0.16 mg/dl, 0.64±0.21 mg/dl, 0.56±0.23 mg/dl, 0.90±0.22 mg/dl, 0.54±0.24 mg/dl respectively. The researcher's attributed that the significant differences among creatinine levels to diet administered to the birds. Obikaonu *et al*.(2011) reported 0.90mg/dl serum creatinine in Anak broiler chicken as within the normal range of a healthy broiler chicken.

2.7.2 Total protein

Total proteins perform a number of different functions in the body (Olukomaiya *et al.,* 2014). In addition to being major structural components of cells, proteins are involved in transport, enzymatic catalysis, homeostatic control, hormonal regulation, blood coagulation, immunity, growth and repair, and heredity (Olukomaiya *et al.,* 2014). Total protein measurements are used in the diagnosis and treatment of a variety of diseases involving the liver, kidney as well as other metabolic or nutritional disorders. Owosibo *et al.* (2013) observed 2.88g/dl level of total protein in Marshal broiler while Nworgu *et al.* (2007) reported 3.50g/dl total protein level in Anak broiler. (Silva *et al.,*2007) also reported 2.96±0.37 to 3.23±g/ dl total protein level in Hybro PG broiler which were comparable with the reference values of 4 to 6 mg/dl (Clinical Diagnostic Division, 1990). The high total protein could be attributed to good protein reserve reflecting the ability of the chickens to store protein for tissue development (Simaraks *et al*., 2004).

2.7.3 Albumin

Albumin constitutes about 60% of the total serum protein in normal, healthy birds (Meluzzi *et al.,* 1992). Unlike most of the other serum proteins, albumin serves a number of functions which include transporting large insoluble organic anions (e.g., long-chain fatty acids and bilirubin), binding toxic heavy metal ions, transporting excess quantities of poorly soluble hormones (e.g., cortisol, aldosterone, and thyroxine), maintaining serum osmotic pressure, and providing a reserve store of protein (Meluzzi *et al.,* 1992). Albumin measurements are used in the diagnosis and treatment of numerous diseases primarily involving the liver or kidneys, Low albumin (hypoalbuminemia) may be caused by liver disease, burns, protein-losing genetic variations and High albumin (hyperalbuminemia) is always caused by dehydration of the birds (Meluzzi *et al.*, 1992). Nworgu, (2007) observed values of Albumin ranging from 2.00 to 2.40g/dl in Anak broiler strain. They noted that birds dietary protein is utilized for transportation of large insoluble organic ions, long chain fatty acid and bilirubin. Obikaonu *et al*.(2011) observed lower values ranging from 1.03 to 1.23g/dl in Anak broiler chicken though the values obtained were within the range of 1.3 to 2.8mg/dl reported by Vasile *et al.* (2013) for healthy broiler chickens. Yakubu *et al.* (2009) also reported that Albumin value of Arbor acre and Titan Anak were 2.77g/dl and 2.48g/dl respectively. Their findings are comparable with the reports of Talebi *et al.* (2005) which they revealed that biochemical values of four strains (Ross, Cobb, Arbor acre and Arain) of chickens were similar.

2.7.4 Glucose

Glucose measurements are used in the diagnosis and treatment of pancreatic islet cell and carbohydrate metabolism disorders (Meluzzi *et al.*, 1992). Olukomaiya *et al.* (2014) observed Glucose levels of 75.67-165.40 mg/dl in Marshal broiler were lower than the reference range of 197 to 299 mg/dl indicated by Clinical Diagnostic Division (1990). They stated that, the observed difference may be due to breed and age difference. Duwa *et al.* (2014) observed glucose levels of 229.16mg/dl and 241.95mg/dl for Arbor acre and Anak Titans, respectively. They indicated that levels were not affected by effect on management practice. Abdi-Hachesoo *et al.* (2011) reported glucose level of cocks and hens of Azerbaijen indigenous birds in Iran were 260.60±35.68mg/dl and 245.60 ± 28.11mg/dl respectively while those of Ross cocks and hens were 260.50±18.71 and 274.50±33.22, respectively. They reported that there was significant difference of glucose level within strains. However, Ross hens had significantly higher ($P<0.05$) glucose content than that of the indigenous hens though the overall mean value (255mg/dl) of serum glucose was within the range (197-299mg/dl) reported for poultry serum by Clinical Diagnostic Division (1990).

2.7.5 Urea

Urea is synthesized in the liver from ammonia produced as a result of deamination of amino acids (Meluzzi *et al.*, 1992). Serum urea is assumed to indicate protein breakdown and higher urea value indicate poor-dietary protein utilization. Obikaonu *et al.*(2011) observed serum urea value to be 3.60mg/dl in turkey poult while Nworgu *et al.* (2007) reported 14.00mg/dl serum urea level in Anak broiler chickens indicating that the value obtained is within the reference values of 1.9-12.5mg/dl (Clinical Diagnostic Division, 1990). Duwa *et al.* (2014) reported lower value of 2.67mg/dl while Obikaonu *et al.*(2011) reported higher value of 30.53mg/dl urea level in Anak broiler chickens. The variation in serum biochemical indices among strains could largely be attributed to type of feed administered to the birds and physiological health of the birds (Abdi-Hachesoo *et al.*, 2011).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Location of the Experiment

This study was carried out at the Teaching and Research Farm, Department of Animal Science, Faculty of Agriculture, Ahmadu Bello University, Zaria. It is located at Latitude 11^0 9' 6' N and Longitude 7^0 38' 55' E at an altitude of 706m above sea level (Ovimaps, 2012). The area is characterized by 6 to 7 months of rain fall ranging from 1100mm to 1250mm annually. The ambient temperature of Zaria is 26^0C. The area lies within the Northern-Guinea Savannah zone of Nigeria, with clear distinctive dry and wet seasons (Kabir and Olufemi, 2013).

3.2 Experimental Birds and Management

Marshal, Ross and Arbor acre commercial broiler strains were purchased from Bnut, Agrited and Zatech hatcheries respectively in Oyo State. A total of 225 unsexed day-old broiler chicks comprising 75 each of Arbor acre, Marshal and Ross commercial strains were allocated into three treatments with three replications (25 chicks per replicate) in a completely randomized design (CRD). Each strain was identified by wing tag and assigned to pen in a brooder house.

Chicks were brooded for four weeks in the restricted brooding section of the Teaching and Research Farm of Department of Animal Science, A.B.U Zaria. Electric bulb and charcoal stoves were used as source of heat. After brooding birds were transferred to the rearing house for another 4 weeks. All necessary routine management practices and the recommended vaccination schedule as shown in Table 3.1 were strictly observed throughout the period of the study.

Table 3. 1.Vaccination schedule for broiler

Age	Type of vaccine	Disease	Route
Day 1	Newcastle disease Vaccine (1st dose)	Newcastle disease	Intra ocular (1/0)
2 Weeks	Gumboro disease Vaccine (1st dose)	Gumboro	Oral
3 Weeks	Newcastle disease Vaccine-lasota (2nd dose)	Newcastle disease	Oral
5 Weeks	Gumboro disease Vaccine (2nd dose)	Gumboro	Oral

3.3 Nutrition

Commercial broiler starter and finisher diets were purchase from LABAR feedmill Samaru, Zaria. The former containing 2722 kcal of ME/kg and 23% CP was given to birds from day old to four weeks and the latter containing 2837 kcal of ME/kg and 20% CP/kg from five to eight weeks respectively. All birds were given access to feed and water *ad libitum*.

3.4 Data Collection

3.4.1 Growth traits measured

The body weights of the individual bird and body linear traits were recorded early in the morning (8:00hr) before feeding at day old and fort-nightly.

The body weight (BWT) was measured in grams (g) from day old to eight (8^{th}) weeks using digital weighing scale.

The body linear traits taken in cm using tailors tape include:

1. Shank Length (SL): From the hock joint to the base of the three toes.

2. Breast Width (BRW): The circumference of the breast around the deepest region of the breast.

3. Body Length (BL): The distance between the base of the neck to the tip of the tail

4. Thigh Length (TL): The distance between the hock joint and the pelvic joint.

3.5 Carcass Traits Measured

At the end of 8^{th} week of age, 2 birds were randomly selected from each replicate making a total of 6 birds per treatment; fasted overnight and slaughtered for carcass analysis. The carcass weight, thigh weight, shank weight, drum stick, breast weight were expressed in grams while liver and gizzard were expressed as percentages of carcass weight.

3.6 Blood Sample Collection and Analysis

From each replicates, two (2) blood samples of 2mls each were collected from fasted birds into heparinized tubes on 4^{th} and 8^{th} in the morning (8:00hr) from the brachial vein using sterile syringes and needles. Immediately after collection, the blood samples were taken to Pathological Laboratory of Ahmadu Bello University Teaching Hospital Shika, Zaria. Each sample was centrifuge at 3000 rpm for 10 min and frozen at – 20^{0}C for the determination of total protein, albumin, glucose, creatinine and urea was calorimetrically determined using ELISA multiplex commercial kits (Pfizer Animal Health, New York, NY) following the steps as described by the manufacturers.

3.7 Data Analysis

3.7.1 Model for body weight and body linear measurement

$Y_{ik} = \mu + A_i + L_k + e_{ik}$

Where; Y_{ik} = Record of measurable traits
μ = Population mean
A_i = Effect of age (i = 2^{nd}, 4^{th}, 6^{th}, and 8^{th} week)
L_K = Effect of strain (k = 1, 2, 3)
e_{ik} = Random Error

3.7.2 Model for blood and carcass analysis

$Y_{ik} = \mu + A_i + L_k + e_{ik}$

Where; Y_{ik} = Record of measurable traits
μ = Population mean
A_i = Effect of age (i = 4^{th} and 8^{th} week for blood collection and also 8^{th} week for carcass)
L_K = Effect of strain (k = 1, 2, 3)
e_{ik} = Random Error

3.7.3 Model for body weight

Gompertz, Logistics models were used to fit data of body weight using Python programming software. (Python Version R 3.0.3 2010).

The following growth models were used

Gompertz

β_0*exp-$\beta_1$exp (-β_2*at)

Logistics

β_0*(1+β_1*exp(-β_2*x))**-1

Where;

β_1 = is the asymptotic weight (g)
β_0 = is the scaling parameter (constant of integration)
β_2 = is the instantaneous growth rate (g)
t = is the time (weeks) when broilers reach maximum growth rate
a,x = Growth rate constant per day

Simple Linear Regression

Y= a + bx

Where,

Y = Independent variable (Weight in grams)
a = Intercept point of regression
b = The slope of the regression Line
x = Dependent variable (Age in weeks)

The accuracy of the model was calculated using the coefficient of determination (R^2). The R^2 is a predictive strength of the variation in bodyweight at different age that was captured by the model.

$$R^2 = 1 - \left[\sum_{1}^{N} \left(\frac{Q_{\exp} - Q_{cal}}{Q_{\exp}{}^{2}} \right)^2 \right]$$

Qexp= Observed value

Qcal = Predicted value

N= Number of observation

3.7.4 Statistical analysis

The data generated from growth traits (body weight and body linear measurements), biochemical profile and carcass traits was subjected to analysis of variance (ANOVA) using General Linear Model Procedure of (SAS, 2000). Significant differences in means were compared using Duncan's Multiple Range Test (Duncan, 1955). The correlation coefficient was used to estimate the association between growth traits (body weight and body linear measurement), biochemical profile and carcass traits from each of the strains using PROC CORR procedure of (SAS, 2000).

CHAPTER FOUR

4.0 RESULTS

4.1 Body Weight and Body Linear Measurement

The least squares means (±SE) of body weight and body linear measurement from 2 to 8 weeks of age for Arbor acre, Ross and Marshal strains are presented in Table 4.1 Ross and Arbor acre had similar ($P>0.05$) BW at 2 weeks of age. However, the two strains were heavier ($P<0.05$) than Marshal birds. The mean and standard error of 2 weeks BW for Marshal birds were 145.64±10g while those of Ross and Marshal broilers were 172.14±4.74g and 168.40±5.70g, respectively. At 2 weeks of age, Ross and Marshal had similar ($P>0.05$) SL of 7.24±0.99cm and 7.07±0.07cm, respectively although both appeared to be significantly ($P<0.05$) higher 6.71±0.07cm SL of Arbor acre strain. BRW at 2 weeks were similar ($P<0.05$) among the three strain with means and standard errors of 13.12±0.13cm, 13.86±0.14cm and 13.22±0.14cm for Arbor acre, Ross and Marshal strains, respectively. At 2 weeks of age, Arbor acre and Ross strains similar ($P>0.05$) TL with mean and standard error of 4.95±0.07cm and 5.00±0.08cm respectively. However, the two strains had significantly longer ($P<0.05$) TL than Marshal strain with (4.62±0.06cm). Arbor acre and Marshal strains had similar ($P>0.05$) BL of 24.17±0.19cm and 24.17±0.28cm, respectively which were significantly ($P<0.05$) lower than 26.16±0.34cm of Ross strain at 2 weeks of age.

Arbor acre and Ross attained average BW of 494.52±19.59g and 505.40±15.72g respectively at 4 weeks of age which were superior to Marshal with 401.65±12.78g. Ross was the most superior in SL at 4 weeks of age with 10.34±0.10cm compare to Arbor acre and Marshal strains with 9.42±0.12cm and 9.45±0.11cm respectively. At 4 weeks of age, all the three strains had significant ($P>0.05$) effect on BRW with Ross appearing to be the most superior with

20.71±0.26cm followed by Marshal with 17.81±0.28cm and Arbor acre appear least with 16.86±0.21cm respectively. At 4 weeks of age, Arbor acre, Ross and Marshal strains had numerically similar value for TL of 6.33±0.10cm, 6.83±0.08cm and 6.22±0.09cm respectively although Ross had significant ($P<0.05$) effect while Arbor acre and Marshal strains had no significant ($P>0.05$) effect. Ross attained BL of 35.01±0.37cm at 4 weeks of age superior to Arbor acre and Marshal with BL of 32.21±0.04cm and 32.54±0.36cm respectively.

At 6 weeks of age, Arbor acre and Ross strains had no significant ($P>0.05$) effect for BW, SL, BRW, TL and BL. However, both strains were superior for all the traits compare to Marshal. The mean and standard error for Arbor acre on BW, SL, BRW, TL and BL were 1085.14±30.55g, 13.15±0.14cm, 25.04±0.30cm, 9.13±0.11cm and 45.81±0.42cm respectively and that of Ross were 1044.79±24.91g, 13.08±0.10cm, 25.08±0.43cm, 9.26±0.19 and 45.45±0.43cm respectively while that of Marshal were 946.58±27.13g, 13.19±0.14cm, 23.68±0.30cm, 8.38±0.12cm and 44.67±0.53cm respectively.

At 8 weeks of age, all the strains were significantly ($P<0.05$) different in terms of BW with Arbor acre appearing to be superior compare to Ross and Marshal strains. The values obtained for Arbor acre, Ross and Marshal on BW were 1458.96±42.10g, 1377.54±37.02 and 1272.06±37.70. Arbor acre and Ross had no significant ($P<0.05$) effect on SL, BRW, TL and BL although the values obtained for these traits were superior compare to the values obtained on Marshal. The values obtained for Arbor acre, Ross and Marshal strains on SL, BRW, TL, BL were 14.59±0.18cm, 27.49±0.30cm, 9.85±0.20cm, 52.92±0.43cm,14.13±0.15cm, 27.10±0.26cm, 9.34±1.14cm,51.97±0.34cm and 13.72±0.22cm, 25.70±0.40cm, 8.52±0.13cm, 50.27±0.32cm respectively.

Table: 4. 1. Least squares means (±SE) of body weight and body linear measurement of Arbor acre, Ross and Marshal broiler chicken.

Traits	Strains	(Age in weeks) 2: Arbor acre (74), Ross (74), Marshal (75)	4: Arbor acre (74), Ross (72), Marshal (73)	6: Arbor acre (69), Ross (72), Marshal (73)	8: Arbor acre (67), Ross (69), Marshal (68)
BW (g)	Arbor acre	168.40±5.70 [a]	494.52±19.59 [a]	1085.14±30.55 [a]	1458.96±42.10 [a]
	Ross	172.14±4.47 [a]	505.40±15.72 [a]	1044.79±24.91[a]	1377.54±37.02 [b]
	Marshal	145.64±4.10 [b]	401.65±12.78 [b]	946.58±27.13 [b]	1272.06±37.70 [c]
SL (cm)	Arbor acre	6.71±0.07 [b]	9.42±0.12 [b]	13.15±0.14 [a]	14.59±0.18 [a]
	Ross	7.24±0.99 [a]	10.34±0.10 [a]	13.08±0.10 [a]	14.13±0.15 [a]
	Marshal	7.07±0.07 [a]	9.45±0.11 [b]	12.19±0.14 [b]	13.72±0.22 [b]
BRW (cm)	Arbor acre	13.12±0.13	16.86±0.21[c]	25.04±0.30 [a]	27.49±0.30 [a]
	Ross	13.86±0.16	20.71±0.26 [a]	25.08±0.43 [a]	27.10±0.26 [a]
	Marshal	13.22±0.14	17.81±0.28 [b]	23.68±0.30 [b]	25.70±0.40 [b]
TL (cm)	Arbor acre	4.95 ±0.07 [a]	6.33±0.10 [b]	9.13±0.11 [a]	9.85 ±0.20 [a]
	Ross	5.00±0.08 [a]	6.83±0.08 [a]	9.26±0.19 [a]	9.34±1.14 [a]
	Marshal	4.62±0.06 [b]	6.22±0.09 [b]	8.38±0.12 [b]	8.52±0.13 [b]
BL (cm)	Arbor acre	24.17±0.19 [b]	32.21±0.04 [b]	45.81±0.42	52.92±0.43 [a]
	Ross	26.16±0.34 [a]	35.01±0.37 [a]	45.45±0.43	51.97±0.34 [a]
	Marshal	24.17±0.28 [b]	32.54±0.36 [b]	44.67±0.53	50.27±0.32 [b]

[abc] Means with different superscripts on the same column are Significant different (P<0.05), Number of Chickens (N), Body Weight (BW), Shank Length (SL), Breast Width (BRW), Body Length (BL), Thigh Length (TL).

4.2 Least Square Mean and Standard Error Mean of Biochemical Traits of Arbor Acre, Ross and Marshal Broiler Chicken

Table 4.2 shows the least square mean and standard error mean of biochemical traits of Arbore acre, Ross and Marshal broiler chicken. The result showed that strain had no significant ($P<0.05$) effect on all the biochemical traits at 4 and 8 weeks of age.

Table: 4. 2. Least square mean and SEM of biochemical traits of Arbore acre, Ross and Marshal broiler chicken

Age (Weeks)	Traits	Arbor acre	Ross	Marshal	SEM	Ref. Value
	GLU(mmol/l)	143.78	152.18	152.78	0.10	197-299
	Urea (mmol/l)	9.51	8.50	10.51	0.17	1.9-12.5
4	CRE (µmmol/l)	0.75	0.77	0.79	0.77	0.3-1.8
	ALB (g/l)	0.76	0.75	0.83	0.45	1.3-2.8
	TP (g/l)	2.18	2.56	2.50	0.50	4-6
	GLU (mmol/l)	193.61	186.10	194.21	0.89	197-299
	Urea (mmol/l)	10.01	7.10	8.50	0.05	1.9-12.5
8	CRE (µmmol/l)	0.67	0.73	0.62	0.27	0.3-1.8
	ALB (g/l)	1.01	0.96	0.60	0.33	1.3-2.8
	TP (g/l)	1.98	2.70	2.33	0.30	4-6

Glucose (GLU), Creatinine (CRE), Albumin (ALB), Total Protein (TP), Reference Value (Reference Value of Clinical Diagnostic Division, 1990)

4.3 Least Square Mean (±SE) of Carcass Traits of Arbor Acre, Ross and Marshal Broiler Chicken

The result of the least squares means (±SEM) of carcass traits of Arbor acre, Ross and Marshal strains are presented in Table 4.3. The results obtained showed that there was no significant effect of stain on the carcass traits (carcass weight, shank weight, thigh weight, breast weight, liver and gizzard) studied except Ross with the highest drum stick (161.33±6.15 g) compare with Arbor acre and Marshal. However, Arbor acre (145.66±6.58) and Marshal (140.33±5.77 g) had similar drum stick.

Table: 4. 3. Least square mean (±SE) of carcass traits of Arbor acre, Ross and Marshal broiler chicken

Traits	Marshal	Ross	Arbor acre
Carcass Weight (g)	911.44 ± 52.37	949.56 ± 62.98	963.56 ± 69.90
Thigh Weight (g)	160.33 ± 9.86	180.00 ± 9.07	174.44 ± 13.98
Shank Weight (g)	65.44 ± 2.41	65.22 ± 2.19	64.11 ± 3.00
Breast Weight (g)	201.89 ±17.91	255.67 ± 17.08	222.11 ± 19.30
Liver (%)	30.11 ± 1.68	27.55 ± 1.02	27.55 ± 1.74
Gizzard (%)	60.88 ± 3.75	54.44 ± 2.15	54.88 ± 4.25
Drum stick (g)	140.33 ± 5.77 ^{b}	161.33 ± 6.15 ^{a}	145.66 ± 6.58 ^{ab}

^{ab} Means with different superscripts on the same row are Significant different (P<0.05)

4.4 Correlations among Body Weight and Body Linear Measurements of Arbore Acre, Ross and Marshal Broiler Strain at Two Weeks of Age (Below Diagonal) and Four Weeks of Age (Above Diagonal)

Table 4.4 shows the correlation coefficients among body weight and linear body measurements of Arbor acre, Ross and Marshal broiler strains at two weeks of age (below diagonal) and four weeks of age (above diagonal). For below diagonal, Body weight (BW) of broilers for each of the three strains had positive and highly significant (P<0.01) correlattions with all but one of the linear body measurements. The exception was thigh length (TL) in Marshal strain, which had though positive but low and in significantly (P>0.05) correlation of 0.16.

Similar pattern of high, positive and significant (P<0.01) relationships were obtained among the linear body measurements except few in all the strains. Breast width (BRW) had high and positive correlated with body length (BL). The coefficients of relationship obtained between BRW and BL were 0.74, 0.62 and 0.62 for Ross, Arbor acre and Marshal strains, respectively. However, the least coefficient was recorded between BRW and TL (0.29, P<0.05) in Marshal strain.

Thigh length (TL) had positive, high and significant (P<0.01) relationships with shank length (SL) and body length (BL) in Arbor acre and Ross. The relationships of these body measurements (SL and BL) with TL was low though positive and significant (P<0.05) in Marshal strain. The coefficients obtained for TL and SL was 0.29, P<0.05 while that of TL and BL was 0.26, P<0.05. SL had positive, high and significant (P<0.01) relationships with BL in all the three strains of broilers at 2 weeks of age.

For above diagonal, Body weight (BW) had highly and positively correlation with breast width (BRW). The coefficients of relationship obtained between BW and BRW were 0.63, 0.59 and

0.21 for Ross, Marshal and Arbor acre strains, respectively although, relationship between BW and BRW in Arbor acre was not significant (0.21, P>0.05).

Positive and significant (P<0.01, P<0.05) relationships were obtained between among breast width (BRW) and other traits in all the strains. Breast width (BRW) was highly and positively correlated with shank length (SL).The coefficient of relationship obtained between BRW and SL were 0.60, 0.50 and 0.36 for Arbor acre, Marshal and Ross strains, respectively. However, the least coefficient was recorded between BRW and TL (0.30, P<0.05) in Marshal strain.

Thigh length (TL) had positive and moderate significant (P<0.01) correlation with shank length (SL) in Marshal strain. The coefficient of relationship obtained between TL and SL were 0.70, 0.59 and 0.50 for Marshal, Ross and Arbor acre strains, respectively. However, the least coefficient was recorded between TL and BL (0.26, P<0.05) in Arbor acre strain. SL had positive, high and significant (P<0.01) relationships with BL in Marshal and Ross strains (0.76 and 0.55) though, the relationship between SL and BL was positive, moderate and significant (0.47, P<0.01) in Arbor acre strain.

Table: 4. 4. Correlation among body weight and body linear measurements of Arbor acre, Ross and Marshal broiler strain at two weeks of age (below diagonal) and four weeks of age (above diagonal)

Traits	BW (g)	BRW (cm)	TL (cm)	SL (cm)	BL (cm)
Arbor acre					
BW(g)		0.21	0.20	0.35**	0.26
BRW (cm)	0.53**		0.45**	0.60**	0.57**
TL (cm)	0.69**	0.49**		0.50**	0.26
SL (cm)	0.68**	0.63**	0.63**		0.47**
BL (cm)	0.55**	0.62**	0.52**	0.51**	
Ross					
BW(g)		0.63**	0.27	0.26*	0.39**
BRW (cm)	0.60**		0.48**	0.36**	0.34**
TL (cm)	0.65**	0.45**		0.59**	0.48**
SL (cm)	0.65**	0.46**	0.54**		0.55**
BL (cm)	0.61**	0.74**	0.58**	0.65**	
Marshal					
BW(g)		0.59**	0.54**	0.55**	0.50**
BRW (cm)	0.71**		0.30**	0.50**	0.41**
TL (cm)	0.16	0.29		0.70**	0.57**
SL (cm)	0.61**	0.53**	0.29		0.76**
BL (cm)	0.51**	0.62**	0.26	0.67**	

Body Weight (BWT), Shank Length (SL), Breast Width (BRW), Body Length (BL), Thigh Length (TL).

*P < 0.05

**P <0.01

4.5 Correlation between Body Weight and Body Linear Measurement of Arbor Acre, Ross and Marshal Broiler Strain at Six Weeks of Age (Below Diagonal) and Eight Weeks of Age (Above Diagonal)

Table 4.5 revealed the correlations coefficient between body weight and body linear measurement correlation of Arbor acre, Ross and Marshal broiler strain at six weeks (below diagonal) Those involving Body weight (BW) were positive and highly significant (P<0.05) in the all strains. BW was highly and positively correlated BRW. The coefficient of the relationship obtained between BWT and BRW were 0.75, 0.68 and 0.66 for Arbor acre, Marshal and Ross strains respectively.

Breast width (BRW) had positive, high and significant (P<0.01) relationships with thigh length (TL) and body length (BL) in Arbor acre and Marshal strains. The coefficient of the relationship obtained between these body linear measurements (TL and BL) with BW were 0.69, 0.75 and 0.72, 0.68 for Arbor acre and Marshal strain respectively. However, the least coefficient was recorded between BWT and SL (0.12, P>0.05) in Ross strain.

Similarly, TL had positive relationship with all the body linear measurements in all the strains. The relationship between TL with SL and BL was positive and highly significant (P<0.01) in Marshal strain and the coefficient of the relationship obtained were (0.59 and 0.58), respectively. However, the relationships between TL and SL in Arbor acre (0.18) and Ross (0.15) strains were though positive, but low and in significant (P>0.05).

SL had positive high and significant (P<0.01) relationship with BL in Marshal strain. The coefficient of the relationship between SL and BL was (0.62) while the least 0.38 and 0.24 were recorded in Arbor acre and Ross strains respectively.

For 8 weeks of age (above diagonal), Body weight (BW) of broilers for each of the three strains had positive highly and significant ($P<0.01$) correlations with all the linear body measurements. The highest correlations of 76, 0.79, and 0.73 were recorded with BL in Arbor acre and BRW in Ross and Marshal strains respectively.

BRW had positive, high and significant ($P<0.01$) relationship with all the traits in all three strains except its relationship between BRW and SL which were though positive but low and insignificant (0.14, $P>0.05$) in Marshal strain. At eight weeks of age, the body weights of Arbor acre and Ross strains proved to have better association with body linear measurement traits than in Marshal strain.

Table: 4. 5. Correlation between body weight and body linear measurement of Arbor acre, Ross and Marshal broiler strain at six weeks of age (below diagonal) and eight weeks of age (above diagonal)

Traits	BW (g)	BRW (cm)	TL (cm)	SL (cm)	BL (cm)
Arbor acre					
BW (g)		0.67**	0.39**	0.58**	0.76**
BRW (cm)	0.75**		0.40**	0.52**	0.66**
TL (cm)	0.59**	0.69**		0.62**	0.46**
SL (cm)	0.48**	0.35**	0.18		0.62**
BL (cm)	0.72**	0.75**	0.65**	0.38**	
Ross					
BW (g)		0.79**	0.63**	0.64**	0.55**
BRW (cm)	0.66**		0.49**	0.50**	0.42**
TL (cm)	0.43**	0.36**		0.67**	0.52**
SL (cm)	0.37**	0.12	0.15		0.55**
BL (cm)	0.53**	0.48**	0.24*	0.24*	
Marshal					
BW(g)		0.73**	0.72**	0.57**	0.67**
BRW (cm)	0.68**		0.60**	0.14	0.48**
TL (cm)	0.57**	0.72**		0.53**	0.48**
SL (cm)	0.69**	0.63**	0.59**		0.62**
BL (cm)	0.53**	0.68**	0.58**	0.62**	

Body Weight (BW), Shank Length (SL), Breast Width (BRW), Body Length (BL), Thigh Length (TL).

*P < 0.05

**P <0.01

4.6 Correlation between Blood Biochemical Traits of Arbor Acre, Ross and Marshal Broiler Chicken at Four Weeks of Age (Below Diagonal) and Eight Weeks of Age (Above Diagonal)

Correlation coefficients between blood biochemical traits of Arbor acre, Ross and Marshal broiler chicken at four weeks of age (below diagonal) and eight weeks of age (above diagonal) are presented in Table 4.6. For below diagonal, The result showed that, blood biochemical traits both had positive and negative associations. For Arbor acre, the association between glucose and creatinine was high and positive (0.47) while the relationship between glucose and total protein was low and positive (0.25). Creatinine had significant but high and negative association of -0.87 with total albumin.

For Ross strain, the relationship between traits were mostly negative. Although, total Albumin had the highest and positive association with total protein (0.60). In Marshal strain, the relationships observed between all the traits were generally low and negative except for high and positive correlation of 0.72 between urea and creatinine and 0.73 between glucose and albumin.

For above diagonal, the relationships estimated in Arbore acre strain ranged from negative, moderate to positive high (- 0.45 to 0.62). Creatinine and total protein had the highest and negative association (0.74) while glucose and total protein had the highest and positive association (0.62).

In Ross strain, glucose had negative correlations which range from low to high (-0.12 to -0.65) with the other traits while the correlations of urea with creatinine and total protein were (0.21 and 0.37) respectively.

In Marshal strain, the relationship between total protein and glucose of 0.79 was high and significant while total Albumin had negative and high correlations of -0.79 with glucose.

Table: 4. 6. Correlation between blood biochemical traits of Arbor acre, Ross and Marshal broiler chicken at four weeks of age (below diagonal) and eight weeks of age (above diagonal)

	GLU(mmol/l)	Urea (mg/l)	CRE (mg/dl)	ALB (g/l)	TP (g/l)
Arbor acre					
GLU(mmol/l)		0.31	-0.45	0.40	0.62
Urea (mg/l)	-0.53		-0.65	0.33	0.53
CRE (mg/dl)	0.47	0.12		-0.49	0.74
ALB (g/l)	-0.19	-0.31	-0.87*		0.52
TP (g/l)	0.25	-0.26	-0.37	0.49	
Ross					
GLU (mmol/l)		-0.45	-0.20	-0.54	-0.65
Urea (mg/l)	-0.50		0.21	-0.11	0.37
CRE (mg/dl)	-0.45	0.58		-0.12	0.46
ALB (g/l)	-0.67	-0.17	-0.12		0.40
TP (g/l)	-0.69	0.41	0.57	0.60	
Marshal					
GLU (mmol/l)		0.35	-0.58	-0.79*	0.79*
Urea (mg/l)	-0.22		0.58	-0.72	0.19
CRE (mg/dl)	-0.19	0.72*		0.24	-0.66
ALB (g/l)	0.73*	0.00	-0.34		-0.39
TP (g/l)	-0.30	0.17	0.11	-0.73	

Glucose (GLU), Creatinin (CRE),Total Albumin (ALB), Total Protein (TP)

*P < 0.05

4.7 Correlations between Carcass Traits (g) of Arbor Acre, Ross and Marshal Broiler Strains

Correlation coefficients between carcass traits of Arbor acre, Ross and Marshal broiler strains are presented in Table 4.7. In Arbor acre strain, the relationship between CW with BRW (0.92), TW (0.84) and DS (0.79) were positive and highly significant ($P<0.01$). The relationship between BRW with DS (0.91) and SW (0.64) were equally positive and highly significant ($P<0.01$). The corresponding coefficients of the relationship between CW with BRW, TW, DS were 0.92, 0.84, and 0.97, respectively. However, the relationships between GZ and either DS or BRW were negative with values of -0.28 and -0.64 which is highly significant ($P<0.01$), respectively.

In Ross strain, CW showed positive and highly significant association with BRW and TW with coefficient of correlation of 0.82 and 0.86, respectively. TW also had positive and highly significant association of 0.72 with DS. However, the correlations between CW and SW (-0.15), BRW and SW (-0.27), TW and SW (-0.08) were negative.

In Marshal, positive and highly significant ($P<0.01$) associations were obtained between carcass traits studied except for SW and GZ (0.35), SW and LV (0.56) which were, though positive, but insignificant. CW and DS, CW and BRW, CW and TW, had the highest correlation coefficients of 0.91, 0.94 and 0.98, respectively.

Table: 4. 7. Correlations between carcass traits (g) of Arbor acre, Ross and Marshal broiler strains

Traits	CW	BRW	TW	DS	SW	GZ	LV
Arbore acre							
CW	1.00						
BRW	0.92**	1.00					
TW	0.84**	0.65	1.00				
DS	0.97**	0.91**	0.81**	1.00			
SW	0.45**	0.64**	0.28*	0.48**	1.00		
GZ	0.39**	-0.28*	0.44**	-0.64**	-0.42**	1.00	
LV	0.55**	0.35*	0.54**	0.54	0.06 **	0.30*	1.00
Ross							
CW	1.00						
BRW	0.82**	1.00					
TW	0.86**	0.63**	1.00				
DS	0.76*	0.50**	0.72**	1.00			
SW	-0.15	-0.27*	-0.08	0.43**	1.00		
GZ	0.44**	0.54**	0.12	0.45**	0.17	1.00	
LV	0.03	0.03	0.20	-0.10	-0.10	-0.26*	1.00
Marshal							
CW	1.00						
BRW	0.94**	1.00					
TW	0.98**	0.86**	1.00				
DS	0.91**	0.86**	0.88**	1.00			
SW	0.77**	0.67**	0.81**	0.87**	1.00		
GZ	0.64**	0.41**	0.66**	0.44**	0.35	1.00	
LV	0.83**	0.82**	0.81**	0.64**	0.56	0.60**	1.00

Carcass Weight (CW), Thigh Weight (TW), Shank Weight (SW), Breast Weight (BRW), Liver (LV), Gizzard (GZ), Drum Stick (DS).

*P < 0.05

**P < 0.01

4.8 Actual Body Weights (g) and Predicted Body Weights (g) of Arbor Acre Strain Using Gompertz, Logistics and Simple Linear Regression Models.

Table 4.8 shows the actual body weights (g) and predicted body weights (g) of Arbor acre strain using Gompertz, Logistics and Simple Linear Regression models. The predicted values of Simple Linear Regression model were more closer to the actual values compared to Gompertz and Logistics models at 2, 4, 6 and 8 weeks for the Simple Linear Regression. The actual values at 2, 4, 6, and 8 weeks were 168.40, 494.52, 1085.14 and 1458.96 g respectively while the corresponding predicted values were (167.50, 490.21, 1085.15 and 1449.28 g) while deviations from the actual values were (-0.05, 0.90, 4.31, -0.01 and 9.68) respectively. The predicted values for Gompertz model at 2, 4, 6, and 8 weeks were 141.30, 529.66, 1040.17 and 1468.31 g with corresponding deviations of 2.20, 27.10, -35.14, 44.94,-9.35, correspondingly. Predicted values for logistics model were 165.58, 526.23, 1123.06 and 1552.77 g with -0.98, 2.82, -31.71, -37.92 and 93.81 deviations. Figure 4.1 shows that Simple Linear Regression curve is more appropriate in fitting the actual body weight curve of Arbor acre than Gompertz and Logistics curve.

Table:4. 8. Actual body weight (g) and predicted body weight (g) of Arbor acre using Gompertz, Logistics and Simple Linear Regression models

	Body Weight (g)						
	Actual Values	**Predicted Values /d**					
Age (Weeks)		GOM	d	LOG	d	SLR	d
Day old	40.00	37.80	2.20	40.98	-0.98	40.05	-0.05
2	168.40	141.30	27.10	165.58	2.82	167.50	0.90
4	494.52	529.66	-35.14	526.23	-31.71	490.21	4.31
6	1085.14	1040.17	44.97	1123.06	-37.92	1085.15	-0.01
8	1458.96	1468.31	-9.35	1552.77	-93.81	1449.28	9.68

Body weight (BW), Gompertz (GOM), Logistic (LOG), Simple Linear Regression (SLR), Deviation (d)

4.9 Actual Body Weights (g) and Predicted Body Weights (g) of Ross Strain Using Gompertz, Logistics and Simple Linear Regression Models.

Table 4.9 shows the actual body weights (g) and predicted body weights (g) of Ross strain using Gompertz, Logistics and Simple Linear Regression models In all the models, the predicted values of Simple Linear Regression model were more closer to the actual values compared to Gompertz and Logistics model at 2, 4, 6 and 8 weeks. The actual values at 2, 4, 6 and 8 weeks were 172.14, 505.40, 1044.79 and 1377.54 g while corresponding predicted values for Simple Linear Regression at 2, 4, 6, and 8 weeks were 171.90, 505.40, 1032.25 and 1372.79 (g) and the deviations from the actual values were 0.1, 0.24, 0, 12.54 and 4.75 respectively. Predicted values for Gompertz and Logistics models at 2, 4, 6, and 8 weeks were 148.51, 554.84, 1043.98, and 1413.67g with corresponding figures of 162.46, 501.72, 554.84, 1043.98 and 1413.67g for Logistic model. Deviations from the actual values for the models were 2.70, 23.63, -49.44, 0.81, -36.13 for Gompertz and 0.22. 9.68, 3.68, 7.91, -30.55 for Logistics model. Figure 4.2 shows that Simple Linear Regression curve is more appropriate in fitting the actual body weight curve of Ross than Gompertz and Logistics curve.

Table:4. 9. Actual body weight (g) and predicted body weight (g) of Ross using Gompertz, Logistics and Simple Linear Regression models

	Body Weight (g)						
	Actual Values	**Predicted Values/ d**					
Age (Weeks)		GOM	d	LOG	d	SLR	d
Day old	40.20	37.50	2.70	39.98	0.22	40.1	0.1
2	172.14	148.51	23.63	162.46	9.68	171.90	0.24
4	505.40	554.84	-49.44	501.72	3.68	505.40	0
6	1044.79	1043.98	0.81	1036.88	7.91	1032.25	12.54
8	1377.54	1413.67	-36.13	1408.09	-30.55	1372.79	4.75

Body weight (BW), Gompertz (GOM), Logistic (LOG), Simple Linear Regression (SLR), Deviation (d)

4.10 Actual Body Weights (g) And Predicted Body Weights (g) of Marshal Strain Using Gompertz, Logistics and Simple Linear Regression Models.

Table 4.10 showing the actual body weights (g) and predicted body weights (g) of Marshal strain using Gompertz, Logistics and Simple Linear Regression models the table reveal that, the predicted values of Simple Linear Regression model were superior and more closer to the actual values compared to Gompertz and Logistics model at 2, 4, 6 and 8 weeks. The actual values at 2, 4, 6, and 8 weeks were 145.64, 401.65, 946.58 and 1272.06 g while the resultant predicted values and deviations from actual for Simple Linear Regression were (145.86, 406.34, 950.34 1270.05 g) and (0.93, -0.22, -04.69, -3.42, 2.01) respectively. Predicted values for Gompertz and Logistics models at 2, 4, 6, and 8 weeks were (109.99, 456.19, 917.02 and 1291.86 g) and (125.65, 431.71, 954.39 and 1331.38 g), respectively while the resultant deviations from the actual values for Gompertz and Logistic were (5.90, 35.65, -54.54, 29.56, -19.80) and (3.46, 19.99, -30.06, -7.81, -59.32) respectively. Figure 4.3 shows that Simple Linear Regression curve is more appropriate in fitting the actual body weight curve of Marshal than Gompertz and Logistics curve.

Table:4. 10. Actual body weight (g) and predicted body weight (g) of Marshal using Gompertz, Logistics and Simple Linear Regression models

	Body Weight (g)						
	Actual Values	**Predicted Values/ d**					
Age (Weeks)		GOM	d	LOG	d	SLR	d
Day old	37.98	32.08	5.90	34.52	3.46	37.05	0.93
2	145.64	109.99	35.65	125.65	19.99	145.86	-0.22
4	401.65	456.19	-54.54	431.71	-30.06	406.34	-04.69
6	946.58	917.02	29.56	954.39	-7.81	950.00	-3.42
8	1272.06	1291.86	-19.80	1331.38	-59.32	1270.05	2.01

Body weight (BW), Gompertz (GOM), Logistic (LOG), Simple Linear Regression (SLR), Deviation (d)

4.11 Goodness of Fit Criteria Results for Gompertz, Logistics and Simple Linear Regression for Arbor Acre, Ross and Marshal Strains.

Goodness of fit criteria results for Gompertz, Logistics and Simple Linear Regression for Arbor acre, Ross and Marshal strains is shown in Table.4.11 In all models, the values of coefficient of determination and correlation coefficient were significant ($P<0.05$, $P<0.01$) in Arbor acre strain. In this strain the coefficients of determination (R^2) for SLR, LOG and GOM models were 0.95, 0.92 and 0.92 respectively while the corresponding correlation coefficients were 0.98, 0.96 and 0.95 respectively. SLR had the lowest Mean Square Error (MSE) of 0.01 compare with LOG (0.02) and (GOM) (0.03).

For Ross strain the values of coefficient of determination (R^2) and correlation coefficient (r) were also significant ($P>0.05$, $P<0.01$) across all the models. In this strain the coefficient of determination (R^2) for SLR, LOG and GOM were 0.96, 0.90 and 0.93 while the corresponding correlation coefficients were 0.97, 0.95 and 0.96 respectively. SLR model had the lowest MSE of 0.01 compare with LOG (0.02) and GOM (0.02).

For Marshal strain, the same trend was observed as in Arbor acre and Ross Stains. Coefficient of determination (R^2) and correlation coefficient (r) were highly significant ($P<0.01$) across all the models except for GOM which shows high significant effect ($P>0.05$). The resultant values obtained were (0.97, 0.95 and 0.90) and (0.98, 0.97 and 0.95) for SLR, LOG and GOM respectively while SLR model had the lowest MSE of 0.01 which was similar to LOG (0.01) but lower than GOM (0.03).

The leading key point indicators (lowest MSE, highest coefficient of determination and correlation coefficient) suggest that SLR is more appropriate for describe growth pattern of Arbor acre, Ross and Marshal strains compared to GOM and LOG.

Table: 4. 11. Goodness of fit criteria results of Gompertz, Logistics and Simple Linear Regression for Arbor acre, Ross and Marshal strains

Strains		**R^2**	**MSE**	**R**
Arbor acre	GOM	0.92**	0.03	0.95**
	LOG	0.92**	0.02	0.96**
	SLR	0.95**	0.01	0.98**
Ross	GOM	0.93**	0.02	0.96**
	LOG	0.90**	0.02	0.95**
	SLR	0.96**	0.01	0.97**
Marshal	GOM	0.90**	0.03	0.95**
	LOG	0.95**	0.01	0.97**
	SLR	0.97**	0.01	0.98**

Coefficient of determination (R^2), Mean Square Error (MSE), Correlation Coefficient (r), Gompertz (GOM), Logistic (LOG), Simple Linear Regression (SLR) .
**P < 0.01

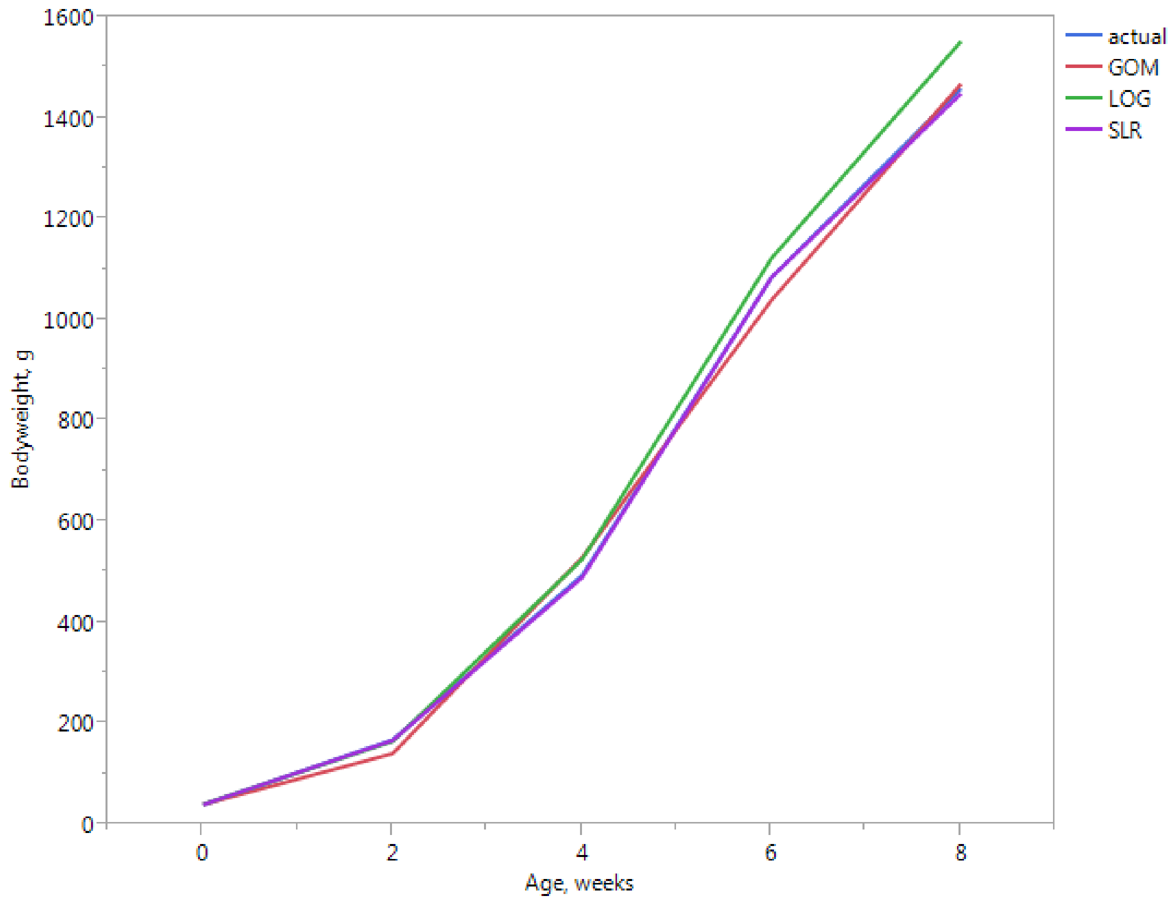

Figure 4. 1. Growth curve of Arbo acre using Gompertz, Logistics and Simple Linear Regression

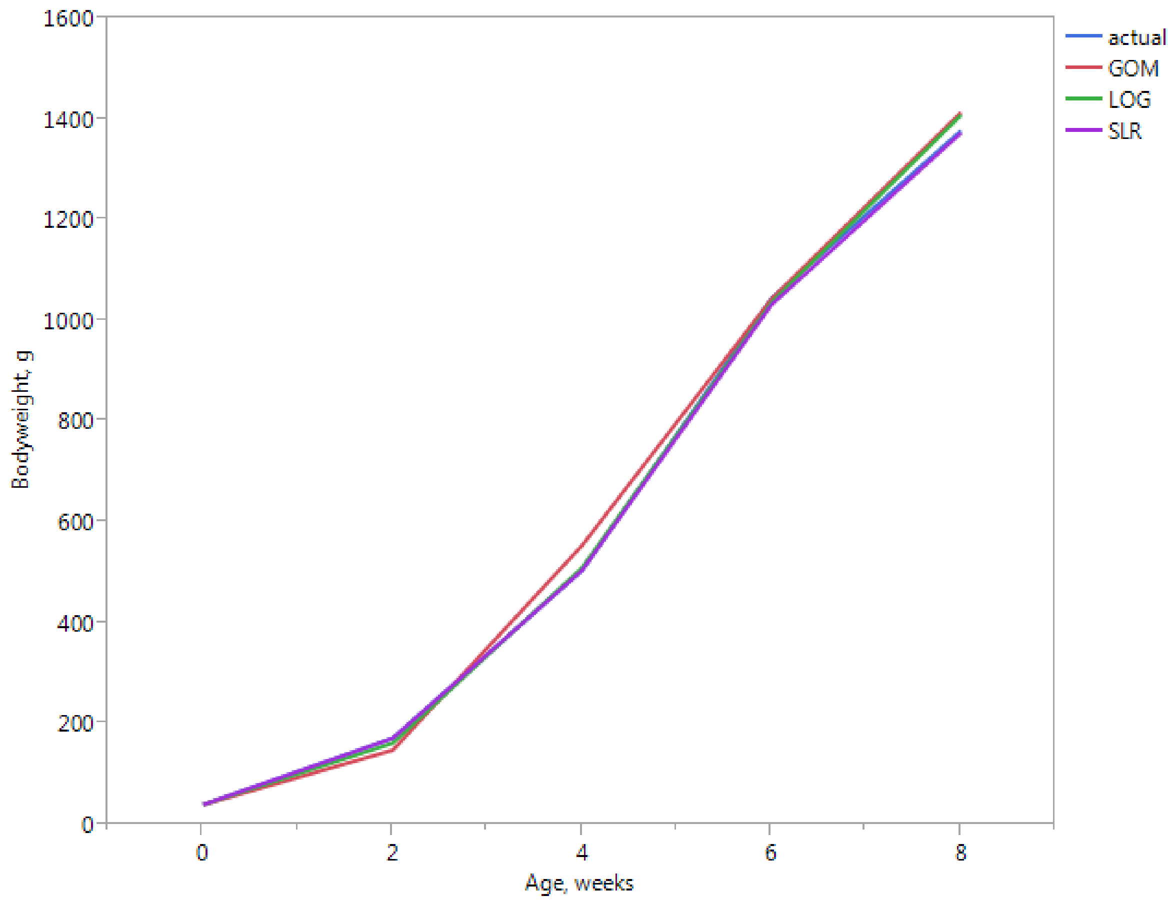

Figure 4. 2. Growth curve of Ross using Gompertz, Logistics and Simple Linear Regression

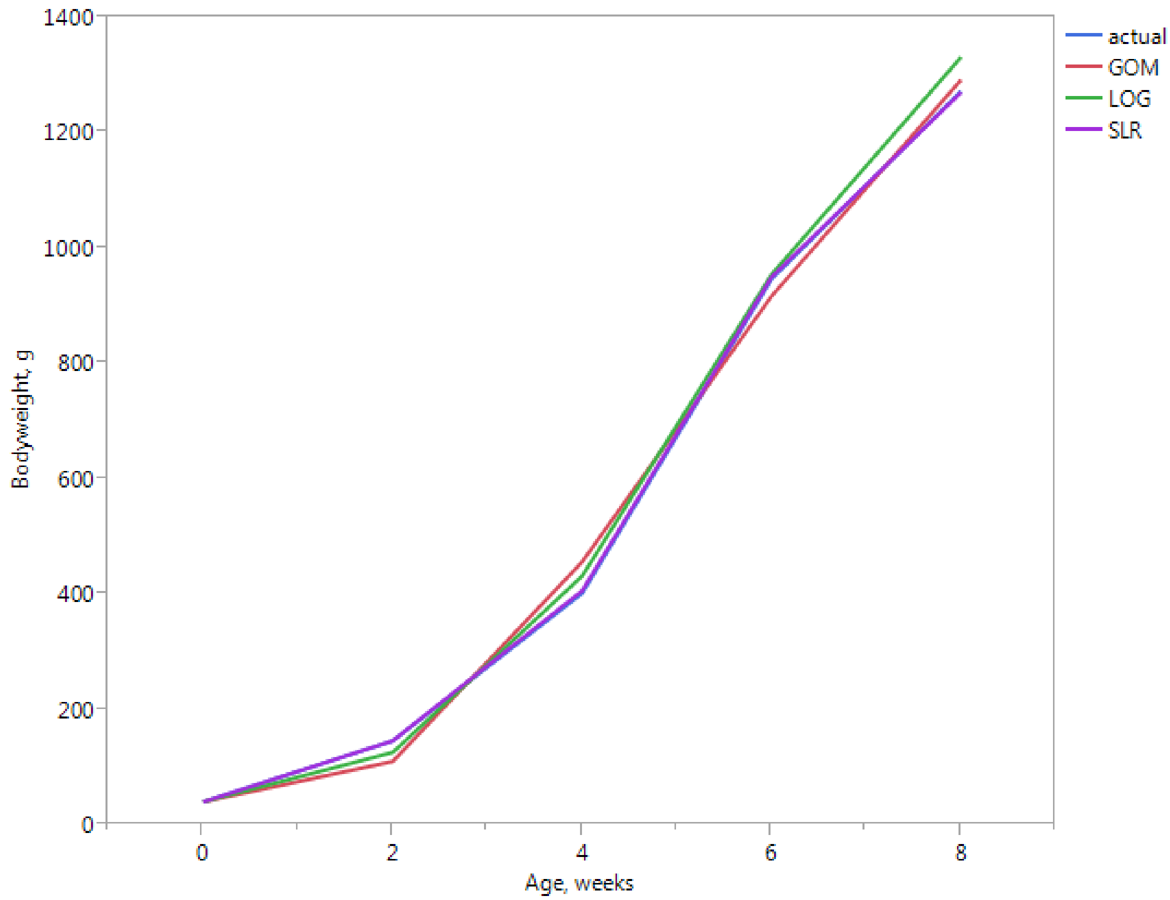

Figure 4. 3. Growth curve of Marshal using Gompertz, Logistics and Simple Linear Regression

CHAPTER FIVE

5.0 DISSCUSSION

5.1 Body Weight and Body Linear Measurement of all the Strains

The result of body weight and body linear measurements in all the strains increases as age advances in this study. This is in agreement with the reports of Adeyinka *et al.* (2004), Udeh *et al*. (2011) who reported that age is a major determinant of growth and physiological development. The average bodyweights of 1458.96g, 1377.54g and 1272.06kg attained by Arbor Acre, Ross and Marshal respectively at 8 weeks of age were in line with the report of Akanno *et al*. (2007) that broiler birds attain a market weight of 1.20-2.00kg at 8-10 weeks of age. Body weight gain at 8 weeks of age were similar among Arbor Acre (1458.96g) and Ross (1377.54g) strain but significantly ($p<0.05$) higher than the value for Marshal (1272.06g). This is line with the report of Udeh and Ogbu, (2011) that, Arbor Acre and Ross broilers had greater genetic potential for growth compared with Marshal.

Arbor Acre and Ross were significantly ($p<0.05$) superior to Marshal broilers for body weights at 2, 4, 6 and 8 weeks of age. A similar result was obtained by Udeh *et al.* (2011) who reported that Arbor Acre and Ross were superior to Marshal in body weight at 8 weeks of age. The report of Amao *et al.* (2011) that Ross was superior to Marshal at 8 weeks of age also agrees with the result obtained in this study. Strain effect on body weights of chickens and different age in this study agrees with the finding of Ajayi and Ejiofor (2009), Enaiat *et al*. (2010), Razuki *et* al. (2011) , Ojedapo *et al.* (2011) who observed significant strain effects on live body weights of broiler chicken slaughtered for carcass evaluation at 8-12 weeks. However, the result contradicted those of Olawumi *et al.* (2012) who found Marshal is superior to Arbor Acre in body weight at 8 week of age.

5.2 Biochemical Traits

The values of all the traits in this study were not significantly different between the strains, however they were within the range reported by Obikaonu *et al*. (2011), Etuk *et al.* (2012) and Olukomaiya *et al.* (2014) for healthy chickens except for total protein, glucose and albumin level which appear to be lower than the values reported by these authors. These differences could be due to feed administer to the birds or due to genetic variation of the birds used (Meluzzi *et al.,* 1992; Simaraks *et al*., 2004). Most of the traits observed in this study increased in values as the birds advanced in age. This could be due to feed administer to the birds for growth and physiological functions as reported by Nworgu *et al*.(2007), Polat *et al*. (2011) and Etuk *et al.* (2012) that change of feed from starter to finisher phase could change the blood profile. Creatinine and total protein had lower value at 8 weeks and when compared to the values at 4 week of age in Arbor acre, Ross and Marshall strains. This might be attributed to change in feed from starter to finisher ration as reported by Abdi-Hachesoo *et al.* (2011).

5.3 Carcass Traits

The findings of this study indicating higher live body and carcass weights in Ross than Arbor acre and Marshal strain are in full agreement with those of Udeh and Ogbu (2011), Egena *et al.* (2014) and Udeh, (2015). The results showed significant (P<0.05) strain effect in drumsticks weight in Ross and non-significant effects in Arbore acre and Marshall strain. weights of breast, thighs, shank, liver and gizzard were not significantly (P>0.05) between strains. This result is in agreement with the findings of Akanno *et al.* (2007) and Ojedapo *et al*. (2012) who observed insignificant effect (P>0.05) in carcass traits of various broiler strained reared under the management and environmental conditions. However, Slight difference in values of carcasses traits between the strains could be attributed to nutrient absorption effects between the strains and effects due to genetic makeup of birds used in the study (Shafey *et al*. 2001).

5. 4 Correlations between Body Weight and Body Linear Measurement of all Strains, Biochemical Profile Correlation and Carcass Correlation

Correlation coefficients obtained in this study ranged from low to high. Medium to high correlation coefficient between body weight and other linear body measurements implies that high correlations among traits will bring about predictability for the other body traits.(Adeleke *et al.*, 2011). Also, positive phenotypic correlation coefficients varying from low to high were obtained in this study are consistent with the reports of Adebambo *et al.* (2006) and Adedeji *et al.* (2008). These results also indicating pleiotropic effects, suggest that the traits are controlled by the same set of genes or linked genes (Adeleke *et al.*, 2011).

This view is supported by Falconer and MacKay, (1996) who stated that pleiotropic effects are usually important in growth traits. The implication of these result is that bodyweights indicates growth of bodyweights will lead to improvement in body measurement traits**.**

The result of these relationship also shows that increase in the growth rate of any of the component will correspondingly increase body weight (Ajayi *et al*., 2008). The result of these positive correlations coefficient agrees with the findings of Udeh and Ogbu (2011); Udeh *et al*. (2011) who reported positive and high significant (P<0.01) correlations among traits within each strain. A similar observation was reported by Pundir *et al*. (2011) and Ojedapo *et al*. (2012). The positive and significant correlations among carcass traits observed in the three strains of broilers indicate high predictability among the variables. A similar observation was reported by Ajayi *et al*. (2008).

5.5 Comparative Evaluation of Growth Models

In all models studied, the value of coefficient of determination (R^2) and correlation coefficient (r) were highly significant ($P<0.01$) for all the strains. Similar result obtained by Kuhi *et al.* (2003) who found discovered that coefficient of determination and correlation of Lopez, Richards, France, Von Bertalanffy, Gompertz and Logistics above 85%. All the models therefore made a good fitness for growth since R^2 measures the amount of variability accounted for by the fitted model (Akpa, 1999) and any value above 70%, indicates good measures of fitness (Olorunju, 1991).

However, among all the models in all the strains, SLR had higher R^2 and lower MSE compare to GOM and LOG. This is an indication of better body weights prediction efficiency of SLR than GOM ad LOG in the three strains. This is in agreement with the report of Aggrey, (2002).

The results of the present study disagree with the previous results by several researchers (Gous *et al* 1999; Santos *et al* 2005) who confirmed that the Gompertz function was the best function for describing growth curve in broiler. Similarly, some other studies (Kuhi *et al*.,2003; Tompic *et al.*,2011; Moharrery and Mirzaei, 2014) found that the Richards function gave the best fit for growth curve in broiler. These differences could be attributed to effect of breeds and environment conditions. (Wang *et al*., 2004; Sun *et al*., 2006).

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 Summary

This research was conducted at the Poultry Unit of Department of Animal Science, Ahmadu Bello University, Zaria. The aim was to model the body weight and to evaluate some biochemical profiles and growth traits in three strains of broiler chickens (Arbor Acre, Marshal and Ross) using Gompertz, Logistics and Simple linear regressions model with the view of identifying best suited model that define body weight curve in broilers. A total of 225 birds (75 per strain) was used.

The traits recorded at 2, 4, 6 and 8 weeks of age were body weight, shank length, thigh length, body length and breast width while blood biochemical traits recorded at 4 and 8 week included Glucose, Total protein, Total Albumin, Urea and Creatinine. Statistical analysis was using Python Version R 3.0.3 (2010) and Statistical Analysis System (SAS, 2000). Arbor Acre and Ross were significantly ($p<0.05$) superior to Marshal broilers for body weight at 2, 4, 6 and 8 weeks of age

Correlation coefficient between body weight (g) and body linear measurement (cm) traits for all the strains at age 2, 4, 6 and 8 weeks, respectively were moderate and high and significant ($P<0.05$, $P<0.01$). Blood biochemical traits had low positive to high negative associations within each strain at 4 and 8 weeks of age. Carcass weight had positive and highly significant ($p<0.01$) association with BRW (0.92), TW (0.84) and DS (0.97) in Arbor acre strain. The same trend was observed for other two with corresponding values were 0.82, 0.86, 0.76 for Ross and 0.94, 0.98 and 0.91 for Marshal.

The comparison of growth curves using mathematical models in this study showed that the leading key indicators (lowest MSE, higher coefficient of determination and correlation coefficient), suggest that SLR is more appropriate for describe growth pattern of Arbor acre, Ross and Marshal strains compare to GOM or LOG.

6.2 Conclusion

The following conclusions are drawn from this study:

1. Ross and Arbor acre attained the highest body weights of about 1377.54g and 1458.96g respectively better than Marshal (1272.06g) at 8 weeks.
2. The moderate to high level of phenotypic correlation obtained between BW and most traits is an indication of pleiotropic or gene linkage effect of growth genes for correlated responses.
3. Among all the models in the three strains, SLR turned out to be most appropriate for predicting bodyweight. This model was characterized by minimum error and narrow differences between the actual and predicted values.

6.3 Recommendations

1. Poultry farmers should adopt rearing of Ross and Arbor acre strains for better profit within 8 weeks of age.
2. SLR is the best method for body weight estimation in Arbor acre, Ross and Marshal strains.
3. There is need for another research on modeling of live weight of broilers breeders in order to ascertain the efficiency of the models beyond 56 days of age.

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