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DEPARTMENT OF ANIMAL SCIENCE

PHENOTYPIC DIVERSITY AND MORPHOLOGICAL CHARACTERIZATION OF LOCAL DUCK *(ANAS PLATHYRYNCUS)* IN THREE SELECTED DISTRICTS IN THE NORTHERN REGION OF GHANA

BY

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A DISSERTATION SUBMITTED TO THE DEPARTMENT OF ANIMAL SCIENCE, FACULTY OF AGRICULTURE, AND UNIVERSITY FOR DEVELOPMENT STUDIES, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF PHILOSOPHY DEGREE IN ANIMAL SCIENCE.

(OPTION: BREEDING AND GENETICS)

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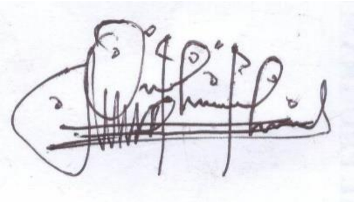
DECLARATION

I, Caleb Sarchie Owusu, hereby declare that this is the result of my own work and that no previous submission for a degree has been made in this university or elsewhere. All literature cited in this work has been duly referenced and acknowledged.



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ABSTRACT

The study aimed at analysing the demographic characteristics of duck farmers and phenotypically characterize ducks' resource in the Kumbungu, Savelugu and Tolon Districts of the Northern Region of Ghana. One hundred (100) duck farmers were sampled from each of the three (3) districts, using snowball sampling method. Farmers were interviewed using a semi-structured questionnaire. Duck farmers were predominantly males with semi-intensive system been predominant. Majority of the farmers fed ducks with cereals. Eighteen, fifteen and twelves eggs were hatched from Kumbungu, Savelugu and Tolon respectively. Thirty (30) ducks were randomly sampled for weight and morphological measurement from each of the districts. Ten (10) ducklings of male and female from each of the district were randomly sampled from 45 hatched eggs from the three districts. They were reared for ten weeks. Body weight and morphological measurements were taken at every week and every two weeks, respectively. Five colour varieties were identified: Pure white, Black dominated white, Black with white stripes, White dominated faded black and White dominated pure black. The various colour varieties were not different ($p > 0.05$) in weight throughout the period of study. Sex was different ($p<0.05$) in weight throughout the period with males being superior throughout the period of study. There was no difference ($p>0.05$) in weight and morphological measurements throughout the period when it comes to the colour, and sex and colour variety interaction. There was a significant difference with sex in some of the morphometric measurements. Body length, foot length, neck length, thigh circumference and breast circumference were significantly different ($p>0.05$) with males having the highest values. With haematology, sexes of ducks were different ($p< 0.05$) in terms of Red Blood Cell, White Blood Cell, Mean Corpuscular Volume, MCH, Haemoglobin Concentration and Mean Corpuscular Haemoglobin Concentration with males having the highest values. The various colour varieties of the ducks were different ($p< 0.05$) in terms of RBC, WBC, MCV, HBC, MCH and MCHC. There were

differences in all the carcass parameters measured in the various colour varieties of the ducks except Whole Gastrointestinal Tract weight. The interaction effect of sex and colour variety of ducks were different ($p<0.05$) in terms of Live Weight, Dressing Percentage, Breast Weight, Thigh and drumstick weight, Wing Weight, Neck Weight, Liver Weight, Abdominal Fat Weight, Gizzard Weight, Heart Weight and Whole Gastrointestinal Tract Weight. All the colour varieties of the ducks were different ($p<0.05$) in terms of colour, flavour liking, flavour intensity, taste, juiciness and the overall liking. The highest correlation of body measurement of on-station ducks was between neck length and foot length (0.803). The weights of the birds were highly correlated with body length (0.660). For correlation between weight and morphological measurements of on-farm animal based on sex, wing length was highly correlated with body length (0.815) in drake. Body weight of drake was highly correlated with neck length (0.4494). The highest correlation of body measurement of ducks was between breast circumference and bill length (0.6755). In ducks, weight was highly correlated with wing length (0.2942).

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DEDICATION

This work is dedicated to my father, Rev. Charles Blessed Adinkrah, my mother, Mrs Elizabeth Adinkrah, Pastor Peter Opoku Adinkrah, my siblings and the entire family.

Also, to my friends, Mr. Nkuah Kofi John, Miss Justina Kumi Djan and Miss Sara Kulibile.

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ABBREVIATIONS

ACRONYMS	MEANING
AnGR	Animal Genetic Resources
BC	Before Christ
DNA	Dioxyribonucleic Acid
FAnGR	Farm Animal Genetic Resources
FAO	Food and Agriculture Organisation
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
FASDEP	Food and Agriculture Sector Development Project
GDP	Gross Domestic Product
GLEAM	Global Livestock Environmental Assessment Model
ILRI	International Livestock Research Institute
LI	Legislative Instrument
NLSP	National Livestock Services Project
NRC	National Research Council
PNDC	Provisional National Defence Council
SARI	Savannah Agriculture Research Institute
USD	United State Dollar

CHAPTER ONE

1.0 INTRODUCTION

1.1 Overview of Animal Genetic Resources (AnGR)

Animal Genetic Resources (AnGR) encompasses animals with economic, scientific and cultural value to humanity in terms of food and agricultural production for the present and the generations to come (Belew *et al.,* 2016a). Around forty (40) animal species have been domesticated or semi-tamed worldwide over the last thousand years (DeWitt, 2020). While reports in the literature differ, there are about 7616 livestock breeds globally among these species, of which about 30 percent are at risk of extinction (Rojas-Downing *et al.*, 2017). Most of these breeds are found in developing countries marked by poor production conditions. The major species include cattle, sheep, goats, pigs, chickens, horses and buffalo (Gilbert *et al*., 2018). For different regions of the world, many other tamed animals such as camels, donkeys, elephants, reindeer and rabbits are also essential (Cawthorn and Hoffman, 2014).

1.2 Importance of Animal Genetic Resources (AnGR)

Animal genetic resources, especially in the developing world, are essential for food and livelihood protection as they are sufficient as an important step of insurance that allows answers to future challenges that are still unknown (Thornton, 2010). Livestock provide meat, milk, eggs, fibres, skins and manure for fertilizer and fuel (Asresie *et al.*, 2015). They provide power for cultivation and transport and a variety of goods and services. Many of the world's rural poor keep livestock and rely on it as a source of income. Animals that have been domesticated help in seed dispersal, pollination and nutrient cycling, to the habitats in which they are found (Dixon *et al.*, 2001). They are used for research in immunology, nutrition, reproduction and genetics and in training activities such as adaptation to climate and other changes in the environment (Belew *et al.*, 2016b). Animal genetic resources (AnGR) are vital to all future innovations and adaptations and are globally responsible for preserving some traits for future usage (Koehler-Rollefson and Meyer, 2014; Philipsson and Okeyo Mwai, 2011). Therefore, to be able to adapt to potential markets, production processes, available feed resources, environmental concerns, laws and regulations and disease and its management is required (Reid *et al.*, 2019). Food supply and security are of greatest impact, while breed and historical values are also significant (Robb *et al.*, 2008).

It is important to note that most attempts to improve the productivity of local breeds in developing countries have involved importing "improved" sires (live animals or semen where there are artificial insemination facilities) to "upgrade" the local breeds (Chebo and Alemayehu, 2012, Jayasuriya, 2008). Ghana was not exception from this act of animal improvement with funding from the World Bank and the government of Ghana in the mid-1990s. Under the National Livestock Services Programme, six animal improvement stations have been developed with unique mandates. Unfortunately, there were no major effects on the productivity of the targeted animals from these breed improvement programmes. Many goals of livestock improvement programmes have failed in many of developing countries.Among these reasons include insufficient involvement and/or participation of beneficiary farmers in the planning and implementation phases of such programmes (Duguma *et al.*, 2010; Mezgebe Weldeslassie, 2018). This has led to inadequate and inappropriate improvement programmes. It has been identified that the objective(s) of the programme must be established in close consultation with the intended beneficiaries in order to achieve lasting change in any animal breed improvement programme. This is particularly so for the many low input, conventional and subsistence production systems. The design of any breed improvement programme must necessarily begin by examining the specific production systems, particularly the local farming communities and must aim to discuss and achieve their breeding goals in a participatory and holistic manner (Wuyep, 2018; ; Gizaw *et al*., 2013). . This is to ensure that the intended recipient farmers are not merely recipients but are seen as owners and drivers of the programme. The fact that animal performance is a function of several factors, and not just genes acting alone, is another key issue that we often lose sight of. In addition, gene and gene interaction is a very complex phenomenon that we believe is not as straightforward. This indicates the tremendous role that farmers or animal managers have to play in order to contribute to improving the performance of farm animals.

Genetic resources for poultry are commonly considered the most vulnerable and under-maintained and strategic conservation measures need to be taken and enforced nationwide (Yakubu, 2013). Knowledge-based management of AnGR is insecure in order to address the current agricultural, socio-economic and environmental challenges facing animal production (Mutemi *et al.*, 2017). The characterisation of the AnGR is therefore one of the main issues of the FAO Global Action Plan, in developing countries in particular, where there is a lack of awareness as to what to conserve, grow and choose among local breeds (Yakubu, 2013).

Family poultry is an effective way to provide high-quality protein to a rapidly rising human population while also delivering additional cash to poor, small farmers (Guèye, 2002). In Nigeria, any growth that increases family poultry productivity by ten percent (10%) would yield much more poultry products than industrial poultry growth of ten percent, which would require much more capital investment.

1.3 Problem Statement and Justification

Poultry is kept in a wide variety of agro-ecological zones and development systems, under different economic systems and with different production objectives, with a high percentage of household consumption (Muchadeyi *et al*., 2007). In developing and transitional economies, poultry meat is the fastest growing meat when it comes to production, consumption and trade (Alem *et al*., 2014; Acheampong *et al*., 2018). Meat from ducks has also become increasingly desirable in most countries and contributes significantly to GDP.

In 2007, duck meat production grew from 1.3 million tonnes in 1991 to 3.6 million tonnes with China accounting for 65% of global production (Folitse *et al.*, 2018). In Nigeria, ducks were ranked as the third (9,553,911) most produced poultry species with chicken (101,676,710) and guinea fowl (16,976,907) being ranked as the first and second, respectively (Mehta and Nambiar, 2007). Almost seventy four percent of Nigerian ducks are Muscovy ducks, and their meat is known to be lower in fat and is thus considered healthier (Yakubu, 2013).

In Ghana, poultry industry has been and remains a very important contributor to agriculture GDP accounting for about 34.5% in 2009 which include duck rearing (Fajemilehin, 2014). They are ranked as the third producing poultry species with chicken and guinea fowl as the first and the second, respectively. There has not been any duck improvement programme on the local duck resources but it is the opposite when it comes to chicken and guinea fowl (Mantey et al., 2014).

Intensified duck rearing serves as a huge asset to the overall poultry production due to the different rearing and its scavenging abilities (Swayne *et al*., 2011; Rath *et al*., 2015). They do not interfere with chicken production. Due to their efficient foraging and incubation habits, Muscovy ducks are particularly ideal for scavenging systems and are more adaptable to hot climates than chickens (Alders *et al*., 2018; Appleby *et al*., 2004; Chatterjee, 2017). They are prolific than chicken and produce 15-20 eggs more than backyard chicken (Snively-Martinez and Quinlan 2019). Ducks have long active and prosperous lives that they still lay until the third year. Marshy, river side, swampy, wetlands and barren lands are not ideal for chicken rearing, but are suitable for duck rearing (Patil *et al.*, 2020; Behera and Sharma, 2007). Ducks are very hardy, less demanding for quality feed, less susceptible to avian diseases as compared to other poultry species , very promising among indigenous poultry species and can produce up to 300 eggs per year (Rana and Chopra, 2013; Sonaiya and Swan, 2004). Compared to chickens, they are fewer in number, mostly because of cultural practices that seem to portray ducks as magical birds in malice of their advantages in terms of production over chicken (Teguia *et al.*, 2008; Caspari, 2003, Ayorinde, 2004). However, scientific and technical advances have steadily eliminated these cultural barriers and improved the productivity of the birds (Downs *et al*., 2017).

In Ghana, the National Biodiversity Country Report clearly mentioned that evidence of past attempts to bring in exotic animals, especially from the temperate regions, and to raise them along the line of what is practiced in their countries of origin, has woefully failed (Ikani, 2003). Among the reasons why all these breed improvement projects do not yield the desired results is that the majority of these programmes are initiated by a researcher, designed by a researcher and conducted by a researcher with very little input from the target beneficiaries, the farmers (Ayizanga, 2017; Wuyep, 2018; Marshall, 2014). Many of the livestock development programmes have failed in small-level input farming systems because sufficient attention was not paid to the abiotic factors affecting animal productivity and sustainability problems (Rege, 2011). It has been established that the local production conditions and production targets must be fully explored and the views of farmers in the intended recipient communities must be taken into account in order to design a viable and sustainable livestock improvement programme under small-scale farming conditions (Ayizanga, 2017; Duguma *et al*., 2010; Mirkena *et al.*, 2010). An animal's outward and production characteristics should be examined in their domestic habitat under conventional management conditions to make the conservation of local breeds a priority to ensure the effective use of their genetic variability (Duguma, 2010; Baker and Gray, 2004)

Physical attributes like size, colour and form are basis for differentiating one animal from the other or one breed from the other breed (Koehler-Rollefson and Meyer, 2014; Mwacharo *et al.*, 2006a). Duck breeds are used based on their unique characteristics, which distinguishes them from other breeds or species. One of the primary areas of livestock conservation activities is a record of proven genetic resources, including the identification of animal's physical features, cultural significance and genetic differences (MacKinnon, 2010; Weigend *et al*., 2004; Adefenwa, 2011).

Food and Agriculture Organization has mandated that there should be characterization of every animal species to have a deeper understanding of the species and breed of animals (Maqhashu, 2019; Taye, 2005; Rischkowsky and Pilling, 2007). Among the poultry breeds such as guinea fowls and chicken in which characterization has been done, no record of characterising ducks has been documented in Ghana. It is within this context that the present study was conducted to provide a comprehensive report on the patterns and distributions of quantitative and qualitative features of these local ducks in the three selected districts in the Northern Region of Ghana.

1.4 Main objective of the Study

To phenotypically characterize the indigenous ducks' resource in Northern Ghana.

1.5 Specific objective.

- To investigate the socio-economic importance of ducks in the study area.
- To characterize production systems of ducks
- To determine the morphological features of ducks.
- To determine the haematological characteristics of the ducks
- To determine sensory and carcass characteristics of ducks

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Poultry Production

2.1.1 Overview of Poultry Production in the World

With the sub-sectors of agriculture, poultry is among the fast-rising sub-sectors. Demand for food from animal sources is growing due to population growth, rising income and urbanization, and the trend has been seen in poultry meat over the past decades. Global egg production amounts to seventy-three (73) million tons, and global poultry meat production is equivalent to 100 million tons (Gizaw *et al*., 2013). Backyard systems contribute to eight percent (8 %) of global egg production and two percent (2%) of global poultry meat production (Pokharel, 2019). Approximately ninety-two percent (92% of the production of poultry meat comes from advanced broiler systems and only six percent (6 percent) of the total comes from layers (Di Pillo *et al*., 2019). But these global figures hide significant regional differences. In Eastern Europe, South Asia and Sub-Saharan Africa, and to a lesser degree in East Africa, Latin America and the Caribbean, backyard systems are making a major contribution to the production of eggs and poultry meat (Scott *et al*., 2017). Over the last five (5) decades, the average annual growth rate was five percent (5%); 1.5 percent (1.5%) for beef, 3.1 percent (3.1%) for pork and 1.7 percent (1.7%) for meat from small ruminants (Mottet and Tempio, 2017; Ludena, 2010). Between 1961 and 2010, global per capita egg consumption has increased from 4.55 kg to 8.92 kg, while global per capita poultry meat consumption has increased from 2.88 kg to 14.13 kg (Alexandratos and Bruinsma, 2012). Production has been particularly dynamic in developing countries, with an annual growth rate of 7.4 percent in poultry meat production, particularly in East and Southeast Asia (Mottet and Tempio, 2017). With nearly twenty (20) million tons a year, the United States is the largest producer of poultry meat, followed by China with eighteen (18) million tons, the EU and Brazil with around thirteen (13) million tons (Steinfeld *et al*., 2006). One of the key factors of the growth of the sector has been technological improvements in manufacturing practices. The transition from free-range to confined poultry activities significantly cause rises in numbers of birds per farmer, enabled the replacement of labour capital to substantial increase in labour productivity (Schneider, 2019). Outputs have also been increased to improve animal size, fertility, growth rate and uniformity through advances in breeding (Kondombo, 2005).

2.1.2 Overview of poultry production and distribution in Ghana

The production of poultry in Ghana is made up of village poultry that includes local chickens, guinea fowls and ducks kept in an extensive system by every household in the rural areas. Approximately 66 percent of the total households in Ghana, particularly in the Guinea Savanna Agro-Ecological Zone (northern Ghana), do poultry production (Zak *et al.*, 2017). In Ghana, there are approximately 25 million free-roaming village poultry (Issahaku *et al.*, 2020). They are raised and sold for meat and eggs and are also used for socio-cultural purposes and for emergency cash needs (Osei-Amponsah *et al.*, 2015). There is also an active sector of commercial poultry production that relies on exotic breeds of chicken and, to a lesser extent, guinea-fowls. This occurs mainly in the urban regions of Greater Accra, Ashanti and Brong-Ahafo, to take advantage of the larger markets. Large-scale (above 10,000 birds), medium-scale (5,000-10,000) and small-scale (50-5,000) farmers, mainly producing eggs, are available. Since 2000, Ghana's total livestock production has increased, but this is largely due to the exponential growth of the poultry sector in the southern regions of the country (Osei-Amponsah *et al.*, 2015). Although total cattle production between 2000 and 2007 increased by 8%, poultry production increased by more than 80% over the same period (Haligah, 2017). Because of its rapid growth, the poultry population was expected to hit over 33 million heads by 2005 and over 38 million heads by 2010 (Kusi *et al*., 2015b). Ghana's rural (village) poultry population was estimated at 12 million and at more than 20 million in 2005 (Kusi *et al*., 2015b; Amakye-

Anim *et al.*, 2000). A total of 3,701,241 households have been registered by the Ghana National Census (2000), of which 65.9 percent reside in rural areas. The total rural poultry population would reach 25 million if each rural household maintains an average of 10 village poultry species (Amakye-Anim, 2000). The 1996 livestock census shows 99.7% of local poultry species in the Upper West, 92.3% in the Upper East and 100% in the Northern region of Ghana as opposed to foreign breeds. Rural poultry in these and other remote and even peri-urban areas of Ghana plays a major role in the livelihoods of farmers (Kusi *et al.*, 2015a).

2.2 Origin, History and Distribution of Ducks

Knowledge of the origin and evolution of domesticated species of ducks also has practical significance for effective maintenance of genetic diversity, in addition to being an important academic subject (Gyasi *et al*., 2014). In the 10th edition of Systema Naturaeus, Mallard was one of many bird species first described by Carl Linaeus (1978). Originally, the word mallard applied to any wild drake and is still used this way occasionally (Frankham *et al*., 2002). In the genus Anas, Mallard also interbreed with their closest relatives in the genus Anas, such as the American black duck, as well as with more distantly related species, such as the Northern pintail, resulting in numerous hybrids that may be entirely fertile (Magnus, 2011). Mallard ducks were first domesticated in Southeast Asia at least 4,000 years ago during the Neolithic Period, and were also farmed by the Romans in Europe and by the Malaysians in Asia (Philips and Husbandry, 1915, Roots, 2007). In ancient Egypt, ducks were caught in nets and then bred in captivity (Rischkowsky and Pilling, 2007). The pekin duck-mallards force-fed on grains during the Ming Dynasty, making them larger. They were recognized to have good genetic features during the Ming Dynasty (Kear and Hulme, 2005a). Among such distinct species, this is very odd and is probably because during the Late Pleistocene, the mallard evolved quite quickly and recently (Cherry and Morris, 2008). Due to non-overlapping ranges and behavioural indications, the distinct lines of this radiation are normally kept apart, but have not yet reached the point that they are entirely genetically incompatible (Kear and Hulme, 2005b). Mallards and their domesticated conspecifics are also fully interfertile. Genetic research has shown that some mallards in the Indo-Pacific are similar to their ancestors, while others in the United States are related to their relatives (Kear and Hulme, 2005b). DNA data from mitochondria for the D-loop sequence indicated that, mallards may have evolved from region of Siberia (Rhymer *et al*., 1996). There are differences in the mitochondrial DNA of mallards of North American and Eurasian population however, there is a noticeable lack of genetic structure in the nuclear genome (Susanti *et al.*, 2017). Mallard bones occur quite randomly in food remains of ancient humans and other fossil bone deposits in Europe without being a suitable candidate for a local predecessor species (Kulikova and Zhuravlev, 2010). The Aleutian Island has a mallard population that appears to be growing into a subspecies, as gene flow with other populations is very small (Roots, 2007). The lack of morphological variations between the mallards of the Old World and the mallards of the New World also indicates the degree to which the genome is shared between them (Kulikova *et al.*, 2005). The Old-World mallard is very similar to the Chinese spot-billed duck. Birds such as the Hawaiian duck are very similar to the New World mallard (Kulikova *et al.*, 2005). Almost all domestic duck types have been derived from the mallard duck, excluding the Muscovy (Lavretsky *et al.*, 2014).

It is not made clear when ducks were being domesticated but there is evidence that ducks were used by ancient Egyptians for sacrifice and presumably raise them for food (Appleby *et al.*, 2004). Prior to 500 B.C., Southeast Asians also raised ducks in captivity (Albarella, 2005). The speciality of Asian duck meat can be traced back to 600 years ago, when Pekin duck meat was part of the main dish of the Chinese Emperor and a delicacy for ruling class members (Adzitey and Adzitey, 2015). At that time, the best cooks from all over China gathered in Beijing to cook for the Emperor (duck roast) and the top cook could reach the rank of minister (Adzitey and Adzitey, 2015).

The domestic duck has appeared in children's stories many times. The Tale of Jemima by Beatrix Potter was published in 1908 by Frederick Warne & Co. The tale was included in the Royal Ballet's Tales of Beatrix Potter, one of Potter's best-known books. It's the tale of how a domestic duck, Jemima, is rescued from a sly fox trying to kill her as she tries to find a safe place to hatch her eggs (Symons, 2003). Make Way for Ducklings is a picture book for children compiled and illustrated by Robert McCloskey. First published in 1941, the book tells the story of a family of mallards who plan to raise their family in the Boston Public Garden, a park in central Boston, on an island in the lagoon. Make Way for Ducklings won the 1942 Calclecott Medal for McCloskey's illustrations. Peter and the Wolf, written by Sergei Prokofiev in 1936, features the domestic duck in the musical composition. The orchestra depicts the story of the children as it is told by the narrator. In this, a domestic duck and a little bird disagree about the flight capabilities of each other. The duck is typified by the oboe. The tale ends with the wolf swallowing the duck alive and hearing its quack from inside the wolf's stomach. Domestic ducks are also portrayed in Ancient Egyptian wall paintings and grave objects (Potter and Craig, 1971). They are featured in a collection of ancient artefacts that revealed that they were a sign of fertility.

All ducks nearly bred in fresh water habitat especially in freshwater lakes, marshes and swamps. Ducks are widespread in marine ecosystems and can be found on all continent except Antarctica. In these environments, most duck species often winter, often utilising additional grain fields and other areas created by humans. On marine coasts, several types of sea ducks breed, wintering in near-shore habitats. The Muscovy is a large, heavy duck originating from the wild roosts of trees in Central and South America (Houlihan, 2002). There is no reliable information on the introduction of Muscovy ducks to West Africa (Stahl, 2008). Another undocumented version stated that the Portuguese had introduced them and spread them inland (Oguntunji and Ayorinde, 2015).

2.3 Taxonomy of Ducks

Scientific names are names used by scientists to classify species, such as mallard duck, which differs from Muscovy duck. Carl Linnaeus (1735) introduced scientific classification, in which he categorised organisms with the idea of giving the two names of an organism, the genus and the species. With the system duck belongs to the genus Anas and the specie Platyrhynchos. Detail of the biological classification of duck has been presented and outlined below.

Domain ⟶ Eukaryota

Kingdom ⟶ Animalia

Phylum ⟶ Chordata

Class ⟶ Aves

Order ⟶ Anseriformes

Family ⟶ Anatidae

Genus ⟶ Anas

Species ⟶ Platyrhynchos

2.4 Importance of Ducks

In addition to manure that can be used to increase soil fertility in agricultural lands, duck rearing offers proteins (egg and meat) (Oguntunji and Ayorinde, 2015). There is great demand for duck products such as eggs and meat as they are a good protein and iron source (Adzitey and Adzitey, 2015). Many advanced and value-added food items such as roasted Pekin duck, crispy duck skin, gingerroot duck, herb duck, pressed salt duck, smoked duck steak, duck roll, tea smoked duck, salted duck eggs, salted duck gizzards, marinated duck tongues, and many more are prepared from duck meat, eggs and parts (Fouad *et al.*, 2018a) .

Ducks may also be used for decorative purposes, for clothing, to monitor water snails in rice fields and to hunt for animals as a game (Biswas *et al.*, 2019). With high quality processing technology, Taiwan exports USD 130 million worth of down-feather products annually

(Adzitey and Adzitey, 2015). Duck raising in low-income countries is one of the potential ways of breaking out the poverty pit of poor small holder families (Tai and Tai, 2001). The most significant asset and source of income for ultra-poor rural women is considered to be ducks. Not only has small-scale duck farming been shown to be a useful occupation for small, marginal and landless farmers, but also a possible source of youth self-employment and distress for women (Islam *et al.*, 2016b). Ducks have been used in rice farms to control insect pests in many parts of South-East Asia (Alauddin, 2018).

2.5 Production Systems of Ducks

2.5.1 Classification of duck raising system

The main livestock production systems are: the Agro Ecological Zone, integrated with crop production, the animal-land relationship, production intensity and type of product (Joshi, 2007). The development systems of Ducks vary depending on the agro-ecological zones (Cecchi *et al.*, 2010). Traditional systems typically follow a seasonal pattern, after the rainy season, farmers buy ducklings and fatten them to be ready for various annual events (Nguyen 2015). It is possible to categorize Duck production systems according to different criteria, including geographical, economic and technological. Categories are rendered most of the time by combining different parameters (Chisembe *et al.*, 2020). Depending on the location, duck systems in the Mekong Delta differ considerably. The three primary systems are distinguished as follows:

- Scavenging systems: scavenging, free range within the farm and the village (garden, home or village pond); frequent herding in rice fields, dikes, rivers, canals and tidal areas (outside of the farm); seasonal supervised transhumant range (beyond the locality).
- Integrated systems for the raising of ducks: rice-fish-duck; fish-duck-pigs (or other domestic species).

- Confined systems: semi-industrial and commercial farms (production of meat and eggs); mixed duck-fish in enclosures or floating cages in ponds/canals/rivers (Mrema *et al*., 2012).

Duck husbandry systems are split into sub-systems in compliance with local requirements (Carlén and Lansfors, 2002). Systems for scavenging may be either absolute or Semi-scavenging, in which ducks at night are enclosed in enclosures or cages. Ducks in the Mekong Delta are mainly raised on small-scale farms, according to experts. They also point out that, due to policy-driven interventions and systemic improvements in rural areas, duck husbandry systems have changed. The FAO and other agencies also suggested another classification, which differentiates programmes according to economic criteria. Poultry production units have been given numerical levels according to their production scale over the past few years (Rao and Birthal, 2008; Moura *et al*., 2006). Levels include as follows:

Integrated industrial system with broiler, layer and breeder farms, probably for export

- Medium commercial production method for poultry (broilers/layers/ducks)
- Medium to small commercial (broilers/layers) poultry production method
- villages or backyards poultry production in a mixed farming system (ducks, pigs, etc.)

Tai and Tai (2001) also grouped duck production systems on the basis of usage criteria and includes:

- "Harvested rice – running duck" system: scavenging system to pick fallen paddy rice after harvesting
- "Rice – duck pest control" system: insect catching, weeding, muddying after rice transplanting

- “River and coast band collector” system: scavenging system to pick tiny fish, shrimps, oysters etc... at low tide
- Fish – duck pond system
- Backyard duck raising (Kelebemang, 2005)

2.5.2 Extensive Production System

This method of production is by far the most common system of production in which poultry is raised in backyards, gardens, courtyards, orchards and freely to range on neighbouring land. The quantity of feed provided to birds does not rely on production quality, but is heavily dependent on the availability of grains that farmers have for personal consumption in storage, as seeds for the next planting season and their livestock's feeding needs. It is a side-line operation, and thus attention to the protection and health of birds is limited to about 40 to 50% percent with high mortality. In general, poultry-derived income is intended to buy clothing, pay for education for children and buy food (Tai and Tai, 2001). Local breeds of animals are mainly raised under this scheme and are sometimes used for traditional celebrations, family presents, weddings and religious offerings in particular (Vu, 2011). The method of free-ranging-scavenging duck husbandry primarily includes small, rural farms. Ducks are mixed year-round with chickens and other animals (porcine, bovine, caprine, and human). They remain mainly within the premises of the farm, but can wander around the village. While performance of ducks of this production system is typically below the intensive production system, the use of low or no-cost feed may compensate for the disadvantage of lower performance. Ducks have been used over rice paddy for insect pests for forage for centuries and this certainly facilitated the common practice of "droving" in many areas of South-East Asia (Mapiye *et al*., 2008). Likewise, duck production, integrated with both rice and fish farming, has continued for centuries to provide a significant source of food and income for the Asian farming community in much the same way (Cherry and Morris, 2008). It was asserted that among many Asian nations, the traditional duck-cum-rice method is different. This confirms the existence and some variations of this system, as well as how widespread and familiar it is among Asian nations. Scavenging ducks in rice fields ('duck-cum-rice production') will feed on cheap material that is otherwise wasted. Twenty (20) days after rice transplantation and until the beginning of flowering, ducklings are forced into the rice fields. Their smaller body size enables them to prevent damage to rice plants (Pernollet *et al*., 2015). Ducks are pushed out of the rice fields to canals, ditches, streams, swamps to forage in water at the beginning of rice flowering. It was asserted that from one or two weeks onwards, the use of integrated duck-rice farming in the early growth stage of rice significantly removes or decreases most of these pests (Teo, 2001). In relation to weed control, Men *et al.* (1999) claimed that the integration of ducks and rice would result in producers continuing to decrease investment by also removing the weeds in the next crop since all parts of the weeds and grass seeds are eaten by the ducks. Duck growth output is very satisfactory and giving the ducks access to a supplement and then allowing them to forage freely clearly helped them to fulfil their nutrient requirements (Men *et al.*, 1999). Weeds and insects are eaten, thereby offering a diverse dietary nutrient intake that is better balanced than that of the supplement alone. Men *et al.* (1999) concluded that the use of ducks in rice farms prevent or reduce the use of pesticides in rice farms. This help and reduce cost of incurring pesticides by the farmer. An integrated ducklings-growing rice system also prevents or reduces the recommended quantity of chemical fertilizer since their droppings serve as a manure. With regard to performance, Zaman *et al.* (2007) recorded that in male and female Nageswari ducks, live weights at 0, 4, 8 and 12 weeks of age were 47.00±0.19g, 229.09±2.59g, 512.20±3.55g and 895.79±5.04g, and 45.03± 0.21g, 198.50±2.49g, 480.46±3.08g and 863.10± 4.31g, respectively, under North Eastern India's free-range system of rearing (Men *et al.*, 1999). The average body weight of Charachemballi ducks was reported by Morduzzaman *et al.* (2015) in Assam as 715.02±5.16g and

1054.63±10.27 g at 8 and 12 weeks under free range conditions, respectively (Zaman *et al*., 2007). The mean live weights of ducks at 1, 2, 3, 4, 5, 6, 7, 8, 10 and 12 weeks of age were 123.21±17.77, 263.16±40.00, 438.92± 57.64, 627.68±73.68, 797.68±85.54, 974.73± 119.44, 1176.11±117.55, 1251.90± 111.28, 1468.08±134.26 and 1522.10±129.35g, respectively under extensive system (Morduzzaman *et al*., 2015).

2.5.3 Intensive Production System

The confined system of production concerns mainly larger federal, international or private semi-commercial or commercial farms. The equipment is well designed and relatively mechanised, with both semi-automatic and automatic systems with higher levels of investment in animal health requirements, housing maintenance and flock efficiency (Morduzzaman *et al.*, 2015a). Burgos et al. (2007) reported that the production mode under this method is intensive, with eggs, meat and breeding stock as the main products. Ducks are kept confined to the production of meat or eggs and are often fed on industrial feed. Fish-cum-duck integration is an example of this method. This method is fixed and strictly confined system for raising ducks (ducks cannot move around). It is common in Asia and has been extensively studied and described by experts (Burgos *et al*., 2007) . The use of manure as the key nutrient supply for ponds is a typical Asian aquaculture management method where manure is used directly or indirectly in the integration of fish and livestock farming (Phong *et al.*, 2007). In fish farming, the use of organic manure is based on the assumption that manure works in two ways: dissolved and particulate substrates for bacterial and bacterially laden particles provide food for filter-feeding and detritus-consuming animals with the readily decomposable organic matter of the manure, while the mineralized portion of the manure enhances the productivity of phytoplankton (Prein, 2002). Increasing efficiency, ensuring productive use of water, spreading the economic risk of price volatility, having minimal environmental effect and a strong mechanism for sustainable agriculture have also been recorded in this system (Tai and Tai, 2001). There is some evidence that the mechanism for the production of fish ducks has played a role in improving the level of food security, nutrition and income of South Indian households involved in the production of fish ducks compared with households not involved in the production of fish ducks (Oribhabor *et al.*, 2006). The purpose of such a system is to maximise the synergies of the exploitation of both fish and ducks by using the waste of each other and sharing scarce space. The closed nutrient cycle is the benefit of this integrated method. Duck droppings, as well as food waste, make it possible to grow plankton and feed fish directly. With regard to efficiency, Bhuiyan *et al.* (2017) reported that under the intensive management system, the average annual production of eggs was 200-220 in Nageswari duck, which is higher compared to other production systems (Dolberg, 2007). Bhuiyan et al. (2017) recorded that under the intensive production method of Bangladesh, the egg production rate of Nageswari duck up to 52 weeks of age was 55.40 ± 2.36%. Morduzzaman *et al.* (2015) noted that ducks began laying earlier than those in free range under intensive conditions with regard to production and reproduction performance.

2.5.4 Semi Intensive System

This production system is larger in size and relatively higher rates of monetization than the extensive system and is capable of following certain practises of the developed countries' agricultural sectors. This system of production reflects a shift between conventional and more market-integrated production of commercial poultry and blends traditional methods with advanced technology and marketing (Bhuiyan *et al.*, 2017). Poultry are both held in enclosures or free to roam in backyards, orchards and gardens. In addition to locally produced animal feed, alternative feedstuffs such as brewery and soy waste and ensiled shrimp waste are also used as supplemented (Burgos *et al.*, 2007). Burgos *et al.* (2007) suggested that either specialised or a mixture of local and exotic imported breeds with flock sizes ranging from fifty-one (51) to two thousand (2000) birds are used in this method. Farmers involved in this system are predominantly former government employees, current local officers or wealthy farmers with permanent incomes and certain farming skills, especially knowledge of market conditions (Nguyen, 2005) .

The production of duck for meat and eggs is globally rising annually. Asia is the continent that produces the largest duck meat and eggs and the main producer is China (Ayana, 2020). Programs for genetic enhancement for meat-type ducks have increased their efficient output successfully. In particular, Pekin ducks are well known as the main meat-type duck and have been genetically improved over 6 weeks to achieve a higher meat yield 3.2 kg and lower carcass fat deposition rate to reach, whereas the unimproved type takes 11 weeks to reach just 1.7 kg (Huang *et al.*, 2012). In addition, many studies have aimed to grow the primary egg-type duck breed (Longyan laying ducks), which is important for a numerous reason, such as: medium size (1.2-1.3 kg), early maturation (110 days), high yield of eggs (more than 280 eggs/year), large populations (more than 300 million birds), adaptation to high ambient temperatures and resistance to disease (Huang *et al.*, 2012). However, the National Research Council Recommendations 1994 (NRC 1994) for the approval of the production of a new meat-type duck strain specified their nutritional requirements on the basis of 40-year data on the results obtained in other species. In addition, for egg-type ducks, NRC 1994 did not specify nutritional requirements. Protein and energy are the first nutritional requirements that should be taken into account when formulating a diet, since they constitute the costliest dietary elements, but also because of their effect on the efficient and reproductive performance of flocks for meat or egg production (Fouad *et al.*, 2018a). Fouad and El-Senousey, (2014) reported that raising the energy level of ducks from 2,600 to 3,100 kcal of AME/kg had a positive effect on the efficiency of production, but had a negative impact on the quality of the carcass by increasing body fat deposition. Thus, they proposed 3,000 kcal of AME/kg based on growth efficiency when the diet contains 18 percent crude protein (CP). Furthermore, Xie *et al*. (2010) suggested

2,900 kcal of AME/kg with 20.5% CP for male White Pekin ducks within the first 3 weeks of age on the basis of growth efficiency and carcass quality when energy levels were assessed from 2,450 to 3,050 kcal of AME/kg (Fouad and El-Senousey, 2014). Wickramasuriya *et al.* (2016) tested rising energy levels (2,600 to 3,300 kcal of AME/kg) to maximize their productive production and carcass weight and showed that native Korean ducks require 2,900 kcal of AME/kg with 18 percent CP from hatching to 21 d of age (Xie *et al*., 2010). On the other hand, few studies have attempted to estimate the laying duck's energy and protein needs. However, Fouad *et al.* (2018) investigated the impact on the production of raising the laying ducks' energy and protein levels (Khaki Campbell) and suggested 2,700 kcal of AME/kg with 16.5 percent CP between the ages of 18 and 37 weeks (Wickramasuriya *et al*., 2016). In China, 2,500 kcal of AME/kg and 17% CP are in the commercially formulated diet to fulfil the egg-laying ducks' energy and protein requirements. Amino acids play a significant role in poultry nutrition because of their effect on productivity, immunity, and meat and egg quality (Fouad *et al*., 2018b). Methionine is the first major restrictive amino acid in poultry feed. Therefore, in order to achieve the highest average daily body weight gain for white Pekin ducks from 3 to 7 weeks of age, white Pekin ducks need 0.337 percent methionine (Met) (Zheng *et al*., 2019). To reach the highest breast meat proportion, this quantity can be adjusted to 0.339 percent. Zhao *et al.* (2018) indicated that the highest body weight gain in White Pekin ducklings required a diet containing 0.338 percent Methionine during the first two weeks of age (Xie *et al*., 2006). While Xie *et a*l. (2006) found that diet formulations containing 0.481 percent methionine maximized growth production in Pekin ducklings during the first 3 weeks of age. Zeng *et al*. (2015) found that White Pekin ducks, aged 15 to 28 days, require 0.510, 0.445, and 0.404 percent methionine diets to maximize their body weight gain, breast meat yield, and feather growth, respectively, but 0.468 percent, 0.408 percent and 0.484 percent methionine will be needed for 15 to 35 days of age to optimize body weight gain, breast meat yield, and feather development (Zhao *et al*., 2018). In addition, Shaoxing laying ducks need 0.40% methionine in their diet to maximize the egg yield, egg weight, and feed conversion ratio (FCR) from 60 to 66 weeks of age (Zeng *et al*., 2015b). Fouad *et al*. (2018) found that egg weight, egg mass, and FCR were maximized in Longyan laying ducks from 19 to 47 weeks of age by feeding a diet containing 0.41 percent methionine. The second amino acid for poultry feed is lysine (Lys). In White Pekin ducks, Zeng *et al*. (2015a) found that 1.06 percent of lysine is required to increase body weight during the first three (3) weeks of age (Fouad *et al*., 2018b). White pekin ducks need 1.02 percent lysine to achieve the maximum body weight gain, carcass yield, and breast yield for 3 to 7 weeks of age. Wang *et al*. (2013) demonstrated that male White Pekin ducklings from 7 to 21 d required 0.84, 0.90, and 0.98 percent lysine to achieve the highest body weight gain and breast meat *(Zeng et al*., 2015a). Optimal body weight gain and feed efficiency were achieved in male Korean native ducklings from 1 to 21 days of age with 0.71 and 1.01 percent lysine, respectively (Wickramasuriya *et al*., 2016). Maximizing performance for Longyan laying ducks from 22 to 38 weeks of age require feeding diets containing 0.80 percent of lysine (Wang *et al*., 2013). The third limiting amino acid is threonine in poultry feed (Thr). Zhang *et al*. (2016) conducted two experiments to estimate the requirements of White Pekin ducks' threonine from 1 to 14 days of age and diets containing 0.86, 0.92, and 0.95 percent threonine achieved the highest body weight gain, feed consistency, and maximum breast meat proportion (Xia *et al*., 2017). Feeding White Pekin ducks, aged 14 to 35 days with diets containing 0.75, 0.74, and 0.73 percent threonine, respectively help to achieve standardised body weight gain, high feed conversion ratio, and relative breast meat yield (Zhang *et al*., 2016). In contrast, maximising egg production, egg mass, and feed efficiency 0.57 percent threonine in the diet from 17 to 45 weeks of age is requires for Longyan laying ducks as reported by Fouad *et al*. (2018). Arginine (Arg) is not classified as a limiting amino acid, but is important for poultry nutrition because avian species are unable to synthesize it and are therefore vital for the production of other molecules with distinct physiological functions as a precursor substrate (e.g., nitric oxide, proteins, creatine, ornithine, glutamate, polyamine, proline, glutamine and agmatine) (Fouad *et al.*, 2012). Arginine percent of 0.95, 1.16, and 0.99 were required for the ideal body weight gain, food conversion rate, and breast meat yield (breast weight relative to live body weight) in male White Pekin ducks from hatching to 21 days of age respectively (Bi *et al.*, 2018) . Reproductive system development in Longyan laying ducks aged 17 to 31 weeks requires feeding them diets containing 1.13 percent arginine, but diets containing 1.46 percent arginine are recommended to achieve the best egg weight with the highest quality eggshell (Xia *et al*., 2017).

Calcium (Ca) in the form of calcium carbonate is 96 percent (96%) of the eggshell, and almost 60-70 percent of the bone weight is Calcium and Phosphorus (P) in the form of hydroxyapatite (Fouad *et al*., 2018b). For example, Ca deficiency in laying ducks decreases the rate of egg production, egg weight, eggshell thickness, eggshell breaking speed, and Calcium deposition in the eggshell due to decreased in calcium levels in the plasma and shell gland, as well as reducing the expression of genes related to calcium transport and eggshell bio-mineralization (Fouad *et al*., 2018b). Calcium deficiency in White Pekin and Mule ducks can lead to rickets, a low growth rate, low feed usage, and a high mortality rate (Hincke *et al.*, 2012). Fouad *et al.* (2015) estimated the calcium requirements of Longyan laying ducks from 20 to 33 weeks of age and suggested, formulating diets containing 3.6 percent calcium with 0.40 percent phosphorus is important to maximize the production of eggs, egg mass, feed usage, and increase bone production (Fouad *et al*., 2018b). Furthermore, 0.806 percent calcium with 0.403 percent non-phytate phosphorus and 0.796 percent calcium with 0.379 percent non-phytate phosphorus were recommended to achieve the highest daily weight gain and lowest feed conversion rate, respectively, in White Pekin ducks during the first three weeks of age. Although 0.72 percent calcium with 0.37 percent non-phytate phosphorus was suggested to optimize daily weight gain in White Pekin ducks from 3 to 6 weeks of age (Fouad *et al*., 2018b). In addition to being a cofactor for other enzymes, such as cytochrome oxidase, lysine oxidase, tyrosinase, dopamine beta hydroxylase, p-hydroxyphenyl pyruvate hydrolase, copper-zinc superoxide dismutase, copper-zinc-superoxide dismutase and copper (Cu), it is a growth enhancer and also has antimicrobial property (Fouad *et al*., 2018b). Hypertriglyceridemia, hypercholesterolemia, anaemia, feather depigmentation, abnormal bones and low bird development are all attributed to deficient Copper diets (Leeson and Summers, 2009). Performance (egg development and egg weight) and egg quality (lower percentage of abnormal eggs, i.e., soft and broken eggs) can be enhanced by increasing the amount of copper in laying bird diets, as well as decreasing the level of total cholesterol, triglycerides and low-density lipoprotein cholesterol, and increasing the level of high-density lipoprotein cholesterol in the blood (Fouad *et al*., 2018b). In addition, copper can increase the productive efficiency, breast meat yield, meat quality (juiciness), immunity and abundance of beneficial intestinal microflora (Lactobacillus and Bifidobacterium), as well as decrease the mortality rate and abundance of harmful intestinal microflora (coliforms and Escherichia coli) in broiler chick diets (Adu *et al*., 2017). Diet containing 7 mg Cu/kg in male White Pekin ducks improve productivity from hatching to 56 days of age (Wang *et al*., 2011). Meat-type ducks and egg-type ducks need low concentrations of copper in their diets, relative to the requirements needed to minimize cholesterol levels in their products. Increasing the copper level in the diets of male White Pekin ducks to 157 mg/kg decreases the cholesterol concentration in their meat (Wang e*t al*., 2020). However, increasing the dietary copper concentration above 120 mg/kg contributes to abnormal morphology of poultry spleen, liver, and the intestine (Wu *et al*., 2019). Zinc (Zn) is a special mineral involved in several enzymes, such as copper zinc superoxide dismutase (associated with the antioxidant defence system), carbonic anhydrase (associated with the supply of carbonate ions during eggshell formation) and alkaline phosphatase (associated with bone structure and calcification), as well as lipid control, protein metabolism and sex hormones(Cheng *et al*., 2020). Therefore, diets with insufficient Zn levels can inhibit egg production, fertility, hatchability, embryo development, hatched chicken availability, feather growth, development and proliferation of immune organs, as well as increase the incidence of leg problems, oxidative damage and mortality rates of poultry (Fouad *et al*., 2018b). It promotes protein synthesis and suppresses protein degradation, it increases growth rate, carcass yield and breast meat yield (Fouad *et al*., 2018b). It increases meat quality (colour, water keeping ability, tenderness, and taste) in broiler chickens (Abd El-Hack *et al*., 2017). Zang *et al*., (2017) reported that egg yield, egg weight, fertility, hatchability, normal number of hatched chickens, and antioxidant strength are improved in broilers (Liu *et al*., 2017). Attia et al. (2013) found that maximizing body weight gain from 1 to 56 days requires diets supplemented with 30 mg Zn/kg in male White Pekin ducks, whereas 120 mg Zn/kg is required to reduce the deposition of body fat and improve the quality of meat (Zhu *et al*., 2017). However, during peak laying season, 30 mg Zn/kg in the diet is adequate to increase the productivity of Longyan laying ducks (Badran *et al*., 2018). Choline is another vital nutrient for poultry as a result of its role in lipid metabolism and liver functions. Perosis, fatty liver syndrome and inhibition of growth rate are triggered in avian species when a choline deficient diet is fed (Chen *et al*., 2017). Found *et al*. (2018) found that adding 2,136 mg/kg of diet for only four (4) weeks during the peak laying period improved the production of eggs and minimized the accumulation of fat in the liver (Fouad *et al*., 2018b). However, Wen et al. (2014) found no increase in the laying rate of Shaoxing laying ducks when fed with choline-supplemented diets for twenty (20) weeks, during their peak laying period (Fouad *et al*., 2018b). However, by adding 500 and 750 mg of choline/kg of diet, liver fat deposition and egg cholesterol content were reduced, respectively, although there was no reason to reduce the amount of egg cholesterol. Wen *et al*. (2014) found that diets containing 778, 810 and 1,182 mg choline/kg were adequate in meat-type ducks during the first three (3) weeks of age to improve phospholipid synthesis, growth rate and prevent perosis (White Pekin ducks), respectively. In order to increase the production of phospholipids and increase the average daily weight gain between the ages of 21 and 42 days, diets containing 779 and 980 mg of choline/kg were required.

Table 2. 1: Ration for growing Ducks

Ingredients	Day-old to marketing	
	Ration 1(%)	Ration 2 (%)
Crushed grain	46	19
Bread	-	40
Bran	18	10
Pollard	18	10
Meat meal	10	11
Soyabean meal	3	3
Lucerne meal	3	4
Milk powder	2	3
Ground limestone	-	-
Total	100	100

Source: Adeola, 2006.

Table 2.2: Minimum basic nutritional requirements of ducklings

Nutrients	Starter	Grower	Breeder
Protein (%)	20-22	17-19	16
Calcium (%)	1	1	3
Fat (%)	5	5	5
Methionine + Cysteine (%)	0.76	0.77	0.80
Lysine	1.16	0.90	0.94
Arginine	0.94	1.0	0.60
Threonine	0.84	0.66	0.60
Phosphorus (%)	0.40	0.35	0.40
Manganese (mg/kg)	60	50	40
Niacin (mg/kg)	55	40	55
Pantothenic acid (mg/kg)	15	10	20
Pyridoxine (mg/kg)	3	3	3
Riboflavin (mg/kg)	10	6	10
Vitamin A (mg/kg)	3100	1720	4130
Vitamin D3 (mg/kg)	300	22.5	62.5
Vitamin K (mg/kg)	2.5	2	2.5
Energy (kcal/kg)	2900	3000	2750

Source:(Wen *et al*., 2014).

2.7 Problems of Duck Production

Ao *et al.* (2019) described higher feed prices and lower duck meat and egg prices as critical problems for coastal duck farming in coastal areas (Adeola, 2006). The three main issues in duck farming are lower duck egg and meat rates, higher feed prices and lack of training for farmers (Ao *et al*., 2019). Jahan *et al.* (2012) continued that the outbreak of disease, inadequate veterinary facilities, irregular supply of duckling, lack of adequate fluctuation of the capital price of duck egg, theft and environmental pollution were other major duck production problems. Constance *et al.* (2013) also pointed out that disease outbreaks are a significant problem in the poultry sector, especially in chicken farming (Jahan *et al.*, 2018). In the Haor region of Bangladesh, lower duck meat and egg prices, lack of credit, scarcity of feed in the dry season, lack of proper treatment and medicine were serious problems in duck farming (Constance *et al*., 2013). Ao *et al*. (2019) reported that the significant problems faced by farmers were poor knowledge of duck housing (48 percent) and management (64.50 percent). The author went on to claim that higher quality feed prices (97%) seemed to be a major constraint for farmers. He said that shortage of summer season scavenging feed (91 percent) and insufficient awareness of duck nutrition (89 percent) are also constraints faced by farmers. It was reported that the main problem of egg-type duck production in the Philippines is the lack of quality breeder stock (Alam *et al*., 2012). Islam *et al*. (2016) reported that farmers have limited understanding of the production efficiency of enhanced duck breeds/varieties. He went on to state that farmers are not familiar with the scientific duck feeding and management system (Chang *et al*., 2003).

2.7.1 Mortality in Ducks

Infections with diseases are major challenges facing rural poultry farmers in developing countries. In Cambodia, diseases were reported as the major challenges facing Nigeria's rural poultry (Islam *et al*., 2016a). Potential salient factors contributing to high disease-induced mortality are the absence of standard routine duck disease vaccination programmes and poor health management practices. The sluggish nature of ducks also significantly contributes to ducks being decimated by vehicles. This submission corroborates the results of the survey carried out in Zaria, Northern Nigeria that cars were a major cause of duck mortality *(Vong et al.*, 2009). Also, duck predators possibly capitalized on their slow movement to capture them, including dogs, cats, and snakes. In the dry season, wild predating activities and water scarcity increases. There is also a substantial reduction in the availability of micro fauna and flora, such as fingerlings, tadpoles, earthworms, insects, water alga, among others. This then triggered the need to scavenge further away from homesteads into bushes, thereby making them the victim of an easy predator. They become unwittingly predisposed to domestic, agricultural and industrial water pollutants such as detergents, effluents, herbicides that are harmful to their well-being and overall efficiency. Water-related activities can also lead to hygiene problems and increase health and food safety risks (Oguntunji and Ayorinde, 2015a). It is intriguing that most of the primary and remote causes of duck mortality are from pathogens and cars. This can be prevented to the bare minimum if intensive or semi-intensive management systems are introduced by duck farmers. About fifty (50%) percent of the mortality reported in free-range Muscovy ducks was traceable to cars (Oguntunji and Ayorinde, 2015b). Standard management help reduce duck mortality. Zero duck mortality was recorded during the study period in semi-intensive and intensive systems of duck in Nigeria (Udedibie and Ogbonna, 2006).

2.8.0 Characterisation of Livestock

The characterisation of the Animal Genetic Resources (AnGR) encompasses all tasks relating to the identification, quantitative and qualitative description and recording of breeding populations in natural environments and systems of production to which they are or are not adapted (Oguntunji and Ayorinde, 2015b). Characterization is distillation of all information that contributes to the reliable prediction of the genetic output of AnGR in a given environment and provides a basis for distinguishing and evaluating the available diversity between different AnGRs (Tixier-Boichard *et al*., 2009). The first step towards an effective conservation strategy for animal genetic resources is a thorough characterization of the conservation value of the different breeds and wild relatives (Getachew, 2006). A comprehensive knowledge of the characteristics of the breeds, including data on population size and composition, geographical distribution, production climate, and genetic diversity within and between breeds, is needed for effective management of farm animal genetic resources (Rege and Gibson, 2003). Another view that has been expressed elsewhere is that information on genetic variance in their respective populations is one of the first steps towards the sustainable use of local animal breeds (Hoffmann, 2010). For the development of effective management and use strategies, documentation of origin or historical knowledge and features of animal genetic resources (AnGR) is important (Ayizanga, 2017). The record of established genetic resources, including the identification of population phenotypic characteristics, cultural significance and genetic uniqueness, is one of the key areas of livestock conservation activities (Rischkowsky and Pilling, 2007). In order to make the protection of indigenous breed a reality and to safeguard the sustainable use of their genetic diversity, it is especially desirable that their phenotypic characteristics and output be assessed in their home tracts and under conventional management conditions (Tanchev, 2015). The knowledge provided by characterization studies is important for local, national, regional and global management planning of the AnGR. Basically, there are two types of characterisation in animal research. These are:

- Phenotypic characterization
- Molecular characterization (Hall, 2008)

2.8.1 Phenotypic Characterization

The phenotypic characterisation of animal genetic resources is the process of defining and recording the morphological characteristics and production parameters of different animal species, together with a summary of their production characteristics in a given environment and under a given set of management conditions, taking into account the social and economic factors that affect them (Vincent *et al*., 2014). It as an act of measuring or describing all of an organism's observable characteristics (e.g., shape, size, colour and behaviour) and non-observable characteristics (e.g., blood group) resulting from its genotype's interaction with the environment (Vincent *et al*., 2014). Phenotypic characterization measures or describes an organism's gross physical and physiological characteristics through the interaction of its genes and the environment (Vij *et al*., 2006). In general, all characterization studies involve the collection of data aimed at providing information on the phenotype of animal population or genetic or historical record. As stated earlier, the Food and Agriculture Organization's guidelines emphasise that the knowledge gained from characterization studies is very important for planning the sustainable use of local farm animal breeds (Woods, 2014). The conservation and suitable use of farm animals is concerned with phenotypic characterisation. Information on the distribution of the breed, breed status (whether the population size of the breed is increasing or declining or stable), its production characteristics and its uses must be given. In addition to quantifying the extent of phenotypic diversity, breed-level statistics and characteristics are required to group individual populations of livestock on the basis of probability of it being extinct. The characterization of phenotypes can be classified into three main categories, namely:

- Physical or Morphological description and measurement
- Performance characteristics
- Adaptation to the environment

Morphology deals with the size, shape and structure of an animal or one of its components as a form of phenotypic characterization (Cammarata *et al*., 2021). In the classification of population/strain/races within a species, physical or morphological features may be especially useful (Klingenberg, 2002). Body shape assessed objectively may enhance the selection of growth by enabling the breeder to distinguish early-maturing and late-maturing animals of various sizes. Performance characteristics tend to be limited to such characteristics as reproductive, maternal ability, carcass and behavioural characteristics, growth and live weight.

Adaptive characteristics include cold and heat stress response, resistance or immunity to diseases, resistance to endo-parasites and ecto-parasites, and survival or mortality.

2.8.2 Molecular Characterization

Molecular genetic data has become increasingly important for the assessment of the level of genetic variability of animal species since the early 1990s (Mwacharo *et al*., 2006a). Since then, several research studies have been performed by scientists in several countries, especially in Europe, to characterise their respective local breeds. Moreover, in the international efforts on breed characterization at the molecular level, joint projects between researchers have assembled comprehensive molecular databases for many different species and breeds of livestock. Consequently, the use of molecular data to determine the extent of genetic diversity within livestock populations has grown over time to become one of the most active fields of animal science research and has attracted significant interest in the scientific press. It is important to state that most molecular work has been conducted using neutral genetic markers for a very long time since the inception of molecular genetic characterization methods, which serve as estimates of the likelihood of very large functional genetic variation within breeds or populations. Nonetheless, some modest milestones have been accomplished by the use of these neutral genetic markers, such as being used to classify the wild ancestral species of most livestock. The processes of breed development and breed uniformity have also provided some insight and a basis for knowledge on the genetic constitution of livestock breeds. In addition, molecular studies using neutral markers have found information that has been used to partly recreate the phylogenetic relationships of certain animal groups and expose the evolutionary path of organisms and populations (Groeneveld *et al*., 2010).

2.8.3 Methods of Breed Characterization

Basically, there are three approaches that can be used to classify breeds of livestock. These include on-farm surveys, on-station studies and molecular laboratory study of on-farm or on-station samples obtained (Lenstra *et al*., 2012). A detailed discussion of the three methods has been given.

An on-farm study: is the type of analysis carried out by the farmer or farming group at the local site. An on-farm breed survey is arranged to collect data on breed phenotypic characteristics, uses and livestock management to understand the reasons for the distribution and survival of a particular breeds (Mogesse, 2007). It can also be designed to collect data on socio-cultural and indigenous knowledge that may be useful in understanding farmers' strategies for the protection of specific breed. On-farm surveys may be useful for collecting basic information on production processes, population statistics, physical or morphological characteristics, and features of breed efficiency. Where breeds are known to occur in small numbers, a survey may need to focus on the areas where they are in order to collect this information. A clear description of priorities for the collection of breed data is very important and careful consideration should be taken of the many different methods that may be used to obtain these data. The goals of a survey of farm animal genetic capital (FAnGR) as outlined by ILRI (1997) are summarized as follows:

- Corroborate available FAnGR within a geographical area, e.g., country or region, in relation to species/breeds/strains;
- Characterize indigenous FAnGR to quantify degree of diversity within the region.

To determine breed status and trends;

- It is necessary to estimate population numbers;
- summarize performance traits;
- Improve the use and conservation of indigenous breeds by:
    - ➢ Identifying users/uses/preferences,
    - ➢ Identifying threats and trends,

- ➢ Identifying unique/special breed attributes,
- ➢ Identifying /developing options for improved uses, and
- Develop framework and capacity for future surveys/updates.

An on-station study: is a controlled environmental study carried out at a research station or a nucleus breeding station. However, only from more detailed on-station studies can a more accurate collection of data on the characterisation of livestock breeds be obtained (Taye, 2005). As simple experimental units, such studies can include entire herd/flock and require data collection over a relatively long-time span. On-station studies may collect information such as livestock performance data, herd or flock structures estimations and population patterns required for assessing decline rates and identifying causes of such declines (Rege et al., 2020). The benefit of the characterization (and evaluation) of on-station breeds is that high accuracy is assured by controlled experimental conditions. In general, on-station unique adaptive characteristics which are difficult to measure at field level (on-farm) are often best studied. As has been stated, despite the fact that they are less effective as performance indicators in herds/flocks of famers, the elevated precision to which on-station studies can be carried out makes them attractive for breed evaluation. Indeed, conclusions drawn from on-station characterization can be misleading in the presence of genotype x environment interaction (Tsegaye, 2009).

Molecular biotechnology is the use of molecular markers to measure genetic diversity and relationships between and within livestock breeds, to investigate biological processes (e.g., mating systems) or to classify particular genotypes (Mwacharo *et al*., 2006b). DNA techniques can be used to examine the phylogeny of race divergence, to track population segregation of genes, and to correlate nucleotide variation with changes in gene function and animal phenotype expression (Cichorz *et al*., 2014). Variability analysis methods are important ingredients for initiatives for animal protection and successful use. Molecular markers are identified as biomolecules (proteins, carbohydrates and DNA) whose heritable characteristics can be checked for variation in species or populations. In the genome of animals, molecular markers can be thought of as constant landmarks that provide clues to gene identification (Ruane and Sonnino, 2007). They are recognisable DNA sequences, located at particular genome locations, and transferred from one generation to the next by normal inheritance laws. The appropriate techniques for assessing DNA variation in a variety of applications include the use of molecular markers (Cheng *et al*., 2013). It should be noted that molecular characterization is not sufficient on its own; characterization must be viewed and carried out in a wider sense of use. Molecular characterization therefore includes a systematic, coordinated approach to the identification of genes, the estimation and confirmation of effects and the use of estimates, with a continued emphasis on phenotypic recording programs.

2.9.0 Non-Genetic Factors

2.9.1 Non-Genetic Factors Affecting Animals

Measurable environmental influences that affect animal output are non-genetic factors (Ruane and Sonnino, 2007). Parity, age, sex, and year of birth are included (Annor *et al*., 2011a). A distinction should be made between contemporary groups of animals when choosing animals to be parents of the next generation. Therefore, for the purpose of raising the rate at which genetic benefit can be achieved, an animal's calculated output with respect to a specific characteristic should be modified for various established environmental or non-genetic factors that mask the expression of that characteristic (Annor *et al*., 2011a). In a typical livestock species raised in both temperate and tropical settings, the effect of non-genetic factors on domestic livestock output is very well known (Beffa *et al*., 2009).

Sex: Males tend to be larger and develop more rapidly than females.

Animal age: Animals of various ages need to be adjusted to a constant age.

Dam parity: For the first time, females giving birth produce smaller ones with lower weights and growth rates than older female

Herd-year-season: Animals in various herds behave differently because different care or management is provided to them. Owing to the variation in climatic conditions in different years, animal output varies between years. Compared to the dry season, there is an adequate amount of food in the rainy season. However, in the rainy season, there are many diseases and pests that attack animals. These were defined by Ampong *et al*., (2019)

2.9.2 Effects of Non-Genetic Factors on Ducks

An animal's environment consists of all those variables that affect it in some way, but are not inherited. The proposed breeding program is a time constraint for the genetic potential of indigenous breed to be increased. In terms of development, body weight and growth efficiency of indigenous ducks are very important traits. While genetics alone plays a potential role in duck growth success, there is also a significant contribution from non-genetic factors. Non-genetic variables such as feeding, flock management, accommodation, season, brooding and vaccination have a major influence on the performance of production (Yakubu, 2013). Management activity helps increase the production capacity of indigenous poultry species and is able to effectively support the livelihoods of poor rural households (Gakige, 2015). Thus, acknowledging small-scale poultry production in Bangladesh as an effective and sustainable enterprise for rural households (Chowdhury, 2013). Proper implementation of the management intervention package could improve the productivity of indigenous chicken flocks and improve their commercialization (Chowdhury, 2013). The relation between the level of capacity and the development of flocks is directly linked to the level of knowledge and management that contributes to profitability of the business (Ochieng *et al*., 2011). In deciding birth weight, the genotype of both mother and foetuses play a crucial role, while the resulting litter weights are essentially dependent on the type of food it is exposed to in addition to the genotype of the foetuses (Adebayo and Adeola, 2005).

2.10 Morphological Characteristics or Traits of Animals

Morphology deals with the size, shape and structure of an animal or one of its components (Abdel-Azeem *et al*., 2007). The classification and identification of species or breeds, morphological features or traits of animals are used. Morphological features are used to distinguish between sexes within species or breeds (Annor *et al.*, 2011b). Indications of sexual dimorphism are the variations in morphological body proportions of the sexes (Annor *et al*., 2011b). Morphological characteristics are also used to predict livestock body weights, allowing poor farmers who cannot afford costly weighing scales to use measuring tapes to estimate body weights (Annor *et al*., 2011b). Body length and heart girth have long been recognised as indicators to predict body weight in livestock production (Annor *et al.*, 2011b). Animals are typically evaluated visually, which is a subjective method of judgement, especially in rural communities (Oke *et al*., 2011). The problem associated with this approach is that, in terms of its body characteristics, it does not provide a true representation of each species. Therefore, the invention of quantitative means (linear body measurements) to define and analyze body size and conformation characteristics will solve many of the problems of visual assessment (Birteeb and Lomo, 2014). Animal linear body dimensions are a significant factor associated with many management activities, including slaughtering, breeding selection, determination of feeding levels, and also a good predictor of animal status (Birteeb and Lomo, 2014). Biometric characteristics are used to classify the various breeds of animals as they provide an indication of body conformation and are often used to compare growth in different individuals *(Brito et al*., 2020). Furthermore, linear body dimensions define an individual or population in a better way than traditional weighing and grading methods. Body measurements were used to denote an individual's breed, origin and relationship or form and size (Pundir *et al*., 2011). The characterisation of livestock breeds is the first path to the sustainable use of animal genetic resources (Pundir *et al*., 2011). The first step of characterization of local genetic resources is based on knowledge of morphological characteristic differences (Hoffmann, 2010b). Morphometric scales have been used to assess the characteristics of various breeds of animals and could provide useful information on the suitability of animals for selection (Gizaw, 2011). The results of genetic improvement programmes can also be checked on a morphological basis (Ajayi *et al*., 2012). Although recent studies have focused on molecular methods, most mammalian species and subspecies were originally described on the basis of morphological characteristics (Manickavelu *et al*., 2006). The use of variance analysis has been confined to previous attempts to phenotypically classify livestock breeds, while the current trend in livestock classification involves the use of multivariate statistical methods (Baker and Bradley, 2006). This is because each variable is evaluated separately by univariate statistical analysis and does not clarify how the populations under investigation differ when all morphological variables measured are collectively considered (Yakubu and Akinyemi, 2010). Due to such variables such as sex, age, breed, and form of the animal, body dimensions differ greatly. It may also differ from one nation to another and even within regions. Some common body measurements of ruminants, however, that researchers have explored, are; chest girth, body length, wither height, chest depth, hip width, hip height, head length, head depth, ear length, body depth, rump height and tail length (Dossa *et al*., 2007). The measurement of the cattle's linear body depends on the animals' race, age, size, height, condition and fattening level. Body measurements as selection criteria for cattle growth can be used for breed characterization (Birteeb *et al.*, 2012). Body weight estimation is most commonly used to measure the growth of the animal body (Adinata *et al*., 2017), but it is not easily measured on the field. This is because of the time and resources spent estimating it. Regression equations have been constructed from body measurements to predict body weight (Yilmaz *et al*., 2013). These regression models influence a rapid assessment of the animal's body parameters, and are also used to optimise nutrition, evaluate the optimum slaughtering age, and selection criteria. In addition, linear body dimensions of meat animals have been considered useful for body size and shape quantification (Birteeb and Ozoje, 2012). To estimate genetic parameters in animal breeding programmes, quantitative measurements of size and shape are required (Molla, 2020).

2.10.1 Measuring Body Weight of Domestic Animals

Body weight is an essential feature which need to be considered when it comes to the assessment of body condition and health status in the measurement of dosages and in the prescription of medication in domestic animals (Bijma *et al.*, 2007). Body weight and condition score are most sometimes used for the assessment of nutritional status (Erat and Arikan, 2010). A range of techniques to obtain information on the body characteristics of animals ranges from simple to sophisticated and costly to inexpensive. The best way to measure the body mass of an animal is to weigh the animal (Mirhosseini *et al.*, 2018). However, in certain circumstances, weighing scale might not be available and prediction of body weight from body measurements may be preferred practically (Erat, 2011).

2.10.2 Growth and Body Weight Characteristics of Duck

Growth is a fundamental characteristic of biological systems and can be characterised as an increase in the number of cells per unit of time in body size (Latshaw and Bishop, 2001). Fowl development is similar to mammalian growth. This consists of three or four cycles which, however, occur after hatching. Like enhanced breeds, indigenous poultry species have a sigmoid growth pattern with growth rate and feed efficiency variations (Malina *et al.*, 2004), although the indigenous fowl seemed to complete the rapid growth process faster than improved breeds (Narinç *et al.*, 2017). Development is affected by genetic and non-genetic factors (Islam and Nishibori, 2009). The evaluation of a growth model is of particular importance in animal production because of its practical consequences (the possibility of testing the adherence of a feeding schedule or a rearing schedule to a reference condition, as calculated by a regression equation) (Thiruvenkadan *et al.*, 2009). Growth curves are used to explain the periodic shift caused by live weight or some part of the animal. Growth curve is usually an S-type curve that increases as age increases. Animal development includes increased size and changes in the functional capacities of the various tissues and organs of animals that emerge from conception to maturity. Increases in cell numbers (hyperplasia) and increases in cell size are part of the growth process (hypertrophy). An animal's growth efficiency is a phenotypic expression that is the external expression of the genetic makeup of the animal. Genetic influences have a significant impact on an animal's performance. This defines the situation in which individual differences in performance are common observations within the same breed or strain. Individuals with superior performance should be identified and used in the genetic improvement programme (Yang *et al.*, 2006). Animal growth has a complicated structure and is affected by genetic and environmental factors. Some of the environmental influences are species, sex, race, treatment, and feeding (Mdladla *et al.*, 2017). While growth is characterized by an increase in body weight, development is characterized by changes in tissue and organ functions, structure, and shape of the body. With age, the influence of sex on growth in poultry becomes more evident. Although growth varies by species in waterfowls, it is usually faster in males than females (Saatci and Tilki, 2007). The live weights of male and female Nageswari ducks at 0, 4, 8 and 12 weeks of age were 47.00±0.19, 229.09±2.59, 512.20±3.55 and 895.79±5.04g and 45.03± 0.21, 198.50±2.49, 480.46±3.08 and 863.10± 4.31g under the free-range system, respectively (Pingel and Germany, 2011). Mafouo and Teguia (2011) recorded that the 12-week-old male duck weighed 1832.0± 180.4 g, while only 68.2% of the male weight was achieved by the female (Morduzzaman *et al.*, 2015a). The average body weight of Charachemballi ducks in Assam as 715.02±5.16 and 1054.63±10.27 g respectively at 8 and 12 weeks under free range condition (Mafouo and Teguia, 2011). The mean live weights of ducks at 1, 2, 3, 4, 5, 6, 7, 8, 10 and 12 weeks of age were 123.21 ± 17.77, 263.16 ± 40.00, 438.92 ± 57.64, 627.68 ± 73.68, 797.68 ± 85.54, 974.73 ± 119.44, 1176.11 ± 117.55, 1251.90 ± 111.28, 1468.08 ± 134.26 and 1522.10 ± 129.35 g under the extensive system, respectively (Morduzzaman *et al.*, 2015a). The body weights of Muscovy ducks for the widely reared Deshi and Khaki Campbell cross in India are higher than the range of 1,515 kg and 1,710 kg (Morduzzaman *et al.*, 2015a). Etuk *et al.* (2006) recorded body weights, respectively, of 2507g and 1733.83g for drakes and ducks (Foluke Eunice *et al.*, 2020). The body weight of seven and eight weeks, Pekin ducks for meat production is 2.6-3.0 kg and 3.6-4.0 kg respectively (Etuk *et al*., 2006b). The average body weights of Kara, Yesilbas, Boz and Turkish Pekin ducks is 42.3g, 44.5g, 48.0g and 46.2g for day-old ducklings respectively as; 1036.5, 1154.5, 1115.3 and 1168.7g for 4-week-old ducklings respectively; 1660.7, 1824.7, 1894.0 and 1744.2 g for 8-week-old ducks; 1816.0, 1999.0, 2044.0 and 1885.5 g for 12-week-old ducks, respectively (Makram *et al*., 2017). Ducks hit about 80% of the adult weight at eight (8) weeks *(*Işguzar *et al.*, 2002b). The weight of most Pekin ducks grown in North America is 3.2 kg, (Işguzar *et al.*, 2002b).

2.10.3 Carcass characteristics of Ducks

Meat of duck contains about 20% crude protein and 2% fat (Farhat and Chavez, 2000). In particular, Muscovy ducks are a heavy breed mainly used for meat production. The meat of Muscovy with yellow creamy skin has an attractive look and is strong. Because of its red gamy and attractively marbled meat, Muscovy is popular, making it a special delicacy (Kwon *et al*., 2014). Ducks have been bred for higher meat yields with lower fat for several years and the impact of selection on the meat quality of this species is relatively mild (Kwon *et al.*, 2014). The consistency and palatability of the breast muscles of Muscovy ducks deteriorate with age. They become less juicy and harder (less tender), which is due to reduced solubility of collagen followed by increased muscle fibre thickness. Carcass yields of ducks in South Western Nigeria is between sixty-six (66%) percent and sixty-eight (68%) percent in Muscovy ducks bred under a semi-intensive method (Baeza *et al*., 2002). With growing age, there is an increase in duck's breast muscle (Galal *et al*., 2011a). The body's growth rate would be decreased, but the muscle of the breast tends to continue its intensive growth up to a higher age. The bone, skin and meat yield without edible organs was 28, 38 and 34 percent, respectively (Witak, 2008). The carcass percentage of males and females was 62.4 percent and 63.44 percent, respectively *(Işguzar et al*., 2002a).

2.10.4 Sensory Characteristics of Ducks

The quality of poultry meat has become increasingly important because the sensory characteristics such as the appearance and tenderness of the meat is required by the customer (Işguzar *et al*., 2002c). The meat must comply with quality characteristics such as texture, palatability and appearance and must also provide safety for unwanted chemical residues (Mir *et al.*, 2017). Factors inherent to livestock, such as age at slaughter, sex, breed, strains, muscle type, production systems, food and pre-slaughter management and post-harvest, may affect the sensory characteristics of meat (Toldrá, 2008). In order to purchase a meat product, the first attribute encountered by the customer is the appearance and after which other characteristics such as tenderness, juiciness and useful life are taken into account, adding value to the product (Berri, 2000). The flesh colour is a preference factor for the acquisition of chicken meat (Moeller *et a*l., 2010). Individually, the texture is the most significant sensory aspect that influences the overall quality of chicken meat (Tomasevic *et al.*, 2019). The management system directly responsible for the quality of animal meat is raising ducks in confinement (Fanatico *et al.*, 2005). Consumers worldwide conclude that ecological rearing systems products have higher nutritional quality and better taste (Rufino *et al.*, 2015). On the other hand, the form of cooking influences the nutritional value, appearance and consistency of meat consumption (Tanganyika and Webb, 2019). Furthermore, it has been found that the post-mortem ageing duration affects sensory characteristics. Consumers typically buy meat and cook directly after dressing or within 4-5 hours of slaughter or after storage in the refrigerator for 10-12 hours because of minimal cold chain facilities (Omojola *et al.*, 2014). Chickens had a brighter colour of meat in the free-range setting, which may be attributed to the content of natural carotenoids in green forage eaten from the environment (Mendiratta *et al.*, 2012). The colour of meat is influenced by the rearing mechanism and influences the option preferences of consumers (Ponte *et al.*, 2008a). Because more forages are eaten, free range may have affected the sensory characteristics of the meat (Ogbeide, 2015). The various rearing systems had an effect on the ducks' meat colour (Ponte *et al.*, 2008b). However, for various rearing systems of chickens, Michalczuk *et al.* (2014) found no variations in sensory characteristics and concluded that access to free range or other rearing systems has no effect on the quality of poultry meat (Lacin *et al.*, 2008).

2.10.5 Haematological Characteristics of Ducks

Muscovy duck and local duck are more prominent than other poultry due to greater tolerance than chicken. Body immunity to disease is one requirement for poultry breeding in the production of poultry strains for industry. The haematological parameter is the measure used to understand the body's immune system against diseases of immunological function and the amount of poultry production is highly influenced by haematological status (Michalczuk *et al.*, 2014). Haematological tests are typically carried out to determine the diagnostic baselines of blood characteristics for the practice of routine farm animal management (Ismoyowati *et al.*, 2012a). In general, haematological components reflect the animal's physiological responsiveness to its external and internal environments and thus serve as a real instrument for monitoring animal health and disease (Daniel-Igwe and Okwara, 2017). Muscovy ducks in south-eastern Nigeria, had an average mean values of $3.22 \times 10^6/mm^3$, 43.59%, 14.92 g/dl, $24.53 \times 10^3/mm^3$,for Red blood cell, Pack cell volume, Haemoglobin and White blood cell respectively (Maceda-Veiga *et al*., 2015). However, for local Muscovy ducks in south western Nigeria, the average mean values of RBC, PCV, Hb and WBC counts are 1.72 x 10^6 mm^3, 38.09%, 11.64 g/dl and 18.21 x$10^3$$m^3$, respectively, which is lower than the values of Muscovy ducks in south-eastern Nigeria (Okeudo *et al*., 2003a). Erythrocyte is a part of blood component that is elliptical with a core in fowl, measuring 12.8 µm and 6.6 µm, respectively in length and width diameter (Okeudo *et al*., 2003b). In the wet and dry seasons, the total amount of erythrocytes in the Nigerian duck (*Anas plathirynchos*) is 2.46±0.45 mil/µl and 2.02±0.56 mil/µl, respectively (Reagan *et al.*, 2019). Ismoyowati *et al*. (2012) reported that the development cycle of haemoglobin in the Tegal duck is 10.96-12.17 g/dl. The highest average of MCV and MCH in female Muscovy duck suggests different erythrocyte volumes of Muscovy duck and local duck in both sexes due to blood water and blood viscosity content (Olayemi and Arowolo, 2009). The optimal heterophile and lymphocyte ratio would provide fowl with welfare to alleviate stress (Olayemi and Arowolo, 2009). There was a comparatively lower H/L ratio in layer chicken and broiler raised in a proper cage (Campo and Davila, 2002). In female local ducks and male local ducks, the maximum number of leukocytes was 9110.00±2845.21 and 3625.00±1233.75/µl, respectively. In the Nigerian duck, the sum of leukocytes was 16.93 x 10^9/l and 6.58x10^9/l in the wet season and 22.55x10^9x/l in the dry season (Ismoyowati *et al*., 2012b).

Table 2. 3: Haematological values of local ducks and drakes of south-eastern Nigeria

Parameters	Mean	Male mean ± SE	Female mean ± SE
Erythrocytes (RBC) ×10^6/mm^3	3.22	3.31±0.10	3.13 ± 011
Packed cell volume (PCV) %	43.59	46.00 ± 1.73	41.17 ± 1.13**
Haemoglobin concentration (HBC) %	14.92	15.67 ± 0.29	14.17 ± 1.13*
Erythrocytes sedimentation rate (ESR) mm/hr	1.79	1.63 ± 0.35	1.95 ± 0.30*

Mean corpuscular haemoglobin concentration (MCHC) %	34.23	34.07 ± 1.01	34.42 ± 2.13
Blood clotting time (seconds)	170.0	155.0 ± 1.00	185.0 ± 11.05
Mean corpuscular haemoglobin (MCH) %	4.63	4.73 ± 0.24	4.53 ± 0.13
Mean corpuscular volume (MCV) %	13.54	13.90 ± 1.03	13.15 ± 0.15
Leucocytes (WBC) × 10^3/mm^3	24.53	23.81 ± 0.88	25.24 ± 1.62
Heterophils (Neutrophils) %	13.67	15.33 ± 4.16	12.00 ± 1.27
Eosinophils %	6.25	5.67 ± 2.08	6.83 ± 2.64
Lymphocytes %	80.09	79.00 ± 3.61	81.17 ± 2.64
Basophils and monocytes %	Na	Na	Na

*= $P < 0.05$, ** = $P < 0.01$. Na = not available
Source: Okeudo *et al.* (2003a).

2.10.6 Egg Characterization

For economic, scientific, cultural and historical reasons, protection of genetically different species living in limited populations and threatened with extinction is needed (Olayemi and Arowolo, 2009). A source of genetic diversity that enables breeding work to be continued is the conservative duck flocks held in situ. Good production characteristics that are the basis of studies on characteristics such as egg quality are characterised by these unique populations (Hoffmann and Scherf, 2005). Egg specific gravity, eggshell thickness, egg shape index and egg white and yolk index are the morphological characteristics of duck eggs from conservative flocks. The retail mean weight of duck eggs is 66.10±0.98g (Okruszek *et al.*, 2008). The indigenous ducks of Assam have a specific gravity value of 1.11±0.006 (Abraham, 2009). The yolk index value for a retail egg is 0.31±0.02, but the yolk index values of farm fresh eggs are very high (Harikrishnan and Ponnuvel, 2012). The shell thickness value at various stages of development for white Pekin duck eggs is 0.385±0.02 (Abraham 2009). The percentage of yolk lipids of light type ducks in freshly laid eggs was 29.1 percent and 30 percent, respectively (Okruszek *et al.*, 2006). The proportion of moisture in Pekin parent stock and progeny of commercial stock originating from England is 4.22 percent and 4.84 percent, respectively (Okruszek *et al.*, 2006).

CHAPTER THREE

3.0 MATERIALS AND METHODS

The study was carried out in four phases. The first phase was a survey which was aimed at collecting demographic information on farmers involved in duck rearing, their production systems, phenotypic description of ducks and information on diseases of ducks. The second phase involved the growth performance on the experimental ducks. The third phase involved the collection of sensory and carcass data from the ducks that were used for the experiment. The fourth phase involves taking blood samples from the experimental birds for haematological characteristics.

3.1 Location of the study

The study took place in three selected districts in the Northern region. The Northern region is one of Ghana's sixteen Region. It is located in the northern part of the country and was the largest of the sixteen regions, covering an area of 70,384 square kilometers and is thirty one percent (31 percent) of the total area of Ghana before the Savannah Region and North East Regions were formed from it in December 2018. These districts include; Kumbungu district, Tolon district and Savelugu-Nanton district. These districts were chosen based on a preliminary survey made by the experimenter and a secondary data from the Ministry of Food and Agriculture Regional Office as to where there were large population of duck farmers. After the survey, these districts were selected and were made the locations of the study.

Kumbungu district is one of the newly established districts that was created out of the Tolon/Kumbungu district with Legislative Instrument (L.I) 2062 of 2011. It was inaugurated with Kumbungu as its district capital on 28 June, 2012. The district is situated on the northern flank of the Northern region and occupies an area of around 1,599 km sq. The district shares borders with the districts of Mamprugu/Moagduri to the north, the districts of Tolon and North Gonja to the west, the district of Sagnerigu to the south, and the district of Savelugu/Nanton to the east. The rains begin in May and end in the latter part of October in Kumbungu district. The peak season is July to September and the district experiences floods during the period. The year is dry for the rest. The annual rainfall average is 1000 mm. Around February to April, the temperature is warm, dry and hazy. Between May and September, it is cold, damp and rainy. In the time from November to February, Harmattan is encountered. In general, the district is hot. The Tolon district was launched by LI in 2011. 2142, with Tolon as the capital of the district. The district was previously part of the Tolon/Kumbungu district, one of the 45 districts created in 1988 by Law 207 of the then Provisional National Defence Council (PNDC). The District was among the 42 districts inaugurated in 2012 in order to increase participation and growth, especially at the grassroots level. The district was carved out of from the then district of Tolon/Kumbungu. The district lies between latitudes 9° 15 'and 10° 0 02' North and longitudes 0° 53 and 1° 25 West. It shares borders to the north with Kumbungu, to the west with North Gonja, to the south with Central Gonja, and to the east with Sagnarigu. The district is characterized by a single rainy season, which begins with little rainfall at the end of April, rises to its height in July-August and decreases sharply and ends fully in October-November. The dry season begins with daytime temperatures ranging from 33°C to 39°C from November to March, while the mean night temperature ranges from 20°C to 26°C. The mean annual precipitation ranges from 950 mm to 1,200 mm.

In 1988, under PNDC Law 207, the Savelugu-Nanton district was carved out of the Western Dagomba District Council. Under the Local Government Act 1993, the law was replaced by the Statutory Instrument (LI) 1450 (Act 462). In March 2012, under the Legislative Instrument (LI) 2071, the Assembly was upgraded to municipal status. The district of Savelugu-Nanton is located in the northern part of Ghana's Northern Region. It shares borders with the north of West Mamprusi, east of Karaga, west of Kumbungu, and south of the Tamale Metropolitan Assembly. The district altitude varies between 400- and 800-feet above sea level. The district also has roughly 2022.6 sq. km of total land area with a population density per sq. of 68.9 individuals. The region receives an annual average rainfall of 600 mm, which is considered adequate for a single season of farming. At the start of the rainy season, the annual rainfall pattern is unpredictable, starting in April and intensifying as the season progresses, often increasing the average from 600 mm to 1000 mm. The district is characterized by high temperatures with an average of 34°C. Low temperatures are encountered from December to late February, during which the municipality is significantly influenced by the North-East Trade winds (harmattan).

Figure 3.1: Map of Northern Region showing the various districts

Source: Ghana Statistical Service (2013)

3.2 Phase One - Survey Experiment

- The study was conducted in three (3) districts of the northern region namely; Kumbungu, Savelugu-Nanton and the Tolon district. One hundred (100) duck farmers were sampled from each of the three (3) districts, using snowball sampling method. Farmers were interviewed using a semi-structured questionnaire. The questions consisted of information on demographic characteristics of farmers, production systems, phenotypic description of ducks and diseases and their management. Thirty (30) ducks of about twelve (12) months of age from each of the three (3) districts were randomly sampled for weight and morphological measurements. The body parts measured were, body weight (BWT), body length (BDL), breast circumference (BTC), thigh circumference (THC), bill length (BLL), neck length (NKL), foot length (FTL) and wing length (WNL) (Okruszek et al., 2006). For the weight measurement, a portable hand electronic LCD digital weight scale (capacity = 5 kg) was used. A measuring tape calibrated in centimetres was used to measure the body length (BDL), breast circumference (BTC), thigh circumference (THC), bill length (BLL), neck length (NKL), foot length (FTL) and wing length (WNL). Measurements were defined by Yakubu *et a*l. (2011a). Globl Positioning Station application on a phone was used for taking coordinates of farm locations.

- **Body weight (BW):** Live adult birds were restrained and placed in a bucket. The bucket was hanged on a digital measuring scale and their weights were recorded. The weight of the bucket was tarred before the weight of the animal was taken.
- **Body length (BDL):** The length between the tip of the rostrum maxillae (bill) and that of the caudal (tip of tail without feathers).
- **Breast circumference (BTC):** The circumference of the breast. It was measured under the wings at the edge of the sternum (from the beginning of the chest to the end).
- **Thigh circumference (THC):** The circumference of the thigh. It is measured as the circumference of the drumstick at the coxa region.
- **Neck length (NKL):** it is measured as the distance between the occipital condyle and the cephalic borders of the coracoids.

- **Foot length (FTL):** It was measured as distance from the shank joint to the extremity of the Digitus pedis.
- **Wing length (WNL):** it was established as the linear measurement from the shoulder joint to the extremity of the terminal phalanx.
- **Bill length (BLL):** bill length was measured as a distance from the rectal apterium to the maxillary nail.
- **Plumage colour**: plumage colours were observed and were recorded by visual inspection. Each measurement was taken twice to ensure precision, and the average was used in subsequent study. The same individual took all measurements and weighed throughout, thereby removing mistakes due to differences in individuals (Yakubu *et al*., 2011a).

3.2.1 Statistical Analysis of Survey Data

Frequencies of demographic of duck farmers, production and management practices and the qualitative characteristics of ducks were computed using descriptive statistics in SPSS 17.0.

Pearson correlation of weight and morphological measurements was also analysed using SPSS 17.0

3.3 Phase Two - Growth performance of experimental ducks

The second phase involved the growth performance of the experimental ducks. This phase of the study was conducted in a poultry house in Nyankpala in the Tolon district. Nyankpala is about 18 km west of Tamale in the Tolon district**.** The district lies between latitude 8ºN, 11ºN and longitude 0ºE 3ºW (Shahin and Hassan, 2000). The vegetation consists of grassland dotted with small drought resistant trees. The area experience one rainfall season annually, beginning in March and ending in September. The average temperature is 31ºC with a minimum of 28.2ºC and a maximum of 42ºC.

3.3.1 Selection and Management of Experimental Birds

Twenty duck eggs were randomly purchased from each of the three districts. Eggs were identified with writings on it with respect to the district they came from. The writing was done with a permanent marker. The writing was made up of the first letter of the name of the district and a number. A sanitizer was added to warm water to wash the eggs by Rivera-Garcia *et al.* (2019). This was done to keep the eggs from contamination by dirt and bacterial. The eggs were incubated for thirty-five (35) days using a locally made incubator called JAK incubator made by JAK farms. JAK incubator is a fully automated incubator which carry out all the incubation processes automatically. Temperature, humidity regulation and turning was done automatically. Eighteen, Fifteen and Twelve eggs were able to hatch from Kumbungu, Savelugu and Tolon respectively at day twenty-eight (28). Ducklings from hatched eggs from each district were put into three woven baskets each representing the district the eggs came from. Rice chaff was spread inside the basket to serve as a bedding material. They were brooded for three weeks before transporting them to the experimental site. Sexing was done through vent examination. They were kept for ten weeks at the experimental site. House were made of locally available material. Walls of the house were made of blocks with the roof being iron sheets. The house was partition into six rooms with a wire mesh and wood**.** Three rooms were used for the experiment. The floor of the room was made of cement and was filled with rice chaff to serve as a bedding material. Litter was changed in every two weeks.

The Starter and Grower rations were sourced from the Koudijs Animal Nutrition Company in Tamale. Feed and water were administered *ad libitum*.

Table 3.1: Nutritional Composition of the Starter and Grower Rations

Nutrients	**Starter Feed Composition (%)**	**Grower Feed Composition (%)**
Crude Protein	22.00	17.00
Crude Fat	7.50	4.00
Crude Fibre	2.50	4.30
Lysine	1.30	1.00
Methionine	0.60	0.45
Cysteine + Methionine	0.90	-
Calcium	0.95	3.80
Sodium	0.20	0.90
Phosphorus	0.60	0.50
AME (Kcal/kg)	3150	2550

Source: Koudijs Animal Nutrition

Data Collection

Data collected included weight and morphological parameters of the various sexes and colour varieties of ducks. Weights of the birds were taken at the end of every week up to the 13th week. Morphological measurements on experimental birds were also taken every two weeks up to the 13th week. The parameters measured were, body weight (BWT), body length (BDL), breast circumference (BTC), thigh circumference (THC), bill length (BLL), neck length (NKL), foot length (FTL) and wing length (WNL) according to Yakubu *et al.*, (2011).

3.3.3 Statistical Analysis of Growth Performance

To investigate the effects of colour variety, sex and the interaction effect of colour and sex on body measurements, the data was analysed using the Two-way Analysis of variance in GenStat (version 11.1). Significant differences were determined at 5% significance level. Means were separated using Duncan multiple range test.

Correlation between weight and morphological measurements was also analysed using SPSS 17.0.

The model used is shown below:

$$Y_{ij} = \mu + V_i + S_j + VS_{ij} + e_{ijk}$$

Y_{ijk} = body weight, body length, breast circumference, thigh circumference, bill length, neck length, foot length and wing length.

μ = the overall mean

V_i = the effect of the i^{th} colour variety of ducks, i =1… 5

S_j = the effect of the j^{th} sex of ducks, j = 1, 2

VS_{ij} = is the interaction effect between i^{th} colour variety and the j^{th} sex.

e_{ijk} = the random error term assumed normally and independently distributed, $(0, \sigma^2 e)$.

3.4.0 Phase Three – Sensory and Carcass Experiment

The third phase of the study was conducted at the meat unit of the Animal Science Department, Faculty of Agriculture, University for Development Studies, Nyankpala campus. Data on carcass and sensory characteristics were collected from thirty (30) birds of different sexes and of different plumage colour. Ducks for the carcass characteristics and sensory characteristics were sampled from the experimental birds in phase two. Ducks were ten (10) weeks old for the experiment. Feed was withdrawn 12 hours prior to slaughter. Slaughtering of ducks was done according to standard abattoir procedure. Parameters measured include;

- Live weight: the weight of the live domestic ducks before slaughter.
- Carcass weight: the weight of the bird after the removal of viscera, shanks, and the head.
- Breast weight: the weight of the breast
- Leg weight: The weight of the leg
- Wing weight: The weight of the wing
- Heart weight: The weight of the heart
- Liver weight: The weight of the liver
- Gizzard weight: The weight of the gizzard
- Whole Gastrointestinal tract weight: The weight of the whole gastrointestinal tract
- Abdominal fat weight: The weight of the abdominal fat.

These parameters were measured by the use of a digital measuring scale. All the measured parameters were in kilogram.

Parameters on sensory characteristics include;

- Juiciness
- Colour
- Aroma
- Flavour intensity
- Flavour liking
- Texture
- Taste
- Tenderness

- Overall liking

3.4.1 Meat Sample and Preparation

Breast muscles of both drakes and ducks of the various plumage colour varieties were used for the sensory evaluation. The samples were randomly numbered for easy of identification. All the samples were subjected to grilling for an hour at 150°C. There was no seasoning or any flavouring added to the meat samples. They were then chopped into smaller sizes and wrapped in an aluminium foil to prevent it from becoming cold. They were placed in a plastic storage bowls with their respective identification numbers written on it.

3.4.2 Test Panel Evaluation

A total of thirty students from different departments of the University for Development Studies were used. The taste panel consisted of eighteen males and twelve females between 20 and 35 years of age who were final year undergraduate students and graduate students. A triangle test was used to select the panellists, where three coded samples were sent at the same time, two were similar and the third sample was unusual (Grandin, 2010), using three sugar solution samples and three other salt solution samples to be classified by the panellists. After this test, duck meat samples were given to the panellists for evaluation on the basis of colour, tenderness, aroma, strength of flavour, taste, texture and juiciness of the duck meat based on sex and colour varieties of duck. Score cards were given to the panellists to record their assessment based on colour, tenderness, aroma, strength of flavour, taste and texture and juiciness.

3.4.3 Experimental Design

Sensory scores on colour, tenderness, aroma, flavour intensity, flavour liking, texture, taste and juiciness of duck meat were determined by students from various departments of University for Development studies, Nyankpala campus using the nine (9) point Hedonic scale. A random 3-digit code was used to label the samples (Heinz and Hautzinger, 2007). The panellists were told to use bread to clean their palates between samples (Abbott *et al*., 2004).

3.4.4 Statistical analysis of carcass and sensory

Effect of sex, colour variety and the interaction effect of colour variety and sex on carcass characteristics were analysed using two-way analysis of variance in GenStat (v.11.1). Significant differences were determined at 5% significance level. Means were separated using Duncan multiple range test.

Effect of sex and colour variety on sensory characteristics was analysed using one-way analysis of variance in GenStat (v.18.1). Significant differences were determined at 5% significance level (Snedecor and Cochran 1989). Results were presented in tables.

The model used for the effect of sex, colour variety and the interaction effect of colour variety and sex on carcass characteristics was

$$Y_{ijk} = \mu + V_i + S_j + VS_{ij} + e_{ijk}$$

Y_{ijk} = Live weight, Carcass weight, Breast weight, Leg weight, Wing weight, Heart weight, Liver weight, Gizzard weight, Whole Gastrointestinal tract weight, Abdominal fat weight

μ = the overall mean

V_i = the effect of the i^{th} colour variety of ducks, i =1… 5

S_j = the effect of the j^{th} sex of ducks, j = 1, 2

VR_{ij} = is the interaction effect between i^{th} colour variety and the j^{th} sex.

e_{ijk} = the random error term assumed normally and independently distributed, $(0, \sigma^2e)$.

For the effect of sex and colour variety on sensory characteristics, the model below was used.

$$Y_{ijk} = \mu + V_i + + S_j + VS_{ij} + e_{ijk}$$

Y_{ijk} = Juiciness, colour, Aroma, Flavour intensity, Flavour liking, Texture, Taste, Tenderness and overall liking

μ = the overall mean

V_i = the effect of the i^{th} colour variety of ducks, i =1… 5

S_j = the effect of the j^{th} sex of ducks, j = 1, 2

VR_{ij} = is the interaction effect between i^{th} colour variety and the j^{th} sex.

e_{ijk} = the random error term assumed normally and independently distributed, $(0, \sigma^2 e)$.

3.5.0 Phase Four – Experiment on Haematology

3.5.1 Collection of Blood Sample

From a punctured wing vein, the birds were bled between 9 and 10.30 am to aspirate blood from each bird. A total of thirty birds consisting of fifteen males and fifteen females were used. Two millilitres of blood samples were collected in Bijou bottles treated with Ethylene Di-amine Tetra Acetic acid (EDTA). The blood samples were then sent to the laboratory at the University for Development Studies clinic for analysis.

3.5.2 Blood Analysis

Blood samples were analysed immediately after collection. The blood was analysed by a fully automated haematology analyser. The EDTA tube was shaken to ensure thorough mixing of the blood with the EDTA to prevent blood from clotting. The sample identity was entered into the analyser. The sample probe of the machine was dipped into the EDTA tube to aspirate a sample of the blood. The blood sample aspirated was analysed. Blood parameters analysed were the White blood cell (WBC), Red blood cell (RBC), Haematocrit (HCT), Haemoglobin concentration (HBC), Mean corpuscular volume (MCV), Mean corpuscular haemoglobin concentration (MCHC) and Mean corpuscular haemoglobin (MCH).

3.5.3 Statistical analysis of haematological characteristics

The data collected for haematological characteristics were analysed by GenStat (v.11.1) using two-way analysis of variance. It was used to analyse the effect of sex, colour variety and the interaction effect of colour and sex on the haematology. Critical differences were determined at 5% significance level. Means were separated using Duncan multiple range test. Results were presented in tables.

The model below was used.

$$Y_{ijk} = \mu + V_i + S_j + VS_{ij} + e_{ijk}$$

Y_{ijk} = Red blood cell, White blood cell, Haematocrit, Haemoglobin concentration, mean corpuscular volume, mean corpuscular haemoglobin concentration and mean corpuscular haemoglobin.

μ = the overall mean

V_i = the effect of the i^{th} colour variety of ducks, i =1… 5

S_j = the effect of the j^{th} sex of ducks, j = 1, 2

VR_{ij} = is the interaction effect between i^{th} colour variety and the j^{th} sex.

e_{ijk} = the random error term assumed normally and independently distributed, $(0, \sigma^2e)$.

All data analysed in the present study were presented in tables.

CHAPTER FOUR

4.0 RESULTS

4.1 Demographic Characteristics of Duck's Farmers, Their Production Systems and Diseases and Their Management

Table 4.1 shows demographic characteristics of duck farmers, their production systems and disease and their management. Duck farmers were predominantly males, about 86% with majority (58.7 %) of them falling in the active work force age range (18 – 50 years). Muslims were dominant (58.7%) than all the other religions with only 3.3 percent who said they do not belong to any religion. Forty four percent (44%) of the duck farmers source their initial stock from colleague farmers. Only eight percent (8%) obtain their initial stock from the market.

Majority (68%) of the farmers practiced semi-intensive system of production with only 32% practising the extensive system of management. No farmer keeps ducks commercially. Most of the farmers keep their ducks in mud houses. Only 2% of farmers keep their ducks in open yard but fenced type of housing. A good number (49.7%) of the duck's houses are made up of mud and thatch with few being made up of mud with iron sheet. A reasonable proportion (34%) of duck farmers provide ducks with water from the borehole with only 15.2% providing water to ducks from the dam. Fifty six percent of duck farmers provide water for ducks all day with only seven percent providing ducks with water twice in a day. Thirty four percent (34%) of duck farmers feed ducks with cereals. Only 12% of duck farmers feed their ducks food left overs. About 23.7% of farmers are into duck's production for meat, money and egg. Only 3.3% are into duck's production for meat, breeding and eggs.

Table 4.1a: Demographic characteristics of farmers

Variable	Frequency	Percentage (%)
Gender		
Male	258	86
Female	42	14
Religion of respondent		
Christians	88	29.3
Muslims	176	58.7
Traditionalist	26	8.7
None	7	3.3
Age of respondents (years)		
18 – 30	53	17.7
31 – 40	40	13.3
41 – 50	83	27.7
51 – 60	45	15.0
Above 60	79	26.3
Source of Initial Stock		
Market	24	8
Colleague farmers	120	40
Inheritance	62	20.7
Gift	94	31.3

Table 4.1b: Production systems of ducks

Variable	Frequency	Percentage
Production System		
Semi-intensive system	204	68
Extensive system	96	32
Type of Housing provided		
Mud house	149	49.7
Open yard but fenced	6	2.0
Cage	56	18.7
None	89	29.7
Materials used for housing		
Mud and thatch	142	47.3
Mud and iron sheet	7	2.3
Wire mesh with wood	23	7.7
Wood	33	11
None	95	31.7
Main source of water		
River	81	27
Well water	71	23.7
Dam	46	15.2
Borehole	102	34
How frequently do ducks get water		
All day	168	56
Once a day	111	37
Twice a day	21	7
Purpose of Keeping Ducks		
Money, meat and manure	29	9.7
Manure, meat and breeding	16	5.3
Money, meat and eggs	71	23.7
Meat and manure	10	3.3
Egg, meat and manure	55	18.3
Money, breeding and eggs	29	9.7
Meat and eggs	30	10
Meat, breeding and eggs	10	3.3
money, eggs and prestige	50	16.7
Feed for Ducks		
Cereals	102	34
Crop residue	36	12
Cereals and food left overs	67	22.3
Cereals and crop residue	48	16.0
Cereals and industrial by products	47	15.7

Table 4.1c: Disease that affects Duck

Variable	Frequency	Percentage
Disease		
Dungbara (paralysis of the leg)	176	58.7
Duck hepatitis	86	28.7
None	38	12.6
Frequency of Disease		
Once every six months	45	15
Once a year	125	41.7
Twice a year	92	30.7
None	38	12.7
Lack of veterinary Assistance		
Yes	268	89.3
No	32	10.7

4.2 Phenotypic description of ducks in the Kumbungu, Savelugu and Tolon districts of Northern region of Ghana.

Table 4.2 shows the phenotypic description of ducks in the Kumbungu, Savelugu and Tolon districts. Most of the ducks produced in the study locations have white skin with only 14.4% with yellow skin. Ducks with white shank colour were 51.1% and only 11.1% were of yellow shank colour. About 63.3% of the ducks were having a brown eye colour with 36.7% having black eye colour. Black dominated white plumage colour was dominant in the various study locations with white dominated faded black plumage colour being the least.

Table 4.2: Phenotypic description of ducks in the Kumbungu, Savelugu and Tolon districts of Northern Region of Ghana

Skin colour	**Frequency**	**Percentage**
Yellow	13	14.4
White	61	67.8
Pale	16	17.8
Shank colour		
Yellow	10	11.1
White	46	51.1
Black	34	37.8
Eye colour		
Black	33	36.7
Brown	57	63.3
Plumage colour		
Pure white	20	22.2
Black dominated white	37	41.1
Black with white stripes	10	11.1
White dominated faded black	9	10
White dominated pure black	14	15.6

4.3 Correlations Matrix of Body Weight and Body Measurements of On-Station Ducks

Correlation coefficients among the various body measurements are shown in Table 4.3. Among the various body parameters, moderate to high positive correlation coefficients were reported. The highest correlation of body measurement was between neck length and foot length (0.803). Wing length and neck length had the second highest correlation value of 0.761 followed by neck length and breast circumference (0.725). The least correlation was between body length and foot length (0.273). There were no negative correlations between the body measurements. The weights of the birds were highly correlated with body length (0.660) followed by bill length (0.620), whereas body weight was least correlated with foot length (0.212). Correlation between morphological measurement and weight are found in Table 4.3.

Table 4.3: Correlation Matrix of Body Weight and Body Measurements of Ducks Kept On-Station

Traits	BW	THC	BTC	BDL	BLL	NKL	FTL	WNL
BW	1							
THC	0.252*	1						
BTC	0.442**	0.633**	1					
BDL	0.660**	0.458**	0.477**	1				
BLL	0.620**	0.534**	0.560**	0.667**	1			
NKL	0.520**	0.524**	0.725**	0.551**	0.699**	1		
FTL	0.212*	0.279**	0.571**	0.272**	0.433**	0.803**	1	
WNL	0.413**	0.530**	0.551**	0.768**	0.687**	0.761**	0.495**	1

*NB: **significant (p<0.01), * significant (P <0.05)*
BW=Body Weight, TC= Thigh Circumference, BC= Breast Circumference, BL= Body Length, BIL= Bill Length, NL= Neck Length, FT= Foot Length, WL= Wing Length.

4.4 Growth Performance of Experimental Ducks

4.4.1 Effect of Plumage Colour on Weekly Weight of Ducks

Table 4.4 shows the effect of colour variety on weight of on-station ducks. The various colour varieties were not different (p> 0.05) throughout the period of study in weight. Black Dominated White ducks were heavier in weeks four, five, ten, eleven and week thirteen as compared to the weight of the other colour varieties. Black with White Stripes ducks were heavier as compared to the other colour varieties in weeks six, seven, eight, nine and twelve.

Table 4.4: Effect of Plumage Colour on weekly weight of Ducks

Week	Mean (Kg)					LSD	P-VALUE @ 5%
	BDW	PW	BWST	WDFB	WDPB		
1-3	0.243	0.206	0.251	0.195	0.188	0.051	0.060
4	0.343	0.271	0.332	0.275	0.258	0.077	0.107
5	0.568	0.480	0.560	0.458	0.462	0.131	0.244
6	0.774	0.633	0.809	0.699	0.681	0.190	0.333
7	1.012	0.898	1.037	0.954	0.833	0.185	0.173
8	1.248	1.132	1.288	1.248	1.067	0.211	0.189
9	1.389	1.265	1.391	1.317	1.184	0.181	0.126
10	1.491	1.365	1.480	1.450	1.339	0.209	0.457
11	1.622	1.455	1.572	1.546	1.507	0.212	0.551
12	1.747	1.595	1.798	1.694	1.597	0.257	0.394
13	1.895	1.737	1.770	1.788	1.696	0.266	0.609

BDW=Black dominated white, PW= Pure white, BWST=Black with white stripes, WDFB=White dominated faded black, WDPB= White dominated pure black, LSD = Least Square Difference.

4.4.2 Effect of Sexes on Weekly Weights of Ducks

Table 4.5 shows the effect of sexes on weekly weights of ducks. Sex had a significant effect ($P<0.05$) on weight of ducks throughout the period with males being heavier throughout the period of study.

Table 4.5: Effect of Sex on Weekly Weight of Ducks

Weeks	Mean Weight (KG)		LSD	P-value @ 5%
	Male (15)	Female (15)		
1-3	0.243^{a}	0.190^{b}	0.032	0.003
4	0.332^{a}	0.261^{b}	0.049	0.008
5	0.566^{a}	0.445^{b}	0.083	0.007
6	0.805^{a}	0.634^{b}	0.120	0.008
7	1.085^{a}	0.809^{b}	0.117	<.001
8	1.371^{a}	1.022^{b}	0.133	<.001
9	1.505^{a}	1.114^{b}	0.114	<.001
10	1.684^{a}	1.166^{b}	0.132	<.001
11	1.855^{a}	1.226^{b}	0.134	<.001
12	2.032^{a}	1.341^{b}	0.162	<.001
13	2.183^{a}	1.371^{b}	0.168	<.001

NB: *Means between colour varieties of ducks with different postscript are significantly different ($p<0.05$), LSD = Least Square Difference*

4.4.3 Interaction Effect of Sexes and Plumage Colour on Weekly Weights of Ducks

Table 4.6 shows the interaction effect of sexes and colour variety on weekly weights of ducks. There was no difference ($p>0.05$) in weight throughout the period when it comes to the sex and colour interaction. BDW males had higher weight in week four and week thirteen than the rest of the birds. Weights of BWST males were heavier than all the remaining birds in weight in week five, six, eight, nine, ten, eleven and twelve.

Table 4.6: Interaction effect of sex and plumage colour on weekly weight of ducks

Colour	Sex	WEEKLY WEIGHT (KG)										
		Initial	**Four**	**Five**	**Six**	**Seven**	**Eight**	**Nine**	**Ten**	**Eleven**	**Twelve**	**Thirteen**
P W	Male (3)	0.205^{a}	0.270^{ab}	0.483^{abc}	0.638^{a}	1.122^{abcd}	1.228^{bc}	1.387^{bcd}	1.547^{bc}	1.673^{b}	1.927^{b}	2.090^{b}
	Female (3)	0.207^{a}	0.272^{ab}	0.477^{abc}	0.628^{a}	0.787^{abcd}	1.037^{ab}	1.143^{ab}	1.273^{a}	1.237^{a}	1.264^{a}	1.383^{a}
BWST	Male (3)	0.290^{cd}	0.388^{b}	0.673^{c}	0.958^{b}	1.258^{e}	1.560^{d}	1.683^{e}	1.813^{c}	1.970^{b}	2.063^{b}	2.248^{b}
	Female (3)	0.212^{abc}	0.275^{ab}	0.447^{ab}	0.660^{ab}	0.815^{abc}	1.017^{ab}	1.098^{a}	1.147^{a}	1.173^{a}	1.533^{a}	1.292^{a}
BDW	Male (3)	0.288^{bd}	0.392^{b}	0.635^{bc}	0.862^{b}	1.102^{cde}	1.375^{cd}	1.575^{de}	1.708^{c}	1.892^{b}	2.060^{b}	2.258^{b}
	Female (3)	0.197^{a}	0.293^{ab}	0.502^{abc}	0.687^{ab}	0.923^{abcd}	1.122^{abc}	1.203^{abc}	1.273^{ab}	1.353^{a}	1.435^{a}	1.532^{a}
WDFB	Male (3)	0.222^{abcd}	0.313^{ab}	0.516^{abc}	0.778^{ab}	1.122^{de}	1.410^{cd}	1.479^{cde}	1.702^{c}	1.845^{b}	2.106^{b}	2.195^{b}
	Female (3)	0.168^{a}	0.238^{a}	0.400^{a}	0.620^{a}	0.787^{ab}	1.085^{abc}	1.155^{ab}	1.198^{a}	1.248^{a}	1.282^{a}	1.382^{a}
WDPB	Male (3)	0.210^{ab}	0.287^{ab}	0.522^{abc}	0.787^{ab}	0.983^{bcde}	1.283^{bcd}	1.400^{bcd}	1.648^{c}	1.894^{b}	2.003^{b}	2.123^{b}
	Female (3)	0.165^{a}	0.228^{a}	0.402^{a}	0.575^{a}	0.682^{a}	0.850^{a}	0.968^{a}	1.030^{a}	1.120^{a}	1.191^{a}	1.268^{a}
L. S. D		0.073	0.109	0.185	0.269	0.261	0.298	0.255	0.295	0.230	0.363	0.376
P-VALUE@ 5%	Sex	0.003	0.008	0.007	0.008	<.001	<.001	<.001	<.001	<.001	<.001	<.001
	Colour	0.060	0.107	0.244	0.333	0.173	0.189	0.126	0.457	0.551	0.394	0.609
	Colour X Sex	0.396	0.578	0.556	0.627	0.414	0.444	0.383	0.547	0.359	0.719	0.863

NB: *Means between colour varieties of ducks with different postscript are significantly different ($p<0.05$); BDW=Black dominated white, PW= Pure white, BWST=Black with white stripes, WDFB=White dominated faded black, WDPB= White dominated pure black, LSD = Least Square Difference*

4.4.4 Effect of Sex, Plumage Colour and Sex and Plumage Colour Interactions on Morphometric Measurements

Table 4.7 shows the effect of sex, colour variety and their interaction effect on morphometric measurements. There was no difference ($p>0.05$) in zoometric measurements when it comes to the colour variety and the interaction of colour variety and sex. There was a significant difference with regards to the effect of sex with some of the zoometric measurements. Body length, foot length, neck length and thigh circumference were significantly different ($p<0.05$) with male being the superior. Breast circumference was highly significant ($p>0.01$) with males being the superior.

Table 4.7: Effect of Sex, Plumage Colour and Interaction effect on Morphological Measurement of Ducks

COLOUR	SEX	PARAMETERS						
		BLL	BDL	BTC	FTL	NKL	THC	WNL
P W	Male (3)	6.13	30.83[a]	34.30[a]	7.73[a]	15.73[a]	13.63[a]	27.87
	Female (3)	5.90	26.17[b]	31.00[b]	7.53[b]	15.13[b]	12.27[b]	28.07
BWST	Male (3)	6.77	33.73[a]	34.00[a]	7.90[a]	16.30[a]	13.50[a]	34.73
	Female (3)	5.67	25.97[b]	25.50[b]	7.30[b]	14.47[b]	10.50[b]	29.37
BDW	Male (3)	6.47	31.60[a]	32.27[a]	7.73[a]	16.87[a]	12.10[a]	32.60
	Female (3)	6.07	28.73[b]	30.53[b]	8.13[b]	15.33[b]	10.63[b]	32.13
WDFB	Male (3)	5.43	30.97[a]	32.90[a]	8.07[a]	16.20[a]	13.30[a]	28.70
	Female (3)	5.70	26.17[b]	28.37[b]	7.00[b]	15.17[b]	10.43[b]	25.50
WDPB	Male (3)	5.87	29.17[a]	31.63[a]	7.57[a]	15.10[a]	13.10[a]	24.73
	Female (3)	5.77	27.97[b]	29.93[b]	6.83[b]	13.03[b]	11.23[b]	26.30
L. S. D		1.014	5.266	4.331	0.879	2.909	3.335	8.496
P-VALUE@ 5%	COLOUR	0.272	0.798	0.393	0.277	0.343	0.723	0.099
	SEX	0.165	0.001	< 0.001	0.030	0.035	0.008	0.434
	COLOUR x SEX	0.400	0.459	0.169	0.172	0.945	0.916	0.757
CV		10.0	10.6	8.2	6.8	11.1	16.2	17.2

PW=Pure white, BWST=Black with white stripes, BDW=Black dominated white, WDFB= White dominated faded black, WDPB= White dominated pure black, BIL= Bill length, BL=Body length, BC=Body circumference, FT=Foot length, NL=Neck length, TC=Thigh circumference, WL=Wing length, LSD = Least Square Difference, CV= Coefficient of variation.

4.4.5 Correlations Matrix of Body Weight and Body Measurements of On-Farm Duck Based on Sex

Table 4.8 shows correlation matrix of body weight and body measurements of on-station ducks based on sex. Among the various body parameters, low, moderate and high positive and negative correlation coefficients were reported. In males, the coefficients of correlation ranged from -0.0346 to 0.8149. The highest correlation of body measurement in drake was between wing length and body length (0.8149) followed by bill length and wing length (0.7464). The least correlation of body measurement of drake was between wing length and thigh circumference (-0.0581). Weight of drake was highly correlated with neck length (0.4494) followed by wing length (0.2331) and was least correlated with foot length (-0.0346).

In females, the coefficient of correlation ranged from -0.0041 to 0.6755. The highest correlation of body measurement of ducks was between breast circumference and bill length (0.6755) followed by foot length and wing length (0.6153). The least correlation of body measurement was between breast circumference and neck length (-0.1089). In ducks, weight was highly correlated with wing length (0.2942) followed by bill length (0.2630) and was least correlated with body length (-0.0041).

Table 4.8: Correlation Matrix of Body Weight and Body Measurements on Sex of On-Farm Ducks

Traits	BW	BLL	NKL	BDL	WNL	FTL	BTC	THC
BW		-0.0758	0.4494	0.2172	0.2331	-0.0346	-0.0633	-0.1537
BLL	0.2630		0.1712	0.5417*	0.7464**	0.2821	0.1584	-0.0802
NKL	-0.4600	-0.2149		-0.0725	0.3004	0.3311	-0.3792	-0.6592**
BDL	-0.0041	0.5649*	-0.2955		0.8149**	0.3395	0.4935	0.1765
WNL	0.2942	0.0882	0.0933	0.3274		0.5907*	0.4257	-0.0581
FTL	0.0598	0.1575	0.2157	0.3718	0.6153*		0.3089	0.016
BTC	-0.0508	0.6755**	-0.1089	0.6105*	0.0241	0.2406		0.6749**
THC	0.0400	0.4022	-0.4997	0.4345	-0.3159	0.0142	0.6016*	

*NB: **, significant at p < 0.01 for all correlation coefficients except otherwise stated; *, significant at p< 0.05, Upper diagonal were male; Lower diagonal were female.*

4.5 Effect of Plumage Colour on Carcass Parameters of Ducks

Table 4.9 shows the effect of colour variety on carcass parameters of ducks. There were differences (p<0.05) in all the carcass parameters measured in the various colour varieties of the ducks except for the WGIT where there were no significant differences (p>0.05). Ducks with WDFB colour variety had heavier LW, CW, BW, TDW and GW than the other colour varieties of ducks. With regards to DP and ADFW, ducks with BWST colour variety had significantly higher values (p<0.05) than all the other colour varieties. WDPB colour variety had significantly heavier weights in terms of WW, HW, WGIT and NW. There was a significant difference (p<0.05) in the LVW among the various duck colour varieties with PW ducks having the heaviest LVW.

Table 4.9: Effect of Plumage Colour on Carcass Parameters of Ducks

Parameters	Mean	PW (6)	BDW (6)	BWST (6)	WDFB (6)	WDPB (6)	LSD	P-value @ 5%
LW (kg)	1.603^{d}	1.548^{e}	1.375^{f}	1.655^{c}	1.755^{a}	1.680^{b}	0.0128	<.001
CW (kg)	1.070^{d}	0.987^{e}	0.960^{f}	1.123^{b}	1.175^{a}	1.105^{c}	0.0400	<.001
DP (%)	66.5^{d}	63.97^{f}	68.51^{a}	67.42^{b}	66.80^{c}	65.92^{e}	2.0670	0.003
BW (kg)	0.299^{c}	0.297^{d}	0.246^{f}	0.324^{b}	0.336^{a}	0.294^{e}	0.0010	<.001
TDW (kg)	0.230^{d}	0.223^{e}	0.199^{f}	0.235^{c}	0.255^{a}	0.238^{b}	0.0004	<.001
NW (kg)	0.10^{d}	0.110^{c}	0.090^{f}	0.095^{e}	0.112^{b}	0.115^{a}	0.0116	<.001
WW (kg)	0.198^{d}	0.189^{e}	0.137^{f}	0.224^{b}	0.212^{c}	0.229^{a}	0.0417	0.001
ADFW(kg)	0.008^{c}	0.006^{d}	0.010^{b}	0.011^{a}	0.005^{e}	0.006^{d}	0.0010	<.001
LVW (kg)	0.030^{b}	0.033^{a}	0.026^{e}	0.031^{c}	0.031^{c}	0.029^{d}	0.0001	<.001
GW (kg)	0.040^{c}	0.034^{e}	0.045^{b}	0.038^{d}	0.046^{a}	0.038^{d}	0.0050	<.001
HW (kg)	0.015^{c}	0.015^{c}	0.013^{d}	0.015^{c}	0.016^{b}	0.018^{a}	0.0001	<.001
WGIT (kg)	0.037	0.187	0.190	0.185	0.185	0.190	0.0116	0.799

NB: Means between colour varieties of ducks with different postscript are significantly different ($p<0.05$); PW=Pure white, BWST=Black with white stripes, BDW=Black dominated white, WDFB= White dominated faded black, WDPB= White dominated pure black, LW=Live weight, CW=Carcass weight, DP= Dressing percentage, BW= Breast weight, TDW= Thigh and Drumstick weight, WW=Wing weight, NW=Neck weight, ADFW=Abdominal fat weight, LVW= Liver weight, GW= Gizzard weight, HW=Heart weight, WGIT= Whole Gastrointestinal weight

4.6 Effect of Sex on Carcass Parameters of Ducks

Table 4.10 shows the effects of sex on the carcass parameters of ducks. Male ducks had significantly heavier ($p<0.05$) carcass parameters than their female counterparts.

Table 4. 10: Effect of Sex on Carcass Parameters of Ducks (kg)

Parameters	Mean	Male (15)	Female (15)	LSD	P-value @ 5%
LW	1.605	2.007^{a}	1.202^{b}	0.0081	<.001
CW	1.019	1.250^{a}	0.788^{b}	0.0252	<.001
DP	66.525	67.59^{a}	65.46^{b}	1.3080	0.003
BW	0.311	0.349^{a}	0.273^{b}	0.0008	<.001
TDW	0.230	0.296^{a}	0.164^{b}	0.0003	<.001
NW	0.105	0.132^{a}	0.077^{b}	0.0074	<.001
WW	0.198	0.244^{a}	0.152^{b}	0.0260	<.001
ADFW	0.008	0.009^{a}	0.007^{b}	0.0004	<.001
LVW	0.030	0.039^{a}	0.021^{b}	0.0001	<.001
GW	0.042	0.045^{a}	0.038^{b}	0.0031	<.001
HW	0.016	0.019^{a}	0.012^{b}	0.0001	<.001
WGIT	0.188	0.244^{a}	0.131^{b}	0.0070	<.001

PW=Pure white, BWST=Black with white stripes, BDW=Black dominated white, WDFB= White dominated faded black, WDPB= White dominated pure black, LW=Live weight, CW=Carcass weight, DP= Dressing percentage, BW= Breast weight, TDW= Thigh and Drumstick weight, WW=Wing weight, NW=Neck weight, ADFW=Abdominal fat weight, LVW= Liver weight, GW= Gizzard weight, HW=Heart weight, WGIT= Whole Gastrointestinal weight.

4.7 Effect of Sex and Plumage Colour interaction on the Carcass Parameters of Ducks

Table 4.11 shows the interaction effect of sex and colour on the carcass parameters of ducks. The interaction effect of sex and colour variety of ducks were different ($p<0.05$) in terms of LW, DP, BW, TDW, WW, NW, LVW, ADFW, GW, HW and WGITW. BDW male was significantly heavier in terms of DP, GW and WGIT than the colour varieties of the ducks. WDPB was also significantly heavier than the other colour varieties of the ducks when it comes to LW, HW and WW. With ADFW and BW, males of BWST colour variety were significantly heavier than the other colour varieties of the duck. WDFB males were significantly heavier than all the colour varieties of duck in TDW. PW males had significantly heavier LVW than all the colour varieties of duck. Males of WDPB and PW had significantly heavier NW than all the colour varieties of duck.

Table 4. 11: Effect of sex and colour on the carcass parameters of ducks

Colour	SEX	PARAMETERS (KG)											
		LW	CW	DP (%)	BW	TDW	NW	WW	ADFW	LVW	GW	HW	WGIT
P W	Male (3)	1.957^{g}	1.233^{e}	63.04^{ab}	0.357^{h}	0.292^{f}	0.150^{c}	0.233^{bc}	0.008^{de}	0.044^{j}	0.043^{bc}	0.019^{e}	0.250^{f}
	Female (3)	1.140^{b}	0.740^{b}	64.17^{abc}	0.236^{b}	0.154^{a}	0.070^{a}	0.144^{a}	0.003^{a}	0.023^{d}	0.027^{a}	0.011^{a}	0.123^{ab}
BWST	Male (3)	2.080^{h}	1.407^{f}	67.41^{c}	0.394^{j}	0.304^{g}	0.110^{b}	0.265^{cd}	0.014^{g}	0.042^{i}	0.043^{bc}	0.019^{e}	0.230^{e}
	Female (3)	1.250^{d}	0.840^{cd}	67.21^{c}	0.253^{d}	0.166^{c}	0.080^{a}	0.183^{ab}	0.007^{d}	$0. 020^{c}$	0.033^{a}	0.012^{b}	0.140^{c}
BDW	Male (3)	1.680^{f}	1.250^{e}	74.41^{d}	0.273^{e}	0.240^{e}	0.110^{b}	0.147^{a}	0.012^{f}	0.034^{f}	0.050^{c}	0.014^{c}	0.270^{g}
	Female (3)	1.070^{a}	0.670^{a}	62.62^{a}	0.218^{a}	0.157^{b}	0.070^{a}	0.128^{a}	0.009^{e}	0.017^{a}	0.040^{b}	0.011^{a}	0.110^{a}
WDFB	Male (3)	2.180^{j}	1.470^{g}	67.43^{c}	0.377^{i}	0.324^{i}	0.140^{c}	0.268^{cd}	0.005^{b}	0.036^{g}	0.046bc	0.021^{f}	0.230^{e}
	Female (3)	1.330^{e}	0.880^{d}	66.17^{bc}	0.294^{f}	0.186^{d}	0.083^{a}	0.157^{a}	0.006^{c}	0.026^{e}	0.047^{bc}	0.012^{b}	0.140^{bd}
WDPB	Male (3)	2.140^{i}	1.400^{f}	65.44^{abc}	0.346^{g}	0.319^{h}	0.150^{c}	0.309^{d}	0.005^{b}	0.038^{h}	0.045^{bc}	0.022^{g}	0.240^{ef}
	Female (3)	1.220^{c}	0.810^{c}	66.39^{c}	0.242^{c}	0.157^{b}	0.080^{a}	0.150^{a}	0.007^{d}	0.020^{b}	0.031^{a}	0.015^{d}	0.140^{bd}
L. S. D		0.018	0.056	2.9	0.002	0.001	0.016	0.059	0.001	0.001	0.007	0.0002	0.016
P value @ 5%	Colour	<.001	<.001	0.003	<.001	<.001	<.001	0.001	<.001	<.001	<.001	<.001	0.799
	Sex	<.001	<.001	0.003	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001
	Colour x Sex	<.001	0.099	<.001	<.001	<.001	0.001	0.036	<.001	<.001	0.022	<.001	<.001
CV (%)		0.7	3.1	2.6	0.3	0.1	9.3	17.4	7.3	0.3	10.1	0.07	5.2

PW=Pure white, BWST=Black with white stripes, BDW=Black dominated white, WDFB= White dominated faded black, WDPB= White dominated pure black, LW=Live weight, CW=Carcass weight, DP= Dressing percentage, BW= Breast weight, TDW= Thigh and Drumstick weight, WW=Wing weight, NW=Neck weight, ADFW=Abdominal fat weight, LVW= Liver weight, GW= Gizzard weight, HW=Heart weight, WGIT= Whole Gastrointestinal weight, L.S. D = least square difference, CV= coefficient of variation, KG=Kilogram

NB: Means between colour varieties and sexes of ducks with different postscript are significantly different (p<0.05).

4. 8 Effect of Plumage Colour of Ducks on their Sensory Parameters

Table 4.12 shows the effects of colour variety on sensory parameters of ducks. All the colour varieties of the ducks were different ($p<0.05$) in terms of their meat colour, the intensity of their meat flavour, taste of the meat, juiciness of the meat, flavour liking and the overall liking of the meat of the various colour varieties. BWST colour variety was significant different in colour, very juicy with high flavour intensity than all the colour varieties. Ducks with BDW colour were significantly higher in the flavour liking and taste. Meat of PW colour variety had a very pleasant aroma but there were no differences ($p>0.05$) in the meat of the other colour varieties of ducks. Meat of WDPB colour variety was softer and smoother but no differences ($p>0.05$) were detected among the other colour varieties of ducks. However, WDPB was significantly higher than all the other colour varieties when it comes to overall liking.

Table 4.12: Effect of Plumage Colour of Ducks on their Sensory Parameters

Colour	**PARAMETERS**								
	CL	**AR**	**FI**	**FL**	**TD**	**TT**	**TA**	**JC**	**OL**
P W (2)	4.88[d]	5.91	5.25[d]	5.33[d]	5.17	5.22	5.88[c]	5.22[d]	6.13[d]
WDFB (2)	5.22[c]	5.52	4.82[e]	5.13[e]	5.42	5.12	5.22[e]	5.05[e]	6.18[c]
BWST (2)	5.87[a]	5.78	5.80[a]	5.82[c]	5.55	5.48	5.65[d]	6.07[a]	5.83[e]
BDW (2)	5.47[b]	5.88	5.62[c]	6.05[a]	5.45	5.12	6.27[a]	5.55[c]	6.73[b]
WDPB (2)	5.22[c]	5.73	5.75[b]	6.02[b]	5.85	5.82	5.92[b]	5.63[b]	6.78[a]
LSD	0.63	0.53	0.57	0.56	0.65	0.64	0.57	0.68	0.53
P-value @ 5%	0.03	0.60	0.003	0.002	0.34	0.23	0.008	0.036	0.001

NB: *Means between colour varieties and sexes of ducks with different postscript are significantly different ($p<0.05$); PW=Pure white, BWST=Black with white stripes, BDW=Black dominated white, WDFB= White dominated faded black, WDPB= White dominated pure black, CL=Colour, AR=Aroma, FI=Flavour Intensity, FL=Flavour Liking, TD= Tenderness, TT=Texture, TA=Taste, JC= Juiciness, OL= Overall Liking.*

4.9 Effect of Sex of Ducks on the Sensory Parameters

The effects of sex of ducks on sensory parameters are shown in table 4.13. The sexes were only different ($p<0.05$) in meat colour with the male been the superior. The males had higher flavour intensity and very soft meat but there was no difference ($p>0.05$) detected between the sexes. Meat of females had a pleasant aroma, high flavour liking, smooth with sweet taste, very juicy and higher overall liking but no difference ($p>0.05$) was detected between the males and the females.

Table 4.13: Effect of sex of ducks on the sensory parameters

Parameters	Mean		LSD	P-value
	Male (5)	Female (5)		@ 5%
CL	5.62[a]	5.04[b]	0.40	0.004
AR	5.85	5.69	0.34	0.35
FI	5.45	5.44	0.37	0.94
FL	5.63	5.71	0.36	0.69
TD	5.59	5.38	0.41	0.31
TT	5.41	5.45	0.40	0.82
TA	5.75	5.83	0.37	0.67
JC	5.37	5.64	0.43	0.22
OL	6.28	6.39	0.34	0.54

CL=Colour, AR=Aroma, FI=Flavour Intensity, FL=Flavour Liking, TD= Tenderness, TT=Texture, TA=Taste, JC= Juiciness, OL= Overall Liking.

4.10 Effect of Sexes of Ducks on Haematological Parameters

Table 4.14 shows the effect of sexes of ducks on their haematological parameters. The various sexes of ducks were different ($p< 0.05$) in terms of red blood cell, White blood cell, mean corpuscular volume, mean corpuscular haemoglobin, Haemoglobin concentration and Mean corpuscular haemoglobin concentration The males had significantly ($p< 0.05$) higher values in terms of WBC, MCV, MCH, HBC and MCHC than females. In HCT, there was no difference ($p> 0.05$) in sexes of the ducks.

Table 4.14: Effect of Sex on Haematological Parameters of Ducks

Parameters	Mean	Male Mean (15)	Female Mean (15)	LSD	P-value @ 5%
RBC ×10⁶/ µl	2.01	2.05[a]	1.97[b]	0.008	<.001
WBC ×10³/ µl	25.6	26.0[a]	25.2[b]	0.003	<.001
HCT (%)	34.94	35.08[a]	34.79[b]	0.422	0.162
HBC (g/dl)	14.40	14.73[a]	14.06[b]	0.081	<.001
MCV (f l)	162.5	164.56[a]	160.48[b]	0.485	<.001
MCH (p g)	69.55	73.24[a]	65.85[b]	0.347	<.001
MCHC (g/dl)	40.55	45.81[a]	35.28[b]	0.422	<.001

RBC= Red blood cell, WBC= White blood cell, HCT= Haematocrit, HGB= Haemoglobin, MCV= Mean corpuscular volume, MCH=Mean corpuscular haemoglobin, MCHC= Mean corpuscular haemoglobin concentration, L.S. D= least square difference.

4.11 Effect of Plumage Colour of Duck on Haematological Parameters

Table 4.15 shows the effect of colour variety of ducks on haematological parameters. The various colour varieties of the ducks were different ($p < 0.05$) in terms of RBC, WBC, MCV, HBC, MCH and MCHC. PW colour variety was superior to the other colour varieties in terms of WBC, MCV, MCH and MCHC. WDPB was superiorly significant among the colour varieties in terms of RBC and HBC. In terms of the MCH, BDW was superiorly significant among all the various colour varieties.

Table 4. 15: Effect of Plumage Colour of Ducks on their Haematological Parameters

Parameters	**PW (6)**	**BDW (6)**	**BWST (6)**	**WDFB (6)**	**WDPB (6)**	**Mean**	**LSD**	**P-value @ 5%**
RBC ($\times10^6$/ l)	2.05^{a}	2.03^{b}	1.92^{f}	2.03^{b}	2.02^{c}	2.010	0.006	<.001
WBC ($\times10^3$/ l)	26.915^{a}	25.180^{d}	24.565^{e}	25.790^{b}	25.585^{c}	25.607	0.055	<.001
HCT (%)	43.50^{a}	32.15^{d}	30.30^{e}	33.12^{c}	35.60^{b}	34.934	0.667	<.001
HBC (g/dl)	14.88^{c}	14.50^{b}	13.05^{e}	14.45^{d}	15.10^{a}	14.395	0.128	<.001
MCV (f l)	166.50^{a}	165.20^{b}	159.05^{d}	162.85^{c}	159.00^{e}	162.52	0.767	<.001
MCH (p g)	68.90^{c}	71.40^{a}	68.15^{e}	71.02^{b}	68.25^{d}	69.544	0.584	<.001
MCHC (g/dl)	44.63^{a}	43.70^{b}	42.95^{d}	43.50^{c}	27.93^{e}	40.542	0.667	<.001

NB: PW=Pure white, BWST=Black with white stripes, BDW=Black dominated white, WDFB= White dominated faded black, WDPB= White dominated pure black, RBC= Red blood cell, WBC= White blood cell, HCT= Haematocrit, HBC= Haemoglobin Concentration, MCV= Mean corpuscular volume, MCH=Mean corpuscular haemoglobin, MCHC= Mean corpuscular haemoglobin concentration.
Means between colour varieties and sex with different postscript are significantly different ($p< 0.05$).

4.12 Effect of interaction of Sex and Plumage Colour of Ducks on Haematological Parameters

Table 4.16 shows the interaction effect of sex and colour variety of ducks on haematological parameters. The interaction of colour variety and sex were different ($p< 0.05$) in terms of RBC, WBC, HCT, HGB, MCV, MCH and MCHC. Female WDPB colour had significantly ($p< 0.05$) higher HGB value than all the other colour varieties. Male PW colour variety had significantly ($p< 0.05$) higher WBC, HCT, MCV, MCH and MCHC value than all the other colour varieties. Male BDW colour variety had significantly ($p<0.05$) higher RBC value than all the other colour varieties.

Table 4.16: Effect of Sex and Plumage Colour of Ducks on Blood Parameters

Colour	Sex	Parameters						
		RBC× 10^6/ µl	**WBC× 10^3/ µl**	**HGB (g/dl)**	**HCT (%)**	**MCV (f l)**	**MCH (pg)**	**MCHC (g/dl)**
P W	Male (3)	2.070^{de}	27.57^{i}	14.57^{d}	45.00^{f}	171.0^{g}	75.3^{f}	49.07^{f}
	Female (3)	2.020^{c}	26.26^{h}	15.20^{f}	42.00^{e}	162.0^{d}	62.5^{a}	40.20^{b}
BWST	Male (3)	2.070^{de}	25.40^{d}	14.50^{d}	31.50^{b}	153.4^{a}	69.8^{d}	45.70^{e}
	Female (3)	1.760^{a}	23.73^{a}	11.60^{a}	29.10^{a}	164.7^{f}	66.5^{b}	40.20^{b}
BDW	Male (3)	2.080^{e}	25.76^{f}	15.30^{f}	32.30^{b}	168.0^{f}	74.8^{f}	45.00^{e}
	Female (3)	1.980^{b}	24.60^{b}	13.70^{b}	32.00^{b}	162.4^{d}	68.0^{c}	42.40^{c}
WDFB	Male (3)	2.030^{c}	26.03^{g}	14.80^{e}	34.20^{c}	168.0^{f}	73.0^{e}	44.0^{d}
	Female (3)	2.020^{c}	25.55^{e}	14.10^{c}	32.03^{b}	157.7^{c}	69.0^{d}	43.00^{c}
WDPB	Male (3)	1.980^{b}	25.15^{c}	14.50^{d}	32.40^{b}	162.4^{d}	73.3^{e}	45.27^{e}
	Female (3)	2.060^{d}	26.02^{g}	15.70^{g}	38.80^{c}	155.6^{b}	63.2^{a}	10.600^{a}
L. S. D		0.008	0.777	0.181	0.943	1.085	0.776	0.943
P-value	Colour	<.001	<.001	<.001	<.001	<.001	<.001	<.001
@ 5%	Sex	<.001	<.001	<.001	0.162	<.001	<.001	<.001
	Colour X Sex	<.001	<.001	<.001	<.001	<.001	<.001	<.001
CV (%)		0.5	0.2	0.7	1.6	0.4	0.7	1.4

NB: Means between colour varieties and sex with different postscript are significantly different ($p< 0.05$). PW=Pure white, BWST=Black with white stripes, BDW=Black dominated white, WDFB= White dominated faded black, WDPB= White dominated pure black, RBC= Red blood cell, WBC= White blood cell, HCT= Haematocrit, HBC= Haemoglobin Concentration, MCV= Mean corpuscular volume, MCH=Mean corpuscular haemoglobin, MCHC= Mean corpuscular haemoglobin concentration, L.S.D = least square difference, CV= coefficient of variation

CHAPTER 5

5.0 DISCUSSION

5.1. Description of Ducks Production in the Northern Region

5.1.1. Demographic characteristics of Ducks farmers

Duck farmers were predominantly males in the selected districts. This is supported by Avornyo *et al*. (2016) who in a baseline study of the characteristics of Guinea fowl production systems in 20 districts in northern Ghana reported that majority of farmers involved in guinea fowl production were males (Park *et al*., 2017). A survey on rural poultry management in the West Mamprusi district also corroborated that rural poultry owners were predominantly males (Avornyo *et al.*, 2016). This was contrary to what was observed in the Ga district in the southern part of Ghana where majority of the poultry owners were rather females (Dankwa *et al*., 2000). The male dominance in duck rearing in the selected districts in this study can be explained by the assertion that animal rearing is a male-dominated activity in Northern Ghana (Ndiweni, 2013).

In sub-Saharan African countries, males control household productive assets due to societal norms and standards (Avornyo *et al*., 2016b). Male dominance in poultry production in the study area may also be attributed to the fact that men are the decision makers in the study area.

Duck farmers were predominantly Muslims in the study area**s**. This can be attributed to the fact that Northern region is dominated by Muslims whose religious doctrine does not forbid the production of ducks unlike animals such as pigs (Fafchamps and Quisumbing, 2002). Majority of the farmers were within the active age group (15 to 64 years) in terms of age distribution. This is supported by the assertion that most of the farmers involved in guinea fowl production in the northern region of Ghana were between twenty to sixty years (Kim, 2007). There is fear of the future of agriculture due to ageing of farmers, therefore, having a lot of young people involved in duck rearing in the selected communities is a good prospect for increasing duck production in the selected districts.

In this study, all the farmers interviewed practice agriculture as their main occupation, with trading as a side job. This corroborates the findings that low-input village poultry production integrates well with crop farming and other rural household livelihood activities as it helps farmers to diversify their resources (Teye and Adam, 2000). It is also supported by the assertion that subsistent production of agriculture remains the primary employer of labour, with livestock playing a critical role (Muchadeyi *et al*., 2004).

5.1.2. Production systems and management practices of ducks

The duck production system in Savelugu, Kumbungu and the Tolon districts can be categorised into semi-intensive and extensive production systems, with most of the farmers practising the semi-intensive system. This is in contrast to the findings that local poultry are mostly kept using the extensive system in Ghana (Adams and Ohene-Yankyera, 2014). In Benin, the extensive method is used by about 95 percent farmers with few practicing the intensive system of production (Dankwa *et al*., 2000). The extensive production method is used by about eighty percent of poultry producers in Africa, Asia and Latin America (Avornyo *et al*., 2016). There was no intensive system as well as commercial duck production practised in the districts. Additionally, there were no association for duck farmers/keepers. Home consumption of duck meat and eggs constituted the key reasons for keeping ducks whereas the surplus is sold for income. All the farmers interviewed do not provide light using electricity in their duck shelters. This can be attributed to the fact that they see it to be of no importance to the ducks. Only local duck breeds were observed in the survey in the selected districts and are all bred naturally and managed by the family without any employed labour. Mud hut for housing ducks was a dominant structure. This is supported with the assertion that most of the houses for poultry in Northern Region of Ghana are mud houses (Besbes *et al.*, 2007). Most of the guinea fowl farms surveyed in north-eastern Benin had their adult guinea fowls roosting in trees (Besbes *et al*., 2007). This assertion is in contrast to what was found in the present study. Most of the mud houses of ducks were roofed with thatch. This is supported with the assertion that eighty percent (80%) of farmers use mud houses roofed with thatching grass for chicken production in the Northern part of Ghana (Avornyo *et al*., 2016). Majority of farmers in the selected districts fed their birds with cereals (such as maize, millet, guinea corn). There is no formulation of the feed, however the quantity of feed depends on its availability and the financial power of the farmer. A significant feature of duck feeding patterns in the districts under examination werethat feed offered to ducks was rarely altered throughout the year. This is in contrast with the assertion that there is seasonal differences in the types of feed offered to ducks in Asia (Ranwedzi, 2001). There was also no special feed for different age groups of ducks. All ducks were fed the same type of feed unlike having starter feed for the starters and grower feed for the growers. However, starter feed and the grower feed of ducks have different protein composition with the starter feed having protein composition of 20-22% whereas the grower has between 17-19% (Patil *et al.*, 2020). Dungbara (paralysis of the leg) and Duck hepatitis were reported by 58.7% and 28.7% of duck farmers, respectively as an occasional disease problem. This is supported by Mantey *et al.* (2014) who reported that duck hepatitis was one of the occasional diseases in ducks in the Northern region. It was observed that duck farmers in the study area had no health arrangement to care for the ducks. However, it was observed that duck producers add the tree bark of mango, baobab and acacia to water for birds to drink to prevent disease. Farmers reported that they encountered mortality in newly hatched ducklings due to a cover on their nostril. To break this cover, a mixture of grinded pepper and warm water is given to the ducklings to drink. It was observed that Dungbara (paralysis of the leg) is treated when a dry maize husk is tied around the leg of the duck expecting that the next day or two, the duck should be able to walk.

5.2 Effect of Sex and Plumage Colour on Weight

The weights range of ducks in the current study is between 1,268g and 2248g and is greater than what was reported by Padhi (2014) who corroborated that the weight range for extensively reared Deshi and Deshi x Khaki Campbell crosses in India is between 1,515 g and 1,710 g. This can be attributed to differences in the type of production systems used in both experiments. The average body weight of Charachemballi ducks in Assam as 715.02±5.16g and 1054.63±10.27 g respectively at 8 and 12 weeks under free range condition (Baéza, 2016). These values were lower than the values obtained in the current study. The live weights of male and female Nageswari ducks at 0, 4, 8 and 12 weeks of age to be 47.00±0.19g, 229.09±2.59g, 512.20±3.55g and 895.79±5.04g and 45.03± 0.21g, 198.50±2.49g, 480.46±3.08g and 863.10± 4.31g under the free-range method, respectively (Morduzzaman *et al.*, 2015). The values obtained are lower than what was found in the current study. The average weight range of male and female ducks obtained for Muscovy ducks imported from France to Poland is between 2.750kg - 5.147 kg (Bhuiyan *et al.*, 2017). This weight range of ducks is higher than what was observed in the current study. Pekin ducks for meat production have body weights ranging from between 2.6-3.0 kg and 3.6-4.0 kg at the age of seven and eight weeks, respectively (Yakubu *et al.*, 2011a). This is higher than what was found in the current study. There were differences in the weight of ducks with different sexes in the present study. These differences in weight of sexes of ducks can be attributed to differences in growth hormones of male and female ducks. In Muscovy ducks, there is a trend of higher growth hormone concentration in male than in female (Wawro *et al.*, 2004). Growth hormone concentration decreases earlier in females (at about four weeks of age) than in males (at about seven weeks of age) in Pekin ducks resulting in higher weight gain in males than in females (Baéza *et al.*, 2001). Differences in weight were not detected in the various colour varieties. This can be attributed to the fact that they may be of the same breed with similar genetic makeup (Baéza *et al.*, 2001).

5.3 Morphological Measurements of Ducks

Foot length obtained in the current study is similar to the finding that the average foot length range of ducks from Fayoum Governorate in Egypt is 7.3- 7.4 cm (Yakubu et al., 2011). However, it is longer than the average foot lengths of 4.3 cm and 5.5 cm for Guinea Savannah duck and Rainforest duck in Nigeria, respectively (Yakubu *et al*., 2011). The average breast circumference for Guinea Savannah ducks and Rainforest ducks is 34.5 cm and 34.2 cm, respectively in Nigeria (Yakubu *et al*., 2011). This is higher than what was found in table 4.7. The average thigh circumference of 7.5 cm and 8.6 cm for Guinea Savannah ducks and Rainforest ducks, respectively in Nigeria as reported by Yakubu *et al*. (2011) are lower than what was found in the present study. The average wing and neck length of Guinea Savannah ducks and Rainforest ducks were 20.4 cm and 20.1 cm as well as 16 cm and 14 cm, respectively as reported by Yakubu *et al.* (2011). These values are lower comparable to what was found in the present study. There was no difference in the morphometric parameters when it comes to the various colour varieties. This assertion can be attributed to the fact that the three study areas are borders to each other and can be easy movement of birds from one district to the other since they are really close. This may lead to inbreeding since no new gene will be introduced into the study area resulting to the offsprings produced being homozygote or similar in their morphometric parameters. This is supported by Yakubu *et al*. (2011) who said not detecting any difference in morphometric parameters of ducks can be attributed to the fact that they may be all related to the same ancestor and hence belonged to the same breed. There were differences in the morphological parameters of male and female ducks. This is supported by the assertion that in local chickens in Nigeria, males had higher body weight and body measurement values than females (Yakubu *et al*., 2011a). Similar observations in indigenous chickens (Momoh and Kershima, 2010). Higher values for body weight and morphometric measurements were recorded in indigenous male pigeons than females (Momoh and Kershima, 2010). In all the body traits and other body parameters investigated, sex-associated variations were observed. Males (drakes) generally had substantially ($p<0.05$) higher body weight, body length, breast circumference, thigh circumference, neck length and foot length. The differences in weight and morphological parameters in male and female can be attributed to sexual dimorphism, which inevitably contributes to differential growth rates among the sexes. This variations in male and female morphological parameters are due to differences in sex hormones that could facilitate greater growth of muscles in males than in females (Assan, 2013).

5.4 Carcass Characteristics of Ducks

Carcass characteristics are significant indexes because they can influence the purchase choices of meat by customers and the economic benefits of poultry production. The mean live weight as reported in this study revealed that male ducks had the heaviest weight than their female counterparts. This is supported by the findings that male Muscovy duck and the Pekin ducks have heavier weights than their female counter parts (Guni and Katule, 2013). However, it was reported that the female Rouen duck has heavier weight than their male counterpart (Omojola, 2007a).

Omojola (2007) had live weight ranging from 1.47 to 2.00 kg when he used Rouen, Pekin and Muscovy ducks for carcass and organoleptic characteristics of duck meat as influenced by breed and sex. This live weight range considered in his study is lower than the live weight range obtained in the current study. This can be attributed to the fact that they used the free-range system where by ducks were allowed to roam and feed themselves whiles birds were confined and was fed *ad libitum* in the present study. The live weight range observed in this study is lower than the live weight range of between 2.29 kg to 2.53 kg in Pekin ducks (Omojola, 2007). The live weight of a male 35-day old Cherry Valley duck is 3.1 kg (Solomon et al., 2006). This is higher than what was reported in the current study. The differences in the live weight in the current study can be attributed to differences in sex. This is supported by the assertion that male birds have higher live weight and feed intake than their females (Chang *et al*., 2016). Male ducks grow faster with more efficient feed conversion rate than females (Novel *et al*., 2009) .

The dressing percentage range of forty-nine days Pekin duck is 62% to 65.0% (Solomon *et al*., 2006a). Galal *et al*. (2011) recorded a dressing percentage of 65% in Dumyati, Muscovy, Peking and Sudani duck breeds during assessing the performances and carcass characteristics of these duck breeds (Bernacki *et al.*, 2008). The dressing percentage of male and female Sudani ducks were 58.22% and 55.95%, respectively (Galal *et al.*, 2011a). The average dressing percentages of Sudani ducks and Muscovy ducks were 60.3% in and 62.18, respectively at twelve weeks of age (Abd El-Samee *et al.*, 2012a). The dressing percentages reported in these studies were lower than what was observed in the current study. The dressing percentage range in the current study is similar to assertion that the dressing percentage range of duck in south western Nigeria was between 66.66% and 68.24% (Abd El-Samee *et al.*, 2012). However, a dressing percentage of 69.8% and 72.7% was reported for forty-nine-day old male and female ducks, respectively (Etuk *e*t *al*., 2006a). This is higher than what was observed in the current study. Values of dressing percentage obtained in this study were also lower than 78.8% in males and 77.4% in females (Kokoszynski *et al.*, 2016). Higher dressing percentages of 73.35% and 73.06 % were observed in Muscovy and in Sudani ducks, respectively (Etuk *et al*., 2006a). The differences in the dressing percentage can be attributed to the sex as well as blood and feather loss differences. This is in support of Omojola (2007a) who reported that the higher the percent blood and feather loss, the lower the dressing out percentage.

The breast is one of the primal cuts of high economic value (Abd El-Samee *et al.*, 2012a). Males had higher breast weight compared to their female counterparts in the current study. This is in support of the findings of Etuk *et al.* (2006a) who observed same in ducks of south eastern Nigeria. However, it was corroborated that female carcass is characterised by a higher percentage of breast weight as compared to their male counterpart (Omojola *et al.*, 2004). It was also reported that there is higher breast weight percentage in female than male in commercial hybrids of Pekin ducks and in genetic reserve ducks (Bernacki *et al.*, 2020a). It was also asserted same that female ducks tend to have higher breast weight at the same age than their male counterpart (Kokoszyński and Bernacki, 2010). Etuk *et al.* (2006b) reported the value of breast weight and thigh weight in male and female ducks in south eastern Nigeria as 0.269kg, 0.160g and 0.215kg, 0.144kg respectively. It was reported that the breast weight percentage of a two strain Pekin duck aged eight weeks is 16.18% and 15.06% (Omojola, 2007). It was also reported the breast weight percentage of two strains of Pekin duck aged eight weeks as 13.49% and 13.59% (Kokoszyński *et al.*, 2020). It was again asserted that the breast weight percentages in two Pekin duck are 10.8% and 10.7% (Kokoszyński *et al.*, 2019b). The values observed in these studies is lower than what was observed in the current study. This may be attributed to differences in feed and breed used in the experiments.

The breast weight of the current study was higher than the breast weight reported by Omojola (2007) who said that breast weight of male and female Rouen and Pekin ducks are 0.21 kg, 0.25 kg and 0.158 kg, 0.25 kg, respectively. He also reported that the male Muscovy ducks has a breast weight of 0.39 kg which is higher than the breast weight reported in the current study. Differences in breast weight can be attributed to differences in sex. This is supported by the assertion that larger size of male birds has greater breast yield progress through very slow rigor process than those that yields less (Kokoszyński e*t al.*, 2020).

Thigh and drumstick weights were different in both sexes and colour varieties of ducks. Males have the highest thigh and drumstick weight. WDPB had the highest thigh and drumstick weight than all the other colour varieties. It was reported that there was a significant difference in thigh weight of geese with males having the higher weight as compared to their female counterparts (Kolluri *et al.*, 2015). Differences in thigh weight can be attributed to sexual dimorphism. Neck and wings were found to be significantly higher in male ducks compared to female ducks. This is supported by the assertion that male geese has significantly higher neck and wing weight than their females (Yakubu *et al.*, 2015). This is in contrast with the report that female chicken has significantly higher neck and wing weight in chicken (Yakubu *et al.*, 2015). Higher weight in neck and wing of males than in females can be attributed to sexual dimorphism.

Males had heavier gizzard, liver, abdominal fat and whole gastrointestinal weight compared to females in table 4.10. This is consistent with the results for commercial Pekin duck hybrids (Mngonyama, 2012). Etuk *et al.* (2006a) reported that weight of heart, liver and gizzard of males are higher than their female counterpart in ducks of south eastern Nigeria. It was observed that male ducks display a greater proportion of gizzards compared to their females (Steczny *et al.*, 2017a). It was reported that drake and a duck of weight 2.559 kg and 2.413 kg, respectively has liver, gizzard and heart weight of 0.043, 0.074 and 0.015 kg, respectively (Budiansyah *et al*., 2020). The values reported were higher than what was reported in the current study except for the heart weight which is lower as compared to what is reported in the current study. It was observed that there was lower gizzard, liver and heart weight from the digestive morphometry of forty-nine days commercial hybrid of a Pekin ducks (Kokoszyński *et al*., 2019a). In this study, the liver weight in males were heavier than in females. This is supported by the assertion that the weight of liver in male ducks is higher than in female ducks (Budiansyah et al., 2020). It was also reported that the proportion of liver was similar in both sexes in Pekin ducks (Kaewtapee *et al.*, 2018). This disagrees with the current findings. Drake had higher abdominal fat percentage as compared to ducks. It was corroborated that males have higher abdominal fat percentage of 1.9% comparing to 1.6% in females (Steczny *et al.*, 2017). However, the percentage values obtained for abdominal fat in the current study is lower than what Kokoszynski *et al.* (2019) reported. Differences in internal organs of ducks in terms of sex and colour varieties can be attributed to differences in feed conversion ratio. Heavier animals with a greater proportion of internal organs, in the body was characterised by better feed conversion ratio. This is supported with the report that the high proportion of gizzard, liver and heart in the body of birds may be indicative of good muscle growth which has a positive impact on the particle size of digesta and nutrient absorption (Kokoszyński *et al.*, 2019a).

5.6 Haematological Characteristics of Ducks

The average mean values of RBC, HCT, HGC and WBC for local Muscovy ducks in south-western Nigeria were reported to be 1.72×10^6 mm^3, 38.09%, 11.64 g/dl and 18.21×10^3 mm^3, respectively

(Steczny *et al.*, 2017). These are lower than what was observed in table 4.15. The differences between what was reported by Okuedo *et al.* (2003) and that in the current study is because birds used in the current study were of the same age and were maintained for thirteen weeks permanently under intensive care whereas birds used by Okuedo *et al*. (2003) were of different ages under the extensive system. Higher values in the current study can be attributed to the differences in feed quality. The overall mean RBC and HCT of drake and duck of the current study were lower than 3.22×106 mm^3 and 43.59%, respectively as reported by Okeudo *et al.* (2003) for local Muscovy ducks in south-eastern Nigeria. However, the total mean of MCH and MCHC of the current study of drake and duck were higher than 4.6% and 34.2%, respectively reported by Okeudo *et al.* (2003a). It was reported that the HbC range of Tegal duck is 10.96 to 12.17 g/dl (Okeudo *et al*., 2003a). This is lower than the range of HbC value of the current study. The HbC, MCV, MCH and MCHC values found in the current study is lower compared with the values in 21-day old Cherry Valley ducks (Ismoyowati *et al*., 2006). The MCH of males were higher than the females in the present study. This is in contrast with Okeudo *et al*. (2003a) who reported higher values of MCH in females than males in local Muscovy ducks in south-eastern Nigeria. The RBC, HCT and the HGC values reported in the current study were higher in males as compared to their female counterparts. These findings were in variance with what Okuedo *et al*. (2003a) reported for local Muscovy ducks in south-eastern Nigeria. The RBC value of male in the present study was significantly higher than their female counterpart. This disagrees with Okuedo *et al.* (2003a) who reported that the RBC of a male Muscovy duck in south-eastern Nigeria is lower than their female counterpart. Differences in RBC and HGC among sex and colour variety can be attributed to the differences in body mass. This is in support with the assertion that HBC variations are due to changes in blood volume per unit of body weight and higher RBC and HBC values are typically reported by birds with greater body mass (Rajput *et al*., 2013). The higher significant difference in HBC in male and female can be attributed to the presence of testosterone in drakes. This is supported by the assertion that increasing HBC, the hormone testosterone stimulates the release of erythropoietin that acts to promote the proliferation and maturation of erythrocytes in the bone marrow (Pavlak *et al*., 2005). It was reported that the higher level of haematocrit may boost the tissue's delivery of oxygen (Obese *et al.*, 2018). Obese *et al.* (2018) pointed out that the rise is expected to be a factor to increase blood volume thereby increasing oxygen rate needed by the body. This will possibly increase the distribution of energy that could be used for production purposes (Okuedo *et al*., 2003a).

One of the most important haematological tests is the determination of the WBC, providing us with knowledge about the animals' health status. In the current study, WBC values were higher than those observed in ducks from Nigeria aged eight to ten weeks. The variability in the WBC of both sex and colour variety can be attributed to individual properties of the birds, the time of blood sampling during the day and infection. It was reported that infection increases in arterial blood pressure, glycaemia, respiratory frequency, muscle tone, and circulating glucocorticoids (Tuman, 1990). It was reported that increased glucocorticoid induces characteristic changes that can be quantified in the WBC portion of the immune system of vertebrates (Ruiz *et a*l., 2002). This brings about physiological changes in the bird. It was reported that the ratio of heterophils to lymphocytes increases in response to infections that influence an animal's WBC magnitude (Davis *et al.*, 2008). It was corroborated that the extent of the WBC shift depends on the stressor's severity and persistence (Krams *et al.*, 2012). The level of plasma corticosterone which is the primary glucocorticoid of birds, increases rapidly immediately after a bird is caught (Johnstone *et al*., 2012). It was reported that enhancement of corticosterone has cascading effects on other physiological functions, including the immune system (Romero and Reed, 2005).

5.5 Sensory Characteristics of Ducks

Colour is an important factor which determines the quality of meat and the decision to purchase it (West and Klukowski, 2018). The present study showed a significant difference in colour among the various colour varieties and the sexes of ducks. This is in agreement with the view that there was difference in colour for hens of different origins after the end of the laying period (Mir *et al.*, 2017). Differences in colour can be attributed to differences in sex intramuscular fat and muscle pigment. This is in supported by the assertion that the differences in duck meat colour are due to the differences in muscle fiber because duck breast has naturally high iron, haem and intermediate muscle fibres (Type 2a) (Puchala *et al*., 2014) . The mean value for tenderness in males is higher than in females. This contradicts with the view that means for tenderness was higher in females than their males in genetic reserve ducks after two reproductive seasons (Kruk *et al.*, 2011) . The difference in mean tenderness value can be attributed to the time of deboning after post-mortem since birds where deboned one after the other. Hence time of deboning the first bird was different from the last birds since it was only one person performing the act. Muscle that are deboned during early post-mortem still have energy available for contraction which cause the meat to be tough. The mean value obtained in the present study for juiciness and taste is higher in females than in males. This disagrees with the assertion that males have higher mean value for juiciness and taste than females (Kokoszyński *et al.*, 2020a). This can be attributed to the differences in the acidity of meat. Higher mean value for taste in male can be attributed to higher decline in muscle acidity than their female counterpart. The higher the decline of the acidity after slaughtering the better the taste. Drakes had a lower mean value in aroma than ducks in the present study. This disagrees with the report of Kokoszynski *et al.* (2020a) who corroborated higher mean value of aroma for drakes than ducks in genetic reserve ducks after two reproductive seasons. Differences in flavour in drakes and ducks can be attributed to the differences in intramuscular fat and the variation in composition of fatty acid in meat. There was no significant difference in tenderness and texture between the sexes and the various colour varieties. This disagrees with the report of Kokoszynski *et al.* (2020) who reported differences in the texture and tenderness of sexes and different strains of genetic reserve ducks after two reproductive seasons. Non-significant differences in the texture and tenderness can be attributed to the fact that the birds were not stressed before slaughtering. Stressing of birds before slaughter cause them to lose energy quicker. Differences in tenderness of breast muscles was observed in eight-week-old Pekin, Khaki Campbell and Mini Duck (Kokoszyński *et al*., 2020a). This finding contradicts what was observed in the current studies. The findings of the study is also in agreement with the assertion that there is no differences in tenderness between male and female pekin ducks (Bernacki *et al*., 2020a). The diameters of muscle fibres of male ducks (Pekin ducks and Muscovy ducks) were higher than those of female ducks (Smith *et al*., 2015). Increasing the diameter of muscle fiber is harmful to meat tenderness and contributes to increased shear strength (Michalczuk *et al*., 2016). It was also asserted that muscle fibre diameter affects the shear force and tenderness of a meat (Hwang *et al*., 2010). No differences in texture and tenderness can be attributed to the fact that they were all having the same shear force and muscle fibre diameter. It was asserted that the texture which depends on the tenderness is an effect of the shear force, the type of muscle and its percentage, the diameter and the contraction of the muscle fibre (Zhang *et al*., 2018). There were significant differences in flavour intensity taste and flavour liking with the colour varieties. This may be attributed to the differences in the levels of lipids in the meat of the ducks. This is supported by the assertion that the development of duck meat flavour and taste is affected by the intramuscular fat levels (Kong *et al.*, 2008). It was also reported that increase in lipid content of breast muscle influences the taste and increases the meat flavour (Chartrin *et al.*, 2006).

5.6 Correlation of Weight and Morphometric Measurements of Ducks

5.6.1 Correlation of weight and morphometric measurements of on-station ducks

Between body weight and other body measurements, there were positive and significantly phenotypic correlation coefficients. This indicates that these body dimensions are correlated concurrently with body weight. This is an indication that these easily measured components can be used as body weight measurement predictor and can thus also be used as selection criteria to increase body weight. There has been a strong and positive link between linear measurements and body weights in local chickens (Calkins and Hodgen, 2007) and pigeons (Dzungwe *et al.*, 2018). Positive and medium to higher correlation were observed with foot length and wing length having the highest correlation value (0.803). However, the least correlation value (0.279) was between foot length and body length. Body length (0.660) had the highest correlation value with body weights. In African Muscovy ducks, strong and positive correlations were recorded between zoometrical measurements and body weights (Victoria *et al.*, 2014). This is in line with the conclusions of the present report. It was asserted that body weight and wing length had a correlation coefficient of 0.990 whereas body weight and chest girth had 0. 993 (Raji *et al.*, 2009). This is in contrast with what was found in table 4.3. Body weight was significantly affected by all the other zoometric measurements. This clearly indicates that the increase in body weight increases the length of the geometric parameters and vice versa. This finding is in contrast with what was observed in table 4.3. This can be attributed to the fact that a different poultry specie was used.

Chest girth and chest width were positively associated with body weight, but the strongest association were found between chest girth and body weight (0.93) (Raji *et al*., 2009). This is different from what was found in the current study.

5.6.2 Correlation of weight and morphometric measurements of on-farm ducks base on sex

Among the various body parameters in both drake and duck, low, moderate and high positive and negative correlation coefficients have been reported. Neck length had the greatest direct influence on weight of drake but it was not significant. Body length and wing length in drake was significantly affected by the bill length. This clearly shows as the body length and the wing length of drake increases the bill length also increase. This increase in bill length suggests that the trait is likely to play an important role in sexual display and territorial defences (Raji *et al*., 2009b). Additionally, increase in the bill length of drake could help them feed at greater depth which increases their weight as well. This is supported by the assertion that superiority of males could be as a result of their ability to feed at greater depth (Araya-Salas *et al.*, 2018). Thigh circumference was significantly affected by the neck length. However, it is a negative correlation which means as the thigh length increases, there is a decrease in the neck length. Wing length was significantly affected by body length. This indicates that as the wing length increases, the body length also increases and the vice versa. This creates a balance in the movement of the animal. Foot length was significantly correlated by wing length. As the foot length increases the wing length also increases. Wing length had the greatest direct influence on weight of duck but it was not significant. Breast circumference and bill length was significantly affected by body length. There was a positive correlation between body length, breast circumference and bill length. This indicates that as body length increases there is also an increase in bill length and breast circumference. Thigh circumference and foot length has a significant effect on breast circumference and wing length respectively. Breast circumference was highly and significantly correlated with bill length. High positive relationships between characteristics imply that they are under the same gene action and can also be predicted individually or in combinations from each other (Yakubu, 2011). The different phenotypic correlation coefficients in the birds' genetic architecture suggest sexual variations in the two sexes.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

Based on results of this study

- The farmers of indigenous Ghanaian ducks practise the semi-intensive system of management.
- Ducks have wide range of colours and mixture of colours. The black dominated white colour was the largest, followed by pure white.
- The various colour varieties were not different in weight gain.
- Sexes were different in weight gain with males being superior.
- Colour variety were not different in morphometric measurements.
- Males had a longer Body length, foot length, neck length and a bigger thigh circumference.
- Sexes were different in terms of RBC, WBC, MCV, MCH, HBC and MCHC with males having the highest values.
- Colour varieties were different in terms of RBC, WBC, MCV, HBC, MCH and MCHC.
- Males were heavier in all the carcass parameters than females.
- Colour varieties were different in all the carcass parameters measured except WGIT.
- Colour varieties were different in colour of meat, flavour liking, flavour intensity, taste, juiciness and the overall liking.
- The sexes were different in meat colour with the male being the superior.
- Neck length was highly correlated with foot length.

- Weights were highly correlated with body length.

6.2 RECOMMENDATION

- Duck farmers should be encouraged to engage in training programmes to further inform and educate them on proper feeding, husbandry, biosecurity measures and how to efficiently use the resources available.
- Further research work, including phenotypic, genetic, molecular, and immunological characterization and genetic parameter estimation, should be carried out on the characterization of the local Ghanaian ducks. This will support decisions on breeding and conservation.
- Selection and breeding programmes should be carried out in order to enhance the efficiency of duck production. Specific area that needs immediate improvement is the body weight.
- For improvement of body weight selection should be done within regions.

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APPENDIX

APPENDIX 1. QUESTIONNAIRE FOR PRODUCTION AND MORPHOLOGICAL CHARACTERISTICS OF DUCKS.

DEMOGRAPHIC CHARACTERISTICS

1. Date of survey (DD/MM/YYYY)	
2. Enumerator Name	
3. Head of Household Name	
4. Gender [Code 1 = Male, 2 = Female	
5. Did the household consent to the interview? 1 =Yes, 2 = No	
6. Time interview started	
7. Time interview ended	
8. Household GPS coordinates	
9. Community / Village Name:	
10. Name of survey Respondent:	
11. Age of respondent	
12. Religion of Respondent [1=Christian, 2= Moslem, 3= Traditionalist, 4= None	
13. Source of initial stock [1=Market, 2= Colleague farmers, 3= Inheritance, 4= Gift]	

Ducks numbers and farmer status

Duck species		Number owned by adult male	Number owned by adult female	Number owned jointly by male and female	Number owned by children less 17	Number owned by household but kept elsewhere	Total
	a. Indigenous						
	b. Cross (Exotic X Indigenous)						
	c. Cross (Indigenous X Indigenous)						
	d. Exotic						

Cross refers to a cross-bred either of two local breeds, or two exotic or of a local breed and an exotic.

PRODUCTION SYSTEM AND PURPOSE OF KEEPING DUCKS

What is the system of production that you use for the duck? [1=Extensive, 2= Semi Intensive, 3= Intensive] [ ]

What is the purpose of keeping the livestock? Rank purpose 1, 2 and 3

Ducks	What is the purpose of keeping this Ducks? Rank the top three (code a)	Which type of production system used for the different duck species during rainy season? (code b)	Which type of production system do you use for different duck species during dry season? (code b)	What is sort of trending management do you use? (code c)	What sort of feeding management do you practice during the rainy season? (code d)	What is the sort of feeding management do you practice during the dry season? (code d)	Which type of feed do you give your livestock? (code e)

Interpretation of code

Code a Purpose of keeping ducks	1 = Meat, 2 = breeding, 3 = Manure 4 = Eggs, 5 = Feathers, 6 = prestige, 7 = Money
Code b Production system	1 = Mixed crop with ducks, 2 = Pastoral 3= Range system 4 = Other (Specify)
Code c Trending management	1 = Free range, 2 = Mainly grazing with some stall feeding, 3 = Other (Specify)
Code d Feed management	1= Grazing only throughout the year, 2 = Grazing and supplementation during dry season 3 = Grazing and supplementation during critical physiological states, 4 = Other (specify)
Code e Type of feed	1 = Cereal, 2 = Crop residue, 3 = Food left overs, 4 = Industrial by product,

HOUSING FOR THE DUCKS

Do you house your ducks? 1 = Yes, 2 = No

Ducks	Which type of housing do you have for your duck (Code a)	What type of materials have you used to construct the house (code b)	Form of housing (code c)

Interpretation of code

Code a Type of housing for livestock	1 = Mud house, 2 = open yard but fenced, 3 = cage, 4 = None
Code b Material for housing	1 = Mud and Thatch, 2= Mud and Iron sheet 3 = Wood, 4= Wire mesh with Wood, 5 = None
Code c	1 = Roof is present, 2 = structure has solid walls,

Form of housing	3 = Floor concrete ,4 = Floor wooden, 5 = Open shed (pillars and roof present) 6 = Other (Specify)

SOURCE OF WATER FOR DUCKS

1. Indicate the water use only for ducks and not including home use
2. What is the distance (KM) to the main water source during the (a) dry season?........................ (b) Wet season……………………………...
3. How long does it take (hrs? /minutes) to get to the watering point during the (a) dry season? (b) Wet season…………………………

Do you pay for the water for Ducks? (Yes = 1; No = 2) ……………………………………….

4. What is the average cost per month for the water in cedi?..................................

Ducks	What is your main source of water (Code a)	How are the ducks watered during the rainy season? (Code b)	How are the ducks watered during the dry season? (Code b)	Do you transport any water for ducks? If yes what mode of transport did you use (Code c)	How frequently do you water the ducks? (Code d)	What is the quality of water for ducks (Code e)	Who is responsible for watering the ducks? (Code f)

Code a Main water source	1 = River, 2 = Borehole, 3 = Water well, 4 = Dam
Code b How do ducks get access to water	1 = Animals walk to the water source, 2 = Water is provided, 3 = Both, 4 = Other (Specify)
Code c Water transport	1 = Own car, 2 = Hired car, 3 = My own animal drawn cart, 4 = Carrying, 5 = Other
Code d Frequency of watering	1 = All day, 2 = Once a day, 3 = Twice a day
Code f Who waters the animal?	1 = Household head, 2 = Spouse, 3 = Adult male, Adult female, 5 = Boys, 6 = Girls, 7 = Hired labourer
Code of the Water quality	1 = Good/clear, 2 = Muddy, 3 = Twice a day 4 = Salty, 5 = Other (Specify)

POPULATION PHENOTYPE	Indicate one response if the breed is homogeneous. If it is heterogeneous indicate proportion (%) for each category	
A1	Skin colour	Yellow…………. Black…………

		White………….. Peal…………
A2	Shank colour Shank length	Uniform……….. Spotted…… Green…………… Yellow……… Blue- grey…….. White……… Black…………….
A3	Plumage colour	
	plumage length	
A4	Earlobe colour	White……….. Red……………
A5	Eye colour	Orange……… Black………… Red………….. Pink…………… Brown……… Other…………
A6	Thigh circumference Breast circumference	
	body length Body weight	
	Neck length	
	Total leg length	
	Bill length	
	Foot length	
	thigh length	

INFORMATION ON DISEASE

1. What are the diseases that affect local ducks?

2.

Disease	Local Name

3.

Disease	Type of Treatment		Reason of choice	How is treatment done
	Modern	Traditional		

4. Do you lack veterinary Assistance [Yes = 1, No = 2]
5. Is there any vaccination schedule? [Yes=1, No = 2]

APPENDIX 2. FEED BACK FORM

Assessing the sensory characteristics of colour variety and sexes of duck in the three selected districts in the Northern Region.

Name of Assessor………………………………..
Department……………………………………….. contact…………………..

Data taken will be used for educational purposes only

Evaluate and score the sample 0001-010 based on the parameters indicated using the scale 1-9. See description in the table.

Sensory Analysis outline

Parameter	Scale								
	1	2	3	4	5	6	7	8	9
Colour	Extremely Dark	Very Dark	Moderately Dark	Slightly Dark	Intermediate	Slightly Pale	Moderately Pale	Very pale	Extremely Pale
Aroma	Extremely Offensive	Very Offensive	Moderately Offensive	Slightly Offensive	Intermediate	Slightly Pleasant	Moderately Pleasant	Very Pleasant	Extremely Pleasant
Flavour intensive	Extremely weak	Very weak	Moderately Weak	Slightly Weak	Intermediate	Like Slightly	Like Moderately	Like Very Much	Like Extremely
Flavour liking	Dislike Extremely	Dislike Very much	Dislike Moderately	Dislike Slightly	Intermediate	Like Slightly	Like Moderately	Like Very Much	Like Extremely
Tenderness	Extremely Tough	Very Tough	Moderately Tough	Slightly Tough	Intermediate	Slightly Soft/Tender	Moderately Soft/Tender	Very Soft/ Tender	Extremely Soft/ Tender
Texture	Extremely Rough	Very Rough	Moderately Rough	Slightly Rough	Intermediate	Slightly Smooth	Moderately Smooth	Very Smooth	Extremely Smooth
Taste	Extremely Bitter	Very Bitter	Moderately Bitter	Slightly Bitter	Intermediate	Slightly Sweet	Moderately Sweet	Very sweet	Extremely Sweet

Juiciness	Extremely Dry	Very Dry	Moderately Dry	Slightly Dry	Intermediate	Slightly Juicy	Moderately Juicy	Very Juicy	Extremely Juicy
Overall liking	Dislike Extremely	Dislike Very much	Dislike Moderately	Dislike Slightly	Intermediate	Like Slightly	Like Moderately	LikeVery Much	Like Extremely

APPENDIX 3: HOUSING OF DUCKS

MUD WITH THATCH

WIREMESH WITH WOOD AND SHEET

APPENDIX 4: SOME OF THE MORPHOLOGICAL MEASUREMENTS

NECK LENGHT

WING LENGHT

SHANK LENGHT

APPENDIX 5: SOME OF THE EQUIPMENT USED IN THE FOR THE EXPERIMENT

AUTOMATED HAEMATOLOGY ANALYSER

JAK INCUBATOR