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World Rural Observations

MARSLAND PRESS
Multidisciplinary Academic Journal Publisher

Commercial Intensive Poultry Production in Tropical Environments with Particular Reference to Nigerian Poultry Industry

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Abstract: This paper discusses the different production environment factors that influence commercial intensive poultry production at tropical locations such as Nigeria. The intensive production system in the tropics is made up of medium to large-scale commercial enterprises, and characterized by full confinement of birds either in houses or cages. Feed is the most important variable cost component and accounts for 65 to 70% of production costs. The environmental conditions that affect the performance of chicken include ambient temperature, relative humidity, light, sunshine prevailing at a given time, housing system and ventilation. Most producers follow established vaccination schedules and bio-security measures added to strict hygienic practices such as disinfection of equipment and segregation sick birds to control endemic diseases. Urban dwellers seem to consume larger amounts of poultry products due to their relatively higher income levels and greater access to fresh or frozen poultry products sold in markets and fast food outlets. Maximal productivity decisions under the intensive production system could be made by combining all aspects and knowledge of production such as factors related to diet, animal and environment that affect the growth rate of poultry within a computer growth model. Specifically, empirical and mechanistic models that predict broiler responses of growth rate, feed conversion ratio, carcass yield and breast meat yield, to dietary balanced protein levels have been used to stimulate the growth of broiler chickens.
[A.V. Ifeduba, C.C Achonwa, C.P. Ukwu, I.P. Ogbuewu, E.B. Etuk and I.C. Okoli. **Commercial Intensive Poultry Production in Tropical Environments with Particular Reference to Nigerian Poultry Industry.** *World Rural Observ* 2020;12(3):67-84]. ISSN: 1944-6543 (Print); ISSN: 1944-6551 (Online). http://www.sciencepub.net/rural. 6. doi:10.7537/marswro120320.06.

Keywords: Poultry, chicken, feed, meat, egg, broiler

Introduction

Poultry meat and eggs play a very useful role in bridging the protein gap in Nigeria. They are palatable and generally acceptable. Poultry birds mature earlier than most breeds of livestock and can bring economic returns within relatively short periods of about 10 - 12 weeks. The commercial poultry production system as the name implies is industrial in its prototype and therefore based on large, dense and uniform stocks of modern poultry hybrids. This commercial system has become the dominant production system in developed countries, and has also expanded in many developing countries including Nigeria, where it accounts for about 30% of the industry (Geidam *et al.,* 2007). It is one of the most important sectors of the agricultural economy in the country that has experienced significant growth in recent years (FAO, 2000; Geidam *et al.,* 2007). The system is characterized by large vertically integrated production units and use of high producing modern strains of birds.

Poultry production systems are generally influence by factors such as housing (Natukunda *et al.,* 2011), feed sources (Byarugaba *et al.,* 2002), health and diseases (Simainga *et al.,* 2011), marketing/sales (Ali, 2012), socio-economic background of the farmer and birds type (Okoli *et al.,* 2005b). In the commercial intensive systems, feed is the most important variable cost component, accounting for 65 to 70% of production costs (Adene and Oguntade, 2006), since high productivity and efficiency depend on feeding nutritionally balanced feeds that are formulated to meet the bird's nutritional requirements. The system is therefore capital and labor intensive as well as inputs and technology demanding (Leeson and Summers, 2005) in any part of the world, since it is based on the manipulation of genetic and environmental factors that affect the farmed poultry (Chima *et al.,* 2012). The quality feed however, remains the foundation on which commercial intensive poultry productive efficiency is built among other determinants.

Commercial intensive poultry farming provides optimum conditions for the concentration of pathogens and transmission, due to the crowding of thousands of birds in enclosed warm and dusty environments conducive for disease transmission (Chima *et al.,* 2012). Furthermore, selection of birds for faster growth rate and higher meat yield leaves the bird's immune system less able to cope with infections, while the higher degree of genetic uniformity in the population makes disease spread easier (Delany, 2003). Thus, commercial poultry production systems are influenced by endemic factors such as type of birds, housing, socio-economic background of practitioners, disease incidence, financial sources and feeding as well as products disposal methods and channels (Adedeji *et al.,* 2013).

This review paper discusses the different production environment factors that influence commercial intensive poultry production at tropical locations such as Nigeria.

Poultry Genetic Resources

Breeds of poultry today are better in egg numbers, egg weight, fertility, hatchability, growth rate, body conformation, meat yield, egg and meat quality and other variabilities that maximize the efficiency of production and increase profitability than they were one hundred years ago (Ifeduba, 2018). Much of this progress in poultry efficiency is the result of the use of good breeding programmes based on application of the principles of genetics that has allowed breeders to select birds for desirable characteristics (Tuleun, 2008). A breed is a group of related individuals that possess the same ancestry and are true for a number of characteristics that identify the breed. Breed recognition is conferred by a recognized breeders' association that registers the breed. Thus, all breeds and varieties of chicken farmed today are due to natural selection to produce those that are now commercially exploited (NOUN, 2011).

There are many methods of classifying chicken depending on different principles. These include biological classification, economical classification and geographical classification (Khalid, 2011). Under economical classification, chickens could be regarded as egg, meat or dual purpose types. The egg type breeds have small body size and slower growth rate. Examples are Harco, Ancona, Rhode Island Red, Black Leghorn, White Leghorn etc (Smith, 2001; Khalid, 2011). The meat type breeds are raised for meat production. They have large body size and also heavy breeds that grow faster than the egg type breeds. Examples are Light Sussex, White Sussex, White Wyandotte, Plymouth Rock and Anak (Smith, 2001; Khalid, 2011). The dual purpose birds are raised for both meat and egg production and include the Light Sussex, Rhode Island Red, and Plymouth Rock, New Hampshire etc. In today's economic reality, in developed countries, dual-purpose breeds are regarded as inefficient, producing neither meat nor eggs very efficiently. However, in Nigeria dual-purpose birds can be very useful, especially in less intensive systems of production. For example, the cocks are used for meat production and the hens for the production of both eggs and meat. Both are considerably older when slaughtered than are broilers and therefore, have more flavor (Khalid, 2011).

Geographical classification from the Nigerian perspective is based on the whether the bird is exotic, local or hybrid. The exotic breeds include the Rhodes Island Red, Leghorns, Light Sussex, Barred Plymouth Rock and Harco among others (Smith, 2001). The local breeds are the birds' peculiar to the West African sub-region. They are generally small with tough flesh, are poor layers but good brooders. Their feather varies in color from white to black including multi-color mixtures. The hybrids are commonly seen and use in commercial farms. They are generally high yielding in both meat and egg production and are fast replacing most standard birds (NOUN, 2011).

Poultry Production Systems

There are many husbandry systems employed in the poultry industry with each representing a particular economic method of poultry production under a given situation. The type or class of chicken and farm location plays a major role with respect to the rearing system adopted (Okoli *et al.,* 2005b). The systems which are most suited to small-scale poultry husbandry are free range, in which the birds can roam at will over an extensive area; intensive, in which the birds are wholly confined, such as the deep-litter system; and semi-intensive, in which the birds are partially confined, but have at least occasional access to an outside run or scratching shed or straw yard (Adene and Oguntade, 2006). Among these, the extensive or the traditional systems are not only favored by small of farmers, but already have a place in many developing countries (Bailey *et al.,* 2010).

Nigeria is now the sixth most populated nation in the world after China, India, USA, Indonesia and Brazil with more than 180 million persons (NPC, 2014). Poultry outnumbers all other forms of livestock in Nigeria, and, not surprisingly, is found throughout the country wherever there is human settlement. Typically, they are maintained under traditional, low input, free-range management systems, but substantial numbers are also reared intensively on commercial basis, particularly in the southern states of Nigeria. Commercial holdings account for some 10 million chickens, or 11 % of the total estimated population of 82.4 million (Okeudo, 2004; Adene and Oguntade, 2006; Fayayola *et al.,* 2013).

Poultry production in Nigeria applies to a wide variety of birds of several species including chicken, guinea fowl, pigeons, ducks, geese, turkey etc (Koeslag, 1992). These different types are found in the small - holder poultry system of Africa, defined as family poultry. These birds in their natural habitat scavenge for their food and seek shelter in natural surroundings in trees and bushes. Over the years, human has intervened on their natural habitat through domestication and research which have resulted into different management systems (Amao *et al.,* 2010). Thus, there are two distinct production systems in Nigeria; namely commercial and rural poultry production system as found in most developing countries of Africa and Asia (Adene and Oguntade, 2006). Each of these two systems is associated with characteristics of stock, scale, husbandry and productivity that define it as a distinct production system. However, the industry is essentially a two-way production system in which the traditional or rural production system exists side by side with the commercial system (Chima, 2011).

Intensive Poultry Production System

In Nigeria the intensive poultry production system is practiced by medium to large-scale commercial enterprises, and also at the household level. Birds are fully confined either in houses or cages. Capital outlay is higher and the birds are totally dependent on their owners for all their requirements; production however is higher (FAO, 2004). This system of management is not easily affordable or practiced by peasant farmers. In addition, it is not practiced using native chickens in Nigeria due to high cost of housing, feeding, medication and other veterinary services and facilities. The intensive system of managing native chickens can only be found on the research farms whose results have not been properly documented (Ikani and Annatte, 2000). There was a boom in intensive chicken production in Nigeria in the early 1980s, when the government of Nigeria subsidized the prices of day old chicks and feed ingredients (Farayola *et al.,* 2013). There are three types of intensive systems; deep litter, slatted floor and battery cage system.

(a) Deep litter system: Under this system, birds are fully confined (with floor space allowance of 3 to 4 birds/m^2) within a house, but can move around freely. The floor is covered with a deep litter (a 5 to 10 cm deep layer) of grain husks (maize or rice), straw, wood shavings or a similarly absorbent (but non-toxic) material. The fully enclosed system protects the birds from thieves and predators and is suitable for specially selected commercial breeds of egg or meat-producing poultry (layers, breeder flocks and broilers) (FAO, 2004).

(b) Slatted floor system: Wire or wooden slatted floors are used instead of deep litter, which allow stocking rates to be increased to five birds/m^2 of floor space. Birds have reduced contact with faeces and are allowed some freedom of movement.

(c) Battery cage system: This is usually used for laying birds, which are kept throughout their productive life in cages. There is a high initial capital investment, and the system is mostly confined to large-scale commercial egg layer operations.

Poultry Production Environment

The environment in the poultry pen is a combination of physical and biological factors which exist as a complex dynamic system of social interaction, husbandry system, light, temperature and the aerial environment (Sainsbury, 1992).

Nutritional environment of intensive poultry

There is no other factor that is directly or indirectly related to proper nutrition and high performance of poultry that is more critical than feed quality evaluation, control and ration consistency (Richardson, 1994). According to Jones (2005), under commercial production, the overall mission of feed formulation and manufacturing is to provide farmers with efficiently manufactured feeds that are correctly delivered to their facilities and consistently contain the available materials required by animals for body maintenance, growth and reproduction having considered the nutrient and physical characteristics of the feed raw materials.

The nutrition of animals involves various activities that result in the conversion of feed into animal tissues or animal products such as, egg, meat and milk (Richard and Church, 1998). Pond *et al.* (1995) defined nutrition as a series of processes by which an organism takes and assimilates food for promoting growth and replacing worn out tissues. Also, Obioha (1992) defined nutrition as a process which provides nourishment to a living organism and thus the food which a living organism takes in is used primarily for two major purposes; maintenance and productive function. Olomu (1995) emphasized that in modern poultry, nutrition is more critical than in other farm animals because poultry birds are usually reared in confinement. Poultry are also more active and more sensitive to environmental influences than other farm animals. Again, poultry have high growth rate, intensive metabolic rates and rapidly developed reproductive organs. Therefore, during the first ten weeks of post embryonic growth, the weight of broilers may increase about thirty to forty times and such rate of growth has not been encountered in other farm animal (Obioha (1992). The ultimate aim of poultry nutrition is to increase the productive efficiency of the poultry. The economic importance of intensive poultry feeding becomes apparent, when it is realized that feed is the highest single cost factor, about two third of the total production cost (Esonu, 2006). Thus, many cases of poultry business failures can be traced to poor or improper feeding of the birds (Adene and Oguntade, 2006). Therefore, it is pertinent that the right nutrients in adequate quantities must be supplied to the birds after proper evaluation (Richard and Church, 1998).

Poultry feeding in Nigeria

Feed types: Different kinds of chicken feeds are available as commercially or home manufactured feeds in Nigeria. Commercial feeds in most cases will come in the form of dry mixtures called mash and sometimes pellets or crumbles. Whether commercial or home mixed, feeds must match the different protein needs of chicks, broiler and layers. It is the protein content which distinguishes what feed should be given to different ages and types of chicken (Okoli, 2005). Among the methods of feeding chickens are all mash, pellet or crumbles, whole grain and cafeteria system (Okoli, 2005; Tuleun, 2008).

(a) The all mash system: This is the use of a complete ground feed, which is adapted to use in the mechanical feeding system.

(i) Wet Mash: Chicken usually eat more wet mash than dry because they enjoy its consistency. However, wet mashes, particularly in hot weather, go bad very quickly, hence only an amount which will be consumed within two hours should be feed.

(ii) (Dry Mash: When it is well balanced and sorted properly, dry mash usually is the best way of feeding confined chickens. According to Tuleun (2008), it is commercially sold with designations; Chick mash (contains 20 % protein); Grower mash (contains 16 - 17 % protein); Broiler mash (contain 20 - 23 % protein); Layer mash (contains 15 - 17 % protein).

(b) Pellets or crumbles: Commercial mixtures in pellet or crumble forms are excellent but usually cost more than mash. Chickens may produce slightly better with the pellet/crumble forms. Pellet and crumble feeds reduce feed waste and the chickens may eat them a little better.

(c) Whole grain: Feed is often used as whole grain, either by itself or mixed with other nutrients. Sometimes whole grain is scattered in the litter. The whole grain method of feeding is however not recommended for commercial farming systems. When fed with other ingredients, the grain is eaten first, resulting in improper diets, when scattered, much is contaminated or lost.

(d) The cafeteria system: This allows the birds to balance their own rations. Grain is fed in one feeder and high (26%) protein supplement is fed in another feeder. Feed is kept in feeders at all times. Older birds may tend to eat too much grain and not enough protein supplements when this system is used (Esonu, 2006: Tuleun, 2008).

Feeding practice: The success of raising poultry depends very much on adequate feeding of the birds. Feed is offered to poultry at all times (*ad libitum*) or controlled (restricted) (Esonu, 2006; Tuleun, 2008).

(a) The unrestricted/ad libitum feeding programme: Feed must be available to birds at all times. This practice is commonly referred to as *ad libitum* feeding. This method of feeding allows the poultry to consume feed to appetite or want. Birds raised for meat (broilers) are preferable fed *ad libitum*. Advantages include more uniform weight attainment at maturity, feed management technique is less complicated as compared to feeding regime in feed restriction program, since birds that feed themselves at will are less stressed up (Esonu, 2006). Disadvantages include facts that birds may overeat and increase feed cost during rearing period, while meat type (broiler) breeders tend to overeat and grow excessively, thus compromising production efficiency and profitability, since overweight broiler breeders are prone to prolapses, reduced fertility, hatchability and reproductive failures (Tuleun, 2008).

(b) The restricted/controlled feeding programme: Feed is supplied to the birds in limited quantity and/quality. The strains of birds must be grown on the controlled feeding programme to limit weight, particularly with broiler breeder strains. The female feed intake may be adjusted to delay egg at sexual maturity to maintain desired body weight and reduce prolapses (Tuleun, 2008). If the birds are overweight, some form of feed restriction may be imposed. It is advisable to start the restricted feeding programme from 6 weeks of age, although some breeders recommend earlier ages (2–3 weeks of age). Advantages include reduction in the cost of feeding the birds during the growing period. Feed restriction may also result in later maturing birds that lay larger eggs at the initial period, the birds may have less fat, thus protecting the birds from breeding problems due to excess fat. The practice may also lead to the production of more hatchable eggs during the laying year. Disadvantages include the facts that management of restricted feeding programme is more complicated than *ad libitum* feeding. Birds may be more uneven in body size mainly because of the differential feed intake of “boss” vs. “timid” birds. It is more troublesome to feed the birds because they fight among themselves in a bid to get at the feed thus increasing cannibalism and mortality problems (Tuleun, 2008).

Feed quality: Given the increasing number of people venturing into poultry business in Nigeria and the consequent high demand for commercial feeds, there is increasing tendency for feed manufacturers to produce substandard feeds, especially as the quality control agencies in Nigeria are less concerned or non-functional (Okoli *et al.,* 2007; Omede, 2008., Okoli, *et al.,* 2009). It appears the farmer, consumer and the public at large are left at the mercy of commercial feed millers and feed raw materials suppliers and processors. This is not an exaggeration considering the fact that feeding poultry alone accounts for not less than 70% of cost of production (Adebowale *et al.,* 1998; Oyediji, 2001), depending on the region and season of production (Amir *et al.,* 2001). It appears the manufacturers are aiming at high profit margins instead of focusing on quality of their feeds (Jones, 2005).

Factors that determine the nutritive quality of feeds and feedstuffs are numerous. The fact that a feedstuff is eaten by animals is only an indication of acceptability. Usually feedstuffs have physical, nutritional and toxicological characteristics (Omede, 2008; Okoli *et al.,* 2012). The nutritional characteristics could be divided into the biophysical and biochemical components that determine nutrient uptake and availability respectively (Okoli *et al.,* 2009). Information on the proximate composition and sometimes toxicology of novel feedstuffs has been used routinely in determining the suitability of such feedstuffs in poultry feeding, especially during animal feeding trials (Esonu, 2009). Also, too much emphasis is usually laid on the analyses of crude protein and fibre as indicators of the nutritive quality of feeds and feedstuffs (Soetan and Oyewole, 2009). Limited information however exits on the biophysical characteristics of such novel feedstuffs (Okoli *et al.,* 2009). Biophysical characteristics such as Bulk Density (BD), Water Holding Capacity (WHC), Particle Size (PS) and Specific Gravity (SG) play important roles in controlling feeding (Nir *et al.,* 1994; Kyriazakis and Emmans, 1995; Makinde and Sonaiya, 2007), and thus productivity of birds. All available information, both qualitative and quantitative must be used in making judgments about the quality of feed (Soetan and Oyewole, 2009).

Feed quality among other things therefore, includes appropriate particle size and moisture content of the diet fed to highly productive lines of animals (Omede, 2010). Feed quality maintenance usually includes appropriate milling of the feed ingredients, proper storage and packaging as well as proper handling during marketing of the bagged feeds at the various sales outlets from where the farmers collect to feed their animals (Okoli *et al.,* 2013). Particle size and water holding capacity together with bulk density also play important role in feed quality since they influence feed intake (Okoli *et al.,* 2009; Omede, 2008) and thus the productivity of animals, especially poultry.

Litter Environment and Management

Birds pass out concentrated waste (uric acid) making it possible to house a lot of birds on litter with the major problem of only moisture buildup (Jesse, 2004; Asaniyan *et al.,* 2007). A good poultry litter is started using adequate materials applied to a depth of at least 2 cm (Cool sand), 5-10 cm (wood shavings), 10 cm (chopped straw) and 8 cm for any other litter material on a dry damp-free floor (Moore *et al.,* 2004; Asaniyan *et al.,* 2007). For a litter to be well managed, considerations must be given to such factors as type of litter material used at the time of the year, depth of the litter, floor space per bird, feeding and watering devices, kind of floor, ventilation system, routine litter management practices, litter amendment procedure and incidences of disease that can have effects on litter value (Asaniyan *et al.,* 2007). Environmental and indoor conditions of poultry houses (temperatures, flock density and air movements) have significant influences on litter quality and NH_3 emissions (Terzich *et al.,* 1998; Meda *et al.,* 2011). Deep litter management despite its importance seems to be neglected in poultry industry in Nigeria (Ezeokoli *et al.,* 1984).

Depth of the litter varies with the type of litter material in use and will influence performance particularly if it prevents dust bathing (Moore *et al.,* 2004; Asaniyan *et al.,* 2007). High stocking density leads to decreased water and gas exchanges between air and litter (Meda *et al.,* 2011), high chances of feed and water spillage due to space competition, high secretions and excretions in the litter, and high temperature and ammonia build up in the poultry house. (Okoli, 2004). This will subsequently lead to high chances of bad litter occurrence, while naturally well ventilated poultry houses with relatively light stocking densities maintain a good litter. Litters, if well managed can be changed between crops or commonly changed when they appear bad or following diseases outbreaks in most places. Poor litters are dusty, wet and cake easily, while a good litter should adhere slightly and easily breaks up when dropped from the hand (Oluyemi and Roberts, 2000). When litter is too wet, it normally balls up if squeezed in the hand, while too dry litter does not normally adhere (Anonymous, 1990). Litter materials on earthen floors have been reported to hold as much as 30% moisture making it almost impossible to effectively manage than litters on damp-proofed concrete floors (Terzich *et al.,* 1998). If the back of the hand feels damp when applied onto a litter, then it possibly contains at least 30% moisture which encourages breast blisters, rapidly converts uric acid to toxic ammonia and supports the growth of fly larvae and coccidian organisms (Anne, 2007).

Litter management has few rules but most decisions are subject to operator’s judgment. Litter materials should be checked for bacterial and fungal contaminations, while fine particle litter materials should be covered with paper to avoid litter eating.

New litter material should be treated with approved antifungal agents, while litter intended to be reused should also be treated with lime (Anne, 2007). Special attention should be paid to drinker points, since such areas are liable to caking and should be rotated to activate litter or removed and fresh litter material added (Sanjay *et al.,* 2006; Anne, 2007). However, tilling of litters is frequently associated with rapid increase in ammonia levels in poultry houses and therefore usually done with windows open or fans on to rapidly dissipate the ammonia (Anne, 2007). A working litter warms the poultry house, while a wet litter cools the house by taking away heat in the process of drying out (Ruszler and Carson, 1968).

Ammonia levels of 15 - 20 ppm in the poultry pen is acceptable and can be estimated fairly accurately by using the operators sense of smell or litmus paper or more accurately using a dragger gas detector which is commercially available (Xin *et al.,* 2002). Ammonia build up beyond 40 ppm is potentially dangerous to the birds and the operator (Ritz *et al.,* 2004; Okoli *et al.,* 2004, 2006). The consequences in birds include decrease feed intake and productivity, as well as respiratory tract infections and blindness (Wheeler *et al.,* 2004). The concept of litter amendments has shown drastic reduction of ammonia levels in poultry houses thereby improving birds health and performance (Sanjay *et al.,* 2006).

Poultry litter amendments to effectively control ammonia levels involves application of acidifiers, alkaline materials, absorbers, inhibitors, microbial and enzymatic treatments, superabsorbent polymers and even dietary manipulations (Blake, 2001; Sanjay *et al.,* 2006; Meda *et al.,* 2011; Timmons and Harter-Dennis, 2011). Acidifiers such as alum, sodium bisulphate, ferrous sulphate and phosphoric acid are the most effective and widely used poultry litter amendment and work by creating acidic conditions in litter so that ammonium rather than ammonia is retained and this helps facilitate bacteria and enzyme inactivity so that ammonia is not produced in the litter (Sanjay *et al.,* 2006; Moore *et al.,* 1996). Alum reduces NH_3 by 71 -92%, while phosphoric acids reduce it by 56 - 92% (Moore *et al.,* 1996). They suppress ammonia levels below 25 ppm for 3 - 4 weeks post application and improve in-house air quality in poultry houses (Sanjay *et al.,* 2006).

According to Sanjay *et al.* (2006) alkaline materials like agricultural lime (CaCO3), hydrated or slaked lime ($Ca(OH)_2$), or burnt lime (CaO) work by increasing litter alkalinity (pH>7) which help to convert more of the ammonium within litter to gaseous ammonia that can be readily lost through venting so that lower ammonia level is achieved when next batch of chicks are brought. However, this practice is associated with loss of soluble phosphorus level in litter with low fertilizer value and may have negative impact on the environment as ammonia levels may later increase significantly when fresh manure is added to the litter. Absorbers like certain natural clay types (zeolite) and peat are good in adsorbing ammonia and lowering ammonia levels if used in poultry houses. Inhibitors in poultry litter slowly convert uric acid and urea to ammonia by the process of inhibiting enzymes and microbial activities. For example, phenyl phosphorodiamidate was reported to inhibit urease activity and reducing conversion of urea in to ammonia (Sanjay *et al.,* 2006).

Microbial and enzymatic treatment of litter uses beneficial microbes and enzymes which can convert uric acid and urea fairly rapidly into ammonia which can then be vented out thereby reducing the ammonia levels before chicks are placed in the house later. Such microbial products like USM-98 or Yucca schidigera extract as a natural feed additive were reported to significantly lower ammonia levels, improve bird weights and reduced mortality (Sanjay *et al.,* 2006). Other dietary manipulations involve reducing the nitrogen intake per bird by reducing the crude protein in poultry diet, because ammonia is formed by the breakdown of undigested protein and uric acid in the manure. A 1% reduction of CP resulted to 10 - 22% reduction in NH_3 emission (Meda *et al.,* 2011). Increased age and weight at slaughter will influence NH_3 emissions because nitrogen excretion per day per bird increases with increasing daily feed intake (Amanullah *et al.,* 2010).

The Nature of Poultry Waste

The major components of poultry waste include the bedding material, feather, the split feed and manure (Kelley *et al.,* 1996; Tasistro *et al.,* 2004). The manure contains considerable amounts of nutrients such as nitrogen, phosphorus, and other excreted substances such as hormones, antibiotics, pathogens and heavy metals which are introduced through feed (Steinfeld *et al.,* in FAO, 2006b; Bolan *et al.,* 2010). As with other organic wastes, the moisture content, pH, soluble salt level and elemental composition of poultry manure and litter have been shown to vary widely as a function of types of poultry, diet and dietary supplements, litter type and handling and storage operations (Bolan *et al.,* 2010).

Nutrients: Birds reared in intensive production systems consume considerable amounts of protein and other nitrogen-containing substances in their diets. The conversion of dietary nitrogen to animal products is relatively inefficient; 50 to 80% of the nitrogen is excreted (Arogo *et al.,* 2001). Nitrogen is excreted in both organic and inorganic forms. Nitrogen emissions from manure take four main forms: ammonia (NH_3), dinitrogen (N_2), nitrous oxide (N_2O) and nitrate (NO_3^-).

Phosphorus is an essential element for animal growth but unlike nitrogen, phosphorus is relatively stable once attached to soil particles and does not leach through the soil into groundwater. It does not pose any environmental risks except as a nutrient; it limits biological activity in water resources and builds up in soil when applied in excess (Okoli *et al.,* 2005). Phosphorus emissions from manure occur in one main form: phosphate (P_2O_5).

Heavy metals: Manure contains appreciable quantities of potentially toxic metals such as arsenic, copper and zinc (Bolan *et al.,* 2004). In excess, these elements can become toxic to plants, can adversely affect organisms that feed on these plants, and can enter water systems through surface run-off and leaching (Gupta and Charles, 1999). Trace elements are introduced into poultry diets either involuntarily through contaminated feedstuffs or voluntarily, as feed additives used to supply the birds requirements or, in much greater proportions, as veterinary medicines or growth promoters.

Drug residues: Antimicrobial agents are administered to poultry for therapeutic reasons or to prevent illness. At much lower doses, antimicrobial agents are used as feed additives to increase the rate of growth and to improve feed efficiency (Campagnolo *et al.,* 2002; Steinfeld *et al.,* in FAO, 2006). Irrespective of dosage, an estimated 75% of antimicrobial agents administered to confined poultry may be excreted back into the environment. Some studies suggest that the interaction between bacterial organisms and antimicrobials in the environment has contributed to the development of antimicrobial-resistant bacterial strains (Chee-Stanford *et al.,* 2001). Campagnolo *et al.* (2002), in a study that evaluated the presence of antimicrobial compounds in surface water and groundwater resources proximal to intensive poultry operations, found antimicrobial residues to be prevalent or present in 12 water samples collected proximal to poultry farms.

Pathogens: Manure also contains pathogens which may potentially affect soil and water resources, particularly if poorly managed. Parasites such as cryptosporidium and giardia *spp.* can easily spread from manure to water supplies and can remain viable in the environment for long periods of time (Bowman et *al.,* 2000).

Aerial or Gaseous Environment and Management

Air hygiene is an important factor to be considered in intensive poultry production as it has considerable impacts on the health and wellbeing of farm animals and staff as well as the outdoor environment of the farming enterprise (Nwagwu *et al.,* 2012). An adequate environment within the poultry house is a very important requirement for success in the industry.

Over 100 gaseous compounds are found in the air of poultry buildings (Hartung, 1988), and include aerial ammonia, carbon monoxide, sulphur oxide, hydrogen sulphide, nitrous oxide and flammable gas (methane), among others. Most are simple odorants, which may give rise to complaints among neighbors, while some are greenhouse gases (Wathes, 2001). In Nigeria, concentrations of most of the gases are usually in the range of parts per million or lower with the exception of carbon dioxide which may record concentration levels 5 to 10 times higher than the ambient (Okoli *et al.,* 2004; Nwagwu *et al.,* 2011). These gases have economic and public health importance in poultry production. For example, their concentration levels and emission rates in poultry buildings when high, eventually result in health problems among birds and workers (Okoli *et al.,* 2006). Their public health importance is predicted on the disease they may cause in workers, when their levels become high in the pens (Okoli *et al.,* 2004).

Most studies of noxious gases in livestock pens have focused upon ammonia probably because of its toxicity and role in acid rain formation (Nwagwu *et al.,* 2011). Ammonia concentration in poultry pens varies depending upon several factors, including temperature, humidity, animal density and ventilation rate of the facility. Chickens exposed to ammonia show reduction in feed consumption, feed efficiency, live weight gain, carcass quality and egg production (Reece and Lott, 1980).

Micro-organisms in the litter convert birds excreta and spilled feeds to ammonium ($NH4^+$) which is soluble in water and is convertible to ammonia in the presence of high pH and temperature (Sanjay *et al.,* 2006). On the other hand, a high ammonia level in litter is reported to increase fertilizer value but with a consequence of environmental pollution posing health hazards to neighbors. Ammonia in the presence of rainfall contributes to soil acidification and also facilitates algae growth in water bodies (Sanjay *et al.,* 2006). There is a growing concern in regulating ammonia emissions from livestock worldwide. Ammonia emission could be reduced with regular litter change, use of appropriate litter material, decreased manure moisture and improved indoor conditions (Meda *et al.,* 2011).

Studies on the effects of dust in animal housing generally indicate potential for adverse effects on the health, growth and development of animals (Janni *et al.,* 1985; Feddes *et al.,* 1992). Repairable aerosol particles within poultry housing have been shown to decrease bird growth, increase disease transfer within flocks and condemnation of meat processing plants (Simensen and Olson, 1980). Optimal relative humidity of 60 – 70% has been recommended for laying houses, however, in case of low relative humidity, concentration of dust particles may increase and may be followed by a corresponding increase in respiratory diseases among chickens (Kocaman *et al.,* 2006).

Climatic Environment and Management

When ambient temperature is high, chickens have higher energy needs than when in thermos-neutral environments (Pagot, 1992). Poultry flocks are particularly vulnerable to climate change because there is a range of thermal conditions within which they are able to maintain a relatively stable body temperature in their behavioral and physiological activities (Oluyemi and Roberts, 2000). Hence, birds can only tolerate narrow temperature ranges to sustain the peak of their production for human consumption and any unpredictable climatic changes will therefore trigger a series of adjustment and readjustments by poultry birds in the struggle for survival which may have negative consequence on the viability of poultry production (Okoli, 2004). The environmental conditions affecting the performance and optimal productivity of chicken include temperature, relative humidity, light, sunshine prevailing at a given time, housing system and ventilation (Okoli, 2004; Elijah and Adedapo, 2006). Ambient temperatures significantly influence the survivability and performance of the poultry production. Climate change alters global disease distribution, affects poultry feed intake, encourage outbreak of diseases which invariably affects poultry output and also cost of production (Guis *et al.,* 2011).

Elijah and Adedapo (2006) reported in their study that high rainfall and relative humidity provide conducive environment for breeding of parasites that causes outbreak of diseases, which invariably reduces egg production. They further reported that high temperature reduces the feed intake of poultry birds because more energy is needed to conserve the heat produced due to high temperature, hence, a decreased in the rate of feed intake. The environmental temperature within which poultry are able to keep a constant body temperature with minimum effort (thermos-neutral zone or comfort zone) ranges from 16 - 26°C (Diarra and Tabuaciri, 2014). Environmental extremes have deleterious effects on the productive performance and wellbeing of all domestic animals. Hot ambient temperatures above zones of thermo-neutrality for domestic poultry affect performance and overall adaption to the climatic region (Ilori *et al.,* 2009). For efficient poultry development Scott (1999) emphasized that the temperature of a chicken pen must not go beyond 35°C for any prolong period of time.

Humidity and temperature also have impacts on air quality. Therefore, ventilation is an important consideration for controlling heat, humidity and gas concentrations in poultry houses (Nwagwu *et al.,* 2012). Sterling *et al.* (2003) correlated environmental temperature with many measures of performance including feed and water consumption, body weight, egg production, feed conversion and egg weight. Ellen *et al.* (2000) showed that reduction in egg production under heat stress may be related to altered respiratory pattern, while Sterling *et al.* (2003), showed that reduction in environmental temperature, leads to consumption of more feed in order to maintain body heat.

The Health of Intensive Poultry

Poultry production systems in developing countries are increasingly characterized by rapid changes driven by factors such as human population growth, increased demand for poultry products as income rise with increasing urbanization (Delgado *et al.,* 1998). Climate change effects are also adding to the considerable development challenges posed by these drivers of change (Njoku, 2006). Increasing intensity of environmental stressors and frequency of droughts and flooding events have translated into increased spread of vector borne diseases and macro-parasites, along with the emergence of new diseases and transmissions models (IFAD, 2002). Poultry diseases contribute to important sets of problems within the production system. These include production losses, welfare issues, uncertain food security, loss of income and negative impacts on human health (Ugwu *et al.,* 2017).

Poultry diseases management is made up of two key components; preventive (biosecurity) measures in susceptible flocks and control measures taken in infected flocks (Chima *et al.,* 2012). The probability of infection from a given disease depends on existing farm practices as well as the prevalence rate in host populations in the relevant area (Chima, 2011). As the prevalence in an area increases, the probability of infection increases. According to Wobeser (2002), preventing the entry and spread of disease agents is the most effective way of managing disease. Many of the approaches to poultry diseases management are disease specific, however, improved regulation of flock movement affords better protection. A standard disease prevention program that can be applied in all context does not exist, however, there are some basic principles that are always put in place and include according to Wobeser (2002) the following;

- Elaboration of the poultry health program
- Selection of well-known reliable source the foundation flock. One that can supply healthy stock, inherently vigorous and developed for a specific purpose and free of disease

- Good hygiene, including clean water and quality feed supplies
- Precise vaccination for each batch of flock
- Frequent monitoring of birds for signs of diseases, and when disease problems develop, early, reliable diagnosis and application of best treatment, control and eradication measures for that specific disease
- Disposal of all dead animals by burning
- Maintenance of good records relative to flock health, which include vaccination history, disease problems and medication.

Biosecurity refers to all the management practices aimed at excluding or reducing the potential for the transmission and spread of diseases to animals, humans or an area initially free from the diseases causing agents (Halifa, 2008; Chima *et al.,* 2012). It is a term coined from two words: Bio – life, and Security – protection, with the two main objectives of biosecurity being bio-exclusion and bio-containment (AICP, 2008; USAID, 2009). Either of the two objectives of biosecurity has three components consisting of isolation, containment and sanitation. Biosecurity is of much importance in poultry production in so much that the FAO based the classification of poultry production systems on the levels of biosecurity (Adene and Oguntade, 2006). Strict biosecurity measures in addition to vaccinations, are strategic prevention and control policies adopted to control some contagious poultry diseases as vaccinations alone are not enough to control them under field conditions (Abdu, 2007). Good husbandry practices such as adequate feeding, housing and stocking to avoid overcrowding, good ventilation, proper disposal of wastes, cleaning and disinfection of poultry premises help to keep out infections and their spread (Jordan, 1990; Chima *et al.,* 2012; Omeji *et al.,* 2012).

In rural, traditional systems, disease, particularly Newcastle disease, is the single biggest cause of poultry loss. An estimated 65 % of rural poultry keepers have little or no access to veterinary services, and vaccines are typically only available in large quantities of age-specific doses (Obi *et al.,* 2008). The varied ages and species of birds in smallholder flocks have made it difficult for the government to institute health extension services (Adene and Oguntade, 2006). Commercial producers generally follow established vaccination schedules and bio-security measures. Most operations reduce and control disease outbreaks through hygiene practices such as disinfecting equipment and segregating sick birds (Chima *et al.,* 2012). Large-scale commercial operators often employ their own veterinarians, while medium and small-scale commercial facilities tend to contract with private providers. Most backyard producers do not consult veterinarians; some rely instead on advice from unqualified veterinary impostors (Okoli *et al.,* 2002). These pseudo-experts charge low fees and visit many backyard operations each day, raising the risk of spreading diseases among different flocks (Obi *et al.,* 2008). An example of a recommended vaccination schedule in Nigeria is shown in table 1 (Tuleun, 2008).

Table 1: Vaccination schedule for poultry farmers

Age	Type of Vaccine	Disease	Route
1 day	Newcastle disease vaccine (1st dose)	Newcastle (ND)	Intra ocular (i/o)
2 weeks	Gumboro disease Vaccine (1st dose)	Gumboro	i/o, oral, i/m
3 weeks	Newcastle disease Vaccine lasota (2n dose)	Newcastle (ND)	Aerosol (air spray), oral, i/m,
5 weeks	Gumboro disease vaccine (2nd dose)	Gumboro	i/o, oral, i/m
6 - 8 weeks	Fowl pox	Fowl pox	Wing web stab
7 - 8 weeks	Fowl typhoid /fowl cholera vaccine	Fowl typhoid /fowl cholera	Wing web stab subcutaneously
16 - 18 weeks	Newcastle disease (3rd dose)	Newcastle disease lasota and komorov strain	Subcutaneously
30 weeks	Newcastle disease vaccine	Newcastle disease lasota strain	oral

Source: Tuleun (2008).

Economics of Production

(a) Production costs: For smallholders, poultry keeping is a low-input activity, requiring few financial resources. In commercial operations, feed accounts for a large portion of production costs. Maize, the most common feed ingredient, was banned from import in Nigeria from 2005 to 2008 (USDA, 2010). Maize prices tripled from 2007 to 2008 due to poor domestic harvests, leaving many poultry producers unable to source sufficient quantities for feed (USDA, 2008). Since the import ban was lifted, maize prices have remained high due to rising demand from other sectors and low carry-over stocks from previous years (USDA, 2010). Some producers learnt to substitute cheaper grains, such as sorghum and soft wheat, and tubers like cassava for maize in feed formulations (USDA, 2002; Okoli and Udedibie, 2017).

(b) Trade flows: The government of Nigeria banned egg and frozen poultry imports in 2002 in an attempt to protect domestic producers from foreign competition. Although the ban somewhat curtailed imports due to increased surveillance and seizure by regulatory authorities, frozen products continue to enter the country via land borders (Adene and Oguntade, 2006). Most of the products are re-exports of frozen poultry from European countries, such as the Netherlands, France, and Belgium (USDA, 2002). Prior to the 2002 import ban of poultry products import, the volume of legal frozen poultry imports entering Nigeria was substantial (Obi *et al.,* 2008). Reliable data on the magnitude of imports are unavailable, probably because virtually all imports entered the country unrecorded, without official payment of duties (USDA, 2002). USDA Foreign Agricultural Service, estimated that imports supplied 25,000 tonnes of poultry meat in 2002, or about 21 % of domestic consumption (USDA, 2002). The World Bank estimated that 90% of Republic of Benin's poultry imports are informally re-exported to Nigeria (Andriamananjara *et al.,* 2009).

Traders purchase the frozen poultry in neighboring countries and make unofficial payments to Nigerian border officials to clear border points. The frozen meat is often transported without refrigeration, raising food quality and safety concerns. While most supermarkets have stopped carrying imported frozen poultry to avoid penalties from authorities, local markets still carry the products (USDA, 2002). Estimates of the volume of illegal poultry entering the country are unavailable. Nigeria exports very little poultry to other countries, despite government compensation and tariff incentives that encourage exportation (Obi *et al.,* 2008).

(c) Consumption and consumer preferences: Poultry meat and eggs are still considered luxury foods for many Nigerians. In rural areas, poultry consumption is reserved for special occasions, and meat and eggs typically come from household flocks. Urban dwellers consume larger amounts of poultry due to their relatively higher income levels and greater access to fresh or frozen products in markets and fast food outlets. Eggs are a daily part of the diet in urban areas, while poultry meat is consumed on an occasional basis (Adene and Oguntade, 2006). Throughout the country, demand for poultry meat spikes in December, around Christmas and the New Year, and in April, for Easter (Adene and Oguntade, 2006).

Consumers show a preference for the tough meat that characterizes local poultry varieties. Most poultry meat is used in soups, and meat from non-local birds is too tender to hold up under long cooking times (David, 2004). Consumers prize Guinea fowl eggs over other egg varieties for having a superior taste (Okoli and Udedibie, 2000; Adene and Oguntade, 2006). Poultry are also used for socio-cultural and religious purposes. Households give birds as gifts, and in southwestern Nigeria, chicken entrails are believed to increase libido in older men (Gueye, 2007).

(d) Processing and marketing: In traditional systems, poultry are typically raised for household consumption. The very few sold for income are typically brought to village markets by women and children and sold as live birds (Obi *et al.,* 2008). Buyers from other villages and urban markets often attend village markets to purchase large numbers of chickens and transport them by truck for re-sale in southern cities (Adene and Oguntade, 2006). Smallholders also sell eggs, but up to 50% are estimated to spoil before reaching markets or consumers' kitchens. Backyard, semi-commercial producers sell poultry in live bird markets or directly from their homes or shops. They also sell live birds to distributors for re-sale to hotels and restaurants (Obi *et al.,* 2008).

In the commercial sector, large-scale operators slaughter and process their birds using in-house facilities. About 90% of broilers are processed and sold as frozen chickens, with the remainder sold as live birds (Adene and Oguntade, 2006). Eggs and fresh and frozen poultry meat are sold directly to consumers at the farm gate and open markets, to commercial distributors, and to supermarkets, fast food companies, and hotels and other hospitality industry operators. Poultry products are mainly transported by road in all types of vehicles, including specially designed vans for day-old chicks, refrigerated trucks for frozen products, and cars, buses, trucks, and motorcycles for live birds (Ukwu, 2013). Shipments of day-old chicks are occasionally sent by air (Adene and Oguntade, 2006; Ukwu, 2013).

Modelling of Intensive Poultry Production Processes

Models that can be used to predict performance in animals can be describes as: empirical, mechanistic, deterministic, stochastic static or dynamic models (Zoons *et al.,* 1991).

(a) Empirical and mechanistic models: Empirical models are models in which experimental data are used directly to quantify the relationship mathematically between two or more variables, without any explanation of biological processes (Zoons *et al.,* 1991; France and Dujkstra, 2006). The empirical model can be associated with a curve fitting model for a specific data set.

A mechanistic model describes the relationship between dependent and independent variables, by representing the biological process pathway, in order to predict growth (Zoons *et al.,* 1991). A mechanistic model is constructed by looking at the overall structure of the system under investigation and dividing it into components, which come together to describe the behavior of the whole system (France and Dijkstra, 2006).

(b) Deterministic and stochastic models: Deterministic models describe the average of animal or flock outcome, without taking into account the probability distribution e.g. the nutrition recommendations for feed formulation. In contrast, the stochastic model considers the probability distributions and it has a range of possible outcomes that represent natural variation (Zoons *et al.,* 1991; Black, 1995).

(c) Static and dynamic models: The static model represents the state of the system at only one fixed point of time, or for the mean of a fixed period, whereas the dynamic model takes time as a variable (Zoons *et al.,* 1991; Black, 1995).

Value of models in poultry production

A number of factors related to diet (protein, amino acids and energy concentration), animal (age, sex and genetic potential for growth) and environment (humidity, temperature and flock density) affect the growth rate of domestic chickens. Furthermore, the cost of ingredients is the key factor in determining profitability within the commercial poultry industry. When making decisions for optimal production, such as cost per kg meat yield, all these interacting factors are considered. Making the decisions needed to achieve maximum production can be assisted by combining all aspects and knowledge of animal growth within a computer growth model.

Gous *et al.* (1999) mentioned that it is very important to simulate growth models for each genotype, as an essential step to predicting the effects of different diets, breeds and environmental conditions on broiler performance and profitability. Another advantage of using a growth model is that it can enable manipulation of diet, in order to reduce carcass fat content and to increase protein deposition. Yet another benefit of modeling is that it can be used to explore alternative feed strategies which can reduce the overall cost of production (Hargreave, 2011).

Models application in broiler production

Empirical and mechanistic models are used to stimulate the growth of broiler chickens. The majority of empirical models stimulate growth, based on nonlinear equation (Hancock *et al.,* 1995; Gous *et al.,* 1999; Roush *et al.,* 2006; Zuidhof, 2005; 2009). Eits *et al.* (2005a & b) developed empirical models to predict the feed composition required to maximize performance and profitability in broiler chickens. These models predict broiler responses of growth rate, feed conversion ratio, carcass yield and breast meat yield, to dietary balanced protein levels. These models make it possible to predict the response without actual experimentation under *ad libitum* feed conditions. However, these models cannot deal with compensatory growth, nutrient digestibility and utilization efficiency, or feed restriction.

Other empirical models describe growth as an increase in mass and as a function of time (Gompertz, Logistic, Richards etc). In broiler, the Gompertz model has been used (Gous *et al.,* 1999; Hancock *et al.,* 1995; Roush *et al.,* 2006; Zuidhof, 2005; 2009). In Gompertz model, the growth rate of a biological system is dependent on live body weight and time. The Gompertz equation requires knowledge of the mature live body weight, in order to estimate the parameters within the model. The mature live body weight of the broiler chicken is unknown (Hancock *et al.,* 1995). The method for evaluating the growth of live body and body component in broiler studied, using the Gompertz equation, has been based on data obtained for birds reared between 0 and 12 weeks and before maturity weight (Hancock *et al.,* 1995; Lopez *et al.,* 2007). Hancock *et al.* (1995) reported that at 15 weeks of age, many broilers had stopped growing due to leg problems, and the growth curve was described up to 11 weeks of age only. Commercially, broiler chickens reach slaughter body weight at approximately five weeks and likely without achieving their maximum growth potential. Therefore, the asymptotic values for live body weight and body components are unlikely to represent commercial growth patterns. Lopez *et al.* (2007) predicted empty body weight, protein and fat deposition as a function of time, by using the quadratic model with a good and reasonable accuracy (R^2 greater than 0.97).

The disadvantage of the quadratic model is that there is no mathematical upper boundary for the response of body components growth with increased time, whereas in reality there is a biological limit for body component growth. Zuidhof (2009) described an empirical approach (nonlinear mixed Gompertz model) to predict the growth responses for male and female broilers, under varied metabolizable energy and dietary balanced protein levels. This non-linear mixed model could be extremely useful under a particular condition of the data obtained, but the response of the prediction might be limited under different arrays of data input. All empirical models, so far, have described growth as increasing with feed intake, nutrient intake, body weight or time. These empirical models create equations derived from observations and experiments, but they do not necessarily represent an understanding of biological theories. In contrast, mechanistic growth models prefer to describe the biological process and they are able to be applied and developed within a range of conditions.

A mechanistic growth model that has been widely used in animal science is referred to the work of Whittemore and Fawcett (1976). This model describes the weight gain and carcass composition of a growing pig, as a function of feed intake, feed composition, breed and genetic parameters (maximum protein deposition and minimum lipid to protein ratio). The model is based on portioning the amount of energy and protein taken up by the animal. The energy intake by the animal is first used to meet the maintenance requirement, followed by protein deposition with the physiologically necessary amount of fat, and any remaining energy is deposited as extra fat. In broiler chickens, mechanistic growth models based on nutrient portioning and utilization can be used to predict growth performance, carcass composition and also to estimate an economic feeding strategy (Emmans, 1994; King., 2001; Zoons *et al.,* 1991; Emmans, 1981; Emmans and Fisher, 1986; Gous, 1998). The mechanistic growth model can be used for feed evaluation.

In addition, research findings can be easily incorporated into a mechanistic growth model, which will improve the ability to predict the availability of nutrients (France *et al.,* 2000). Mechanistic models have been used to describe the growth response of animals in general and for broilers (Cooper and Washbun, 1998; Aerts *et al.,* 2003). Such models have helped in gaining in - sight, transfer of scientific knowledge and for simulation of processes. Beside these mechanistic models, many empirical models that are mainly the results of non-linear regression analysis applied to growth data (Fitzhugh, 1976). Such regression models have the advantage that they are accurate and do not have complex structure. An easy way to develop growth models for broilers is through an empirical approach (Zoons *et al.,* 1991). Applying linear data based model structures to describe non-linear phenomena have greater advantage of adaptiveness (Orheruata, *et al.,* 2006).

Conclusion

Nigeria's commercial poultry sector has the potential to expand further to accommodate increasing per capita consumption levels and also produce for export. In addition, the sector has the support of a strong producer groups and links to multinational companies. Increasing production to take advantage of export prospects will likely depend on controlling high feed prices (Obi *et al.,* 2008; USDA, 2002). The interventions proposed by the Presidential Initiative on Livestock (PIL) also offer potential avenues for poultry development. Based on studies of the livestock sector, the government proposed a number of poultry development activities, but many have not been carried out due to lack of funding and poor implementation (Adene and Oguntade, 2006). New interventions in the poultry sector could build on the PIL background studies and lessons learned or revive some of the unfunded projects.

A recent study conducted by Ifeduba (2018) using computer models to simulate the performance of broiler chicken and layers fed alternative feedstuff ii Nigeria. This study shows that available data on the responses in different chicken types to specific alternative feedstuffs could be used to develop database and generate computer models that could simulate performances of chicken to specific alternative feedstuffs. These models could be used to power a computer web based Application Program Interface for easier access to the research result.

Most models developed for broiler starter, broiler finisher and layers egg quality have $R^2 \geq 0.90$ for both general and specific alternative feedstuffs except for layer egg quality which had R^2 of 0.27 when Haugh unit was express as a function of yolk index and in broiler finisher which had a R^2 of 0.17 when feed conversion ratio was expressed as function of levels and average initial body weight for general alternative feedstuffs. $R^2 \geq 0.90$ means that the models satisfactorily explain the experimental data. The study concluded that computer models could be used to predict performances of poultry in response to alternative feedstuffs used in the poultry industry in Nigeria.

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9/19/2020