

UNIVERSITY FOR DEVELOPMENT STUDIES

**PHENOTYPIC AND MORPHOLOGICAL
CHARACTERIZATION OF INDIGENOUS GHANAIAN RABBIT
(*ORYCTOLAGUS CUNICULUS*) RESOURCES IN NORTHERN
GHANA**

B Y

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**A THESIS SUBMITTED TO THE DEPARTMENT OF ANIMAL SCIENCE,
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(BREEDING AND GENETICS)**

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DECLARATION

Student

I, Husein A. Shuaib Mbelayim, hereby declare that this thesis is the result of my own original work and that no part of it has been presented for another degree in this university or elsewhere. All sources of information cited and assistance received in the preparation of this work have been duly referenced and acknowledged.

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ABSTRACT

The aim of this study was to characterize phenotypically, indigenous Ghanaian rabbit resources of northern Ghana. When characterization of the indigenous rabbits is complete, selection and breeding for specific objectives can be systematic. Three hundred local rabbits from the three northern regions of Ghana were randomly sampled. Frequencies for colour varieties were computed. The effects of variety, region and sex on body measurements were analyzed and phenotypic correlations between various body measurements were estimated. Regression equations were also fitted for body weight using body measurements. Thirteen colour varieties were identified: White, Red, Black, Brown, Ash, Black White, Brown White, Black Brown, Red Brown, White Red, White Ash, Ash Brown and Black Brown White. The White colour variety had the largest representation (28.0%). The least represented were the Black Brown (0.3 %) and Ash Brown (0.3 %). The overall mean body weights for the top six colour varieties were: Brown (1.80 ± 0.095 kg), White (1.63 ± 0.084 kg), Brown white (1.52 ± 0.110 kg), Black white (1.48 ± 0.132 kg), Black (1.43 ± 0.157 kg) and Red (1.43 ± 0.146 kg). Rabbits from the Upper West region had much higher body weights than Rabbits from the Northern and Upper East regions. Cases of genotype environment interaction were observed. The effect of variety was a significant ($p < 0.05$) source of variation for body length, heart girth, shoulder-to-tail drop and tail length. The effect of region was highly significant ($p < 0.01$) source of variation for body weight, body length, heart girth, shoulder-to-tail drop, ear length, tail length and head-to-pubic length. Sex was a significant ($p < 0.05$) source of variation for body length, heart girth, shoulder-to-tail drop and head-to-pubic length. The effect of breed was a highly significant ($p < 0.01$) source of variation for all



morphometric traits except tail length. Region * colour variety interaction influenced ($p < 0.05$) body weight while colour * sex interaction exerted effect on ear length ($p < 0.05$) and tail length ($p < 0.01$). None of the morphometric traits was influenced ($p > 0.05$) by interaction effects of the fixed factors. For carcass characteristics, the effect of variety was not significant ($p > 0.05$) for all parameters measured. The effect of sex was a highly significant ($p < 0.01$) source of variation for hot carcass dressing percentage and intestine (empty) weight. Cold carcass dressing percentage and liver weight were also influenced ($p < 0.05$) by sex. The males had higher ($p < 0.01$) hot carcass dressing percentage (50.57 ± 0.491) than the females (47.431 ± 0.556) and higher ($p < 0.01$) cold carcass dressing percentage (47.04 ± 0.641) than the females (44.56 ± 0.677). Rabbits lost about 3% of their live body weight after bleeding. The edible internal organs (lung, heart, liver and kidneys) constituted 4.92 % of the live body weight of the rabbit. Heart girth had the highest correlation coefficient with body weight (0.663; $p < 0.01$). There was positive moderate to high correlation between the various body measurements. The highest correlation was between head to pubic length and shoulder to tail drop (0.839; $p < 0.01$). The best weight prediction equation was given by heart girth, followed by shoulder-to-tail drop/body length, head-to-pubic length and thigh length, with the poorest being leg length, tail length and ear length. Average of 3 kindles per doe was recorded over 9 months. Litter size ranged between 1 to 5 kits in the first kindle (parity) in all the regions. It however increased to between 1 to 8 kits in the second and third parity (kindle). Region had significant effect ($p < 0.05$) on birth weight during the first kindle, both weaning weight and birth weight in the second and third kindles, but had no significant effect ($p > 0.05$) on



gestation, litter size at birth, litter size at weaning. Upper West region had the higher birth weight ($p < 0.01$) than Northern and Upper East regions.



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DEDICATION

Dedicated to my parents, my father, Alhassan Husein, my mother, Fulera Husein, my wife, Alhassan Halimatu Sadia, my siblings and the entire family. Also to my late uncle, Alhassan Iddrisu, may his soul rest in perfect peace.



ACRONYMS/ABBREVIATIONS

ACRONYM MEANING

AFLPs	Amplified Fragment Length Polymorphisms
AnGR	Animal Genetic Resources
ARBA	American Rabbit Breeders Association
BC	Before Christ
CH	Chinchilla
DNA	Deoxyribonucleic Acid
FAnGR	Farm Animal Genetic Resources
FAO	Food and Agricultural Organisation
GLM	General Linear Model
GOG	Government of Ghana
ILRI	International Livestock Research Institute
LBM _s	Linear Body Measurements
LTD	Limited
MOH	Ministry of Health
mtDNA	Mitochondrial Deoxyribonucleic Acid
NAFIS	National Farmers Information Service
NRP	National Rabbit Project
NTS	Nose-to-shoulder
NZW	New Zealand white
P:S ratio	Polyunsaturated fatty acids to saturated fatty acids
R ²	coefficient of determination
RAPDs	Random Amplified Polymorphic



RFLPs	Restriction Fragment Length Polymorphisms
SARI	Savannah Agricultural Research Institute
SNPs	Single Nucleotide Polymorphisms
US	United States
VSD	Veterinary Services Department
War II	Second World War
WHO	World Health Organization



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CHAPTER ONE

1.0 INTRODUCTION

Deficiency of protein is a serious problem in developing countries including Ghana (MOH, 2010). It leads to kwashiorkor in young children (under five years) who do not have enough protein added to their diet (MOH, 2010). Animal protein is the only source that contains all the essential amino acids required by human body (MOH, 2010), and so can help reduce the protein deficiency. Meanwhile there is a problem of inadequate supply of animal protein from conventional sources like sheep, goat and chicken (Chineke 1996). This caused consumption of animal protein to remain low at about 6.0-8.4g/head/day which is far below the 13.5g per day prescribed by the World Health Organization (WHO) (Egbunike, 1997) and 50 grams approximate daily protein needed by one who weighs 150 pounds (MOH, 2010). According to MOH (2010), animal protein is very expensive in Ghana, so the amount of protein consumed by the average person is relatively small compared to other countries. This has led to the search for other sources of animal protein. The rabbit has been seen to be suitable in this regard. The Ministry of Health (MOH) (2010) recommends that one-third of the daily protein intake should be of animal origin. Individuals can supplement their protein intake from animals, (goats/sheep/rabbit) and snail (MOH, 2010). However, animal protein intake in developing countries is still below standards (FAO, 1998; MOH, 2010).

Rabbit production is a veritable way of alleviating animal protein deficiency (Ajala and Balogun, 2004). Rabbit, a non-traditional livestock, appears as one of the most



suitable means of producing high quality animal protein that could make significant contribution towards bridging the gap between local production and demand of animal protein in Ghana (Osei *et al.*, 2012). This is because of its attributes of being affordable low cost management requirements, small body size, short generation interval, high fecundity, rapid growth rate, ability to utilize forage and agricultural by-products, and adaptability to a wide range of ecological environments (Abu *et al.*, 2008).

In many developing countries rabbits are reared purposely to achieve animal protein self-sufficiency for the household (Osei *et al.*, 2012). Rabbit meat is nutritious, high in protein, and low in fat and cholesterol (Cheeke *et al.*, 2000). These qualities make rabbit production the panacea to animal protein deficiency in developing countries (Obike *et al.*, 2010). The productivity of rabbit farms in Ghana has remained low for a very long time (Karikari and Asare, 2009) and the rabbit industry lacks behind the poultry and pig industries in development (Osei *et al.*, 2012).

The rabbit has immense potentials and good attributes which include high growth rate, high efficiency in converting forage to meat, short gestation period, high prolificacy, relatively low cost of production, and high nutritional quality of rabbit meat which includes low fat, sodium, and cholesterol levels. It also has a high protein level of about 20.8% and its consumption is bereft of cultural and religious biases (Biobaku and Oguntona, 1997). The presence of caecal microbes enables the rabbit to digest large amounts of fibrous feed that most non ruminant species cannot (Taiwo *et al.*, 1999).





Animal Genetic Resources (AnGR) are of great importance to every nation since they serve as an important source of income, employment and food (Mogre, 2009). Some of Ghana's indigenous Animal Genetic Resources are cattle, small ruminants, grasscutters, rabbits, pigs, equines and poultry (Mogre, 2009). In Ghana, the increase in population has led to an increased demand for meat (Osei, 2012). In a bid to meet this demand, producers often employ improved and imported AnGR (Mogre, 2009). This use of improved and imported AnGR is due to their perceived superior performance when compared to that of local AnGR (Mogre, 2009), even though it could lead to a loss of many of our indigenous AnGR. In developing countries, the practice of indiscriminate crossing with perceived better exotic breeds has often led to the dilution or loss of the adapted breeds (Boulet, 1999). With such loss, important, undiscovered genes could be lost forever. Genetic erosion of domestic animal diversity has placed 20 percent of the world's breeds at risk of extinction (FAO, 2007). According to Oldenbroek (1999), the increasing demand for animal products has led to an intensification of production systems and the subsequent restriction of the livestock industry to a few specialized breeds. This practice has reduced the use of local breeds and put their survival in danger (Oldenbroek, 1999), which is also the case of Ghanaian breeds of which the rabbit is no exception. To overcome this problem of breed extinction and contain the loss of important undiscovered genes, conservation and sustainable development of farm animal genetic resources (FAnGR) focusing on the many 'adaptive' breeds that survive well in the low external input agriculture typical of developing countries is recommended (FAO, 1997; 2007). The Food and Agricultural Organization (FAO, 2007) of the United Nations recommended establishing conservation programmes for the maintenance of animal

genetic resources. Notable among these programmes include the characterization of these local breeds.

Rabbit keeping is currently receiving much attention in southern Ghana (Osei *et al.*, 2012). The bulk of the nation's conventional livestock come from the northern regions (VSD, 1996). Given that these three administrative regions (the Northern, Upper East and Upper West regions) are among the poorest regions in Ghana (Shepherd, 2009), the improvement and widespread adoption of the indigenous Ghanaian rabbits can form part of the strategies for poverty alleviation in the northern sector as stated by Osei (2012). The prolific nature of rabbits coupled with its short gestation period and generation interval, makes it the choice of animal for multiplication and a quick way of increasing animal protein intake (Akinmutimi *et al.*, 2006). In addition they are easy to rear since they can be fed kitchen left over and some common forage around. Small-scale rural farmers can benefit immensely by incorporating rabbit production into their farming systems (Osei, 2012). Thus, the Indigenous Ghanaian rabbit is one of the important AnGR of Ghana that requires attention and improvement towards poverty reduction. To some extent, numerous studies have been done on rabbits in southern Ghana including characterization. Osei *et al.*, (2012) reported that rabbits in southern Ghana exhibited various hair colour including white, brown and black either as a whole or in combinations. Osei *et al.*, (2012) again noted that California White and New Zealand White breeds were popular among the rabbit keepers as a result of their perceived high growth rate and fertility. Few or none of similar studies has been done in the northern sector including characterization.



Characterization means the distillation of all knowledge which contributes to the reliable prediction of genetic performance of an animal genetic resource in a defined environment and provides a basis for distinguishing between different AnGR and for assessing available diversity (Rege and Okeyo, 2006). Characterization of livestock breeds is the first approach to a sustainable use of its animal genetic resources (Lanari *et al.*, 2003). The first step of the characterization of local genetic resources is based on the knowledge of variation in the morphological traits (Delgado *et al.*, 2001). Morphometric measurements have been used to evaluate the characteristics of various breeds of animals, and could provide useful information on the suitability of animals for selection (Nesamvuni *et al.*, 2000; Rastija *et al.*, 2004; Mwacharo *et al.*, 2006; Araujo *et al.*, 2006; Martins *et al.*, 2009; Yakubu *et al.*, 2010). The outcome of genetic improvement programmes could also be evaluated on morphological basis (Riva *et al.*, 2004). Phenotypic characterization forms the framework or foundation on which rabbits may be effectively selected and improved (Hammond, 2009). When characterization of the indigenous rabbits is complete, selection and breeding for specific objectives can be systematic. The depressed growth rate and reproduction performance or seasonal breeding traits of the Ghanaian (tropical) rabbits (Osei, 2012), when compared with the imported meat-type rabbits, serves as a disincentive to the large-scale commercial production of the local rabbits. One of the prerequisites for genetic improvement is the knowledge of genetic parameters for important economic traits (Akanno and Ibe, 2006). Improvement of economic characters in animals requires estimates of genetic, environmental and phenotypic parameters for the various traits of interest. In order to achieve this goal, proper measurement of growth traits and important economic characters is required



(Chineke, 1996). Zerrouki *et al.* (2004) noted that the utilization of local genetic resources first requires characterization of the population existing in the country. Estimates of genetic correlations between rabbit body weights and morphometric traits are scarce in available scientific literature all around the world (Akanno and Ibe, 2005).

There is therefore a compelling need for the complete phenotypic, genetic, and molecular characterization of the indigenous Ghanaian rabbit resources. This study seeks to lay a foundation for the eventual total characterization of the Ghana rabbits by starting with phenotypic characteristics.

1.1 Main objective of the study

The broad objective of this study was to partly characterize the indigenous Ghanaian rabbit resources.

1.2 The specific objectives were:

1. To estimate the frequencies and describe morphological features of some selected descriptive traits of rabbits in northern Ghana.
2. To investigate the effects of breed, colour variety, region and sex on morphometric traits of rabbits.
3. To estimate phenotypic correlations between some given morphometric traits.
4. To find the best morphological trait predictor of body weight.
5. To examine reproduction and carcass traits of local rabbits based on region.



CHAPTER TWO

2.0. LITERATURE REVIEW

2.1. Origin and Distribution of Rabbit

Knowledge of origin and evolution of domesticated species of rabbits is not only an important academic question, but also has practical value for informed conservation of genetic diversity. Analysis of mitochondrial DNA (mtDNA) has been widely used in the genus *Oryctolagus* and suggests that modern European rabbits had the same roots as the European wild rabbit, *O. cuniculus*, which was discovered in the Iberian Peninsula by the Phoenician in about 5000 BC (Hardy *et al.*, 1995; Monnerot *et al.*, 1996; Fuller *et al.*, 1997). In general, it is thought that there are two maternal lineages in the European rabbit based on data of mtDNA and immunoglobulin genes (van der Loo *et al.*, 1997; Branco *et al.*, 2000). All domestic rabbits belong to **one** lineage (Monnerot *et al.*, 1996). According to Long *et al.* (2003), the origin of Chinese rabbits is controversial. Sequence comparisons and phylogenetic analyses indicated only one mtDNA haplotype (A1) was represented in Chinese rabbits.

Some European breeds were imported into China and they might have retrogressed into Chinese animals, resulting in a decrease in genetic diversity of Chinese rabbits (Long *et al.*, 2003). However, the number of imported rabbits was very small and the effects of European animals were limited. Thus, Chinese rabbit probably originated from a population that carried haplotype A1 (Long *et al.*, 2003). Haplotype A1 was commonly found (about 70%) in many European domestic breeds, such as Fauve de Bourgogne, Argente' de Champagne, and Flemish giant (Bolet *et al.*, 2000), and in



wild populations from France as well as Australia (Fuller *et al.*, 1997). Chinese breeds, especially some of the recently derived ones, and some European rabbits were intermingled in the cluster centered with haplotype A1 (Long *et al.*, 2003). Therefore, a more plausible scenario is that the so-called Chinese rabbits were also introduced from European rabbits (Long *et al.*, 2003). Another hypothesis is that Chinese rabbit was probably domesticated in China (Charles, 1888, cited by Sanford, 1996) and so the lack of rabbit fossils in China was because the bones of rabbits were small, brittle and difficult to retain in fossils (Chen, 1984 cited by Sandford, 1996). Hardy *et al.* (1995) stated that this may be true for some of the bones, but not all as rabbits remains were extremely abundant at many archaeological sites dating back over 10,000 years and even earlier in Europe. However, both hypotheses were based on limited genetic evidence. According to Zeuner (1963), the European wild rabbit, *Oryctolagus cuniculus* is of west Mediterranean origin and was discovered in the Iberian Peninsula by the Phoenician in about 5000 BC. Through natural dispersal and modern introduction of rabbits to different places, the rabbit is now found worldwide. The ecology of the rabbit is in Mediterranean habitats and is of intrinsic importance in understanding its present status as a colonist of a new habitat. All domesticated rabbits in the world have been developed from the European/North African wild rabbit and so many different breeds and characteristics that are seen amongst domesticated rabbits today are the results of enthusiastic and careful selection over many years (Wilson, 1995).

The domestic rabbit is a descendant of the European wild rabbit (Stephen, 2006). Fossil remains suggest that both hares and rabbits developed in the Western



Hemisphere and then migrated to Asia and Europe. North and South America still have the greatest number of species compared to the rest of the continents. The exact dates of domestication are unknown (Stephen, 2006). Stephen (2006) further stated that most sources credit Spain as being the place of origin of the domestic rabbit. Sanford (1996) stated that the name Spain was given to the country where the rabbits originated and where they found rabbits so widespread. According to Stephen (2006), the fact that Phoenicians traded the rabbit to all regions of the world as it was then known to be is evidence to support this early date of domestication. Furthermore, Stephen (2006) again reported that Romans also kept hares and then switched to rabbits from Spain in the Roman leporarium from which they were easily harvested for kitchen use, and thus spread the rabbit to many lands. However, neither of these facts necessarily meant rabbits were domesticated (Stephen, 2006). Rather, the domestic breeds of rabbits we know today had their roots in the French monasteries where, from the early Middle Ages, they were kept in hutches and raised as a food source (Stephen, 2006). This species of rabbit was *Oryctolagus cuniculus*, the progenitor of the modern domestic rabbit. Several breeds were unknown by the 16th century. In the early 17th century, "types" were domesticated (Stephen, 2006). Some present-day breeds appear little changed from those developed in the 18th and 19th centuries.

According to Stephen (2006), rabbits were probably brought to United States before the early 1900s; however, evidence to support this estimate is scanty. Rabbit breeding has never had the wide-spread appeal in the United States that it had; and continuous to have, in Europe. However, there is a thriving, if small, rabbit industry in the

United States (Stephen, 2006). Sanford (1996) stated that the rabbits did not spread quickly as they did in later centuries, for 800 years later, none of the Greek writers mentioned the rabbit, which suggests that it had not reached the eastern Mediterranean by then. No further records occur until the second century BC, when some mention of it in Corsica is made by Polybius.

According to Clutton-Brock (1999), the European rabbit, which now has a ubiquitous distribution, is the sole representative of the genus *Oryctolagus*. From the end of the Pleistocene until the Roman period, it was restricted to the Iberian, Southern France, and possibly North Africa, and if it had not been introduced into the rest of Europe, by the Romans, it could be now extinct like the Mediterranean pika (Clutton-Brock, 1999). In fact the rabbit is the best example of that group of mammals, whose distribution and success as species has been enormously enlarged by human activities. Although the Romans were responsible for the spread of the rabbit out of Spain, they did not attempt to produce artificial breeds from a domesticated stock; they merely fattened them for food or left the rabbits to live as they would in the wild, except that they were kept in enclosed hutches, arrears, or warrens (Clutton-Brock, 1999). Clutton-Brock (1999) further mentioned that the extremely fast rate of reproduction of the rabbit, combined with their burrowing habits, enabled them to escape from the Roman warrens and rapidly invade the countryside, but they probably did not reach the British Isles until the Norman period. Rabbits were also carried by sailors and let loose on oceanic islands so that they could breed and provide a store of fresh meat that would be readily available for passing ships. It is for these reasons that rabbits are now found all over the world and on almost all



islands from Lundy to the Falklands (Clutton-Brock, 1999). France with, certainly after the war II, the largest rabbit industry in the world, has been the leader in this field, followed perhaps by Italy and Spain (Sanford, 1996).

Changes in population distribution pattern in relation to habitat reflect the outcome of ecological process affecting production and survival, owing to factors fundamental to the ecology of a species. Rabbits' populations in different climatic regions are distributed discontinuously, and patterns of distribution bear a direct relationship to landscape feature (Rogers and Myers, 1979). Rogers and Myers (1979) showed that the dynamics of distribution of rabbit population in an arid habitat in Australia were significantly related to changes in climate.

The domestic rabbit was introduced into Ghana by missionaries well over a century and a half ago (Lukefahr, 2000). Congregations under the parishes of the missionaries were encouraged to raise rabbits on a backyard basis since rabbit meat was the only known meat which had no known taboos as to its consumption either on religious or ethnic grounds (Opoku and Lukefahr, 1990 cited by Lukefahr, 2000). In addition to no known taboos, rabbits were easy to handle by women and children, feeding and management practices were simple and locally sustainable, and a plentiful (albeit inexpensive) meat source was secured. Rabbit rearing on small farms has spread throughout the country (Opoku and Lukefahr, 1990 cited by Lukefahr, 2000). The different breeds of rabbits found are the locally adapted Ghanaian rabbit and exotic breeds like the Flemish giant, Chinchilla, Californian and New Zealand White.



2.2 Taxonomy of rabbit

Scientific names are used by scientists throughout the world so they will know exactly what species they are talking about. For instance, a hare in Ghana is completely different from a hare in the United Kingdom. The idea of scientific classification (taxonomy) was developed by Linnaeus (1735). He classified living organisms using different levels and statuses. The basic idea was to create two names for an organism, the genus and the species. That is, a general and a specific name. With this system, the rabbit belongs to the genus *Oryctolagus*, and species *cuniculus*. Detail of biological classification of the rabbit has been presented by Stephen (2006) and is outlined below:

Domain	→	Eukarya
Kingdom	→	Animalia
Phylum	→	Chordata
Sub-Phylum	→	Vertebrata
Class	→	Mammalia
Order	→	Lagomorpha
Family	→	Leporidae
Genus	→	Oryctolagus
Species	→	cuniculus



2.3. Importance of rabbits

Rabbits are raised for a variety of purposes, including for meat, fur, and wool, and for use as laboratory animals (Cheeke, 2005). Cheeke (2005) further stated that large numbers of rabbits are raised for exhibition and many simply as pets.

Small livestock species, including rabbits, have been promoted as tools in poverty alleviation programmes (Dolberg, 2001; Owen *et al.*, 2005). Rabbits are particularly favoured for poverty reduction programmes on account of their low investment and early benefits, and subsistence on renewable resources for feeding, housing and general management. Thus, small-scale rabbit projects could be used as a vehicle for the poor to help themselves (Lukefahr, 1999). According to Sandford (1996), the domestic rabbit is called the "poor man's pig". This is because, a number of variety of use to which rabbit is put by man include; supply of food (the most extensive of all the uses), very high grade wool, serves as a source of miscellaneous products, assists in laboratory and experimental work, and could be kept as exhibition, pet or companion animal and could be used in educational work of varied sorts (Sanford, 1996).

Rabbit furs for clothing purpose have been used for hundreds of years (Sanford, 1996). The skins can be used in the production of toys, craftwork and garment and can be in cottage industries for such purposes (Debray *et al.*, 2003).



Rabbits are bred as pets, for genetic studies, for laboratory experimentation, and for their meat and furs; domestic rabbits' furs are sold under the trade names of arctic seal, clipped seal, and lapin (Redmond, 2009).

In relation to fat with human health, Kerry and David (2002) stated that there is interest in trying to increase the proportion of polyunsaturated fatty acids to saturated fatty acids (the P:S ratio) in meat. It is not difficult to increase the proportion of unsaturated fatty acids in non-ruminants like pigs and poultry and especially rabbit because the fat laid down in their bodies closely reflects the characteristics of the dietary fat. So, feeding rabbit diets high in linseed, rapeseed or fish oils results in softer, more unsaturated carcass fat. From Warriss (2010), this process is more difficult in ruminants. Unsaturated fats in the diet are hydrogenated by the rumen microorganisms to much more saturated fats. This is why the carcass fat of cattle and sheep is hard, despite the fact that the grass they eat contains mainly unsaturated fatty acids.

2.4.0 Production Systems of Rabbits

The main livestock production systems according to Notenbaert *et al.* (2009) are: Agro Ecological Zone, Integration with crop production, the animal-land relationship, intensity of production, and type of product. This classification of the livestock production systems may be based on a number of criteria. Considering the level of intensification, there are three possible systems of management of domestic rabbit production depending on the levels of purchased inputs and the degree of commercialization (Wilson, 1995). These are: extensive, intensive and semi intensive



production systems. The extensive system is widely practiced in most of the developing countries (Lukefahr, 1998). However, rapid increase in human population has exerted pressure on the available land leading to an increasing shift towards more intensive and semi intensive systems of rabbit rearing (Onifade *et al.*, 1999; Adu *et al.*, 2005).

2.4.1. Extensive Production System

This production system is characterized by low initial costs of establishment, including low feeding costs (Lukefahr, 2007). This is because the rabbits are raised purely on forages and kitchen waste that are locally available (Lukefahr, 2007; Wilson, 1995). This system has been described in the developing countries such as Cameroon and Tunisia, where rabbits are partially housed in structures constructed using locally available materials such as wood (Lukefahr and Goldman, 1985). Akugre (2010) stated that majority (70%) of farmers used semi-intensive while 30% practiced intensive system of production in the northern part of Ghana due to capital intensive in the intensive system.

In this production system, farmers keep a small number of rabbits mainly for home consumption. Organized rabbit breeding programs are virtually absent and does nurse their kits for about one and half months (five to six weeks). The does are rebred soon after weaning and are therefore serviced once every one and a half months (Lukefahr, 2007). Projections of 20 to 35 marketable fryers per doe per annum under this system have been given (Lebas *et al.*, 1997; Lukefahr and Cheeke, 1991). But the total annual litter produced is much lower than the projected number above (Lukefahr and



Cheeke, 1991). According to Adu *et. al.* (2005), an average of 5-8 kits per litter is born and kindling boxes are rarely provided in this system. Usually, 4-6 kits per litter are being weaned. . The replacement stocks are obtained from own stock and under these circumstances, locally adapted breeds or crossbreds are usually more suitable than imported exotic animals from intensive production systems (Lukefahr, 2007).

2.4.2. Intensive Rabbit Production System

This system of production is rare in the developing countries but commonly practiced in the developed regions (Lukefahr and Goldman 1985). The main objective of this production system is commercial and rabbits are mainly reared for meat. Other by products of rabbit production are equally important especially the skin, fur and the manure (Lebas *et al.*, 1997). In this system, feeding management is on commercial feeds (total dependence on prepared concentrate food from the feed mill) which are compounded to increase growth rate and to minimize labor requirements (Walsingham, 1972; Wilson, 1995). However feed intake is affected by some of the following factors: water availability, health of animal, temperature, the physiological state of the rabbit, food quality, level of choice and freshness of food. Wilson (1995) further stated that rabbits have proved easily adaptable to the intensive management systems.

According to Ayyat and Marai, (1998), with the high levels of management and proper feeding, rabbits can produce 8.7 liters each of 6.4 live kits or a total of 55.7 live kits per year. The cost of housing is high in this system. However the main challenge of intensive meat-rabbit production is usually incompatibility of the system



with production standards for quality fur and skins due to the early age at slaughter (Lebas *et al.*, 1997).

Balfour (2013) reported from southern part of Ghana that the intensive system of management is widely practiced by rabbit farmers because, it enhances effective monitoring and also the farmers are able to know at a glance, the growth and health conditions of the animals.

2.4.3. Semi-intensive Production System

The main objective of the semi-intensive rabbit production system according to Schlolaut (1985) is both for home consumption and for sale. Rabbit farming is

moving towards intensive and semi-systems in many developing countries (Onifade *et al.*, 1999; Adu *et al.*, 2005). This is due to decline in individual landholdings as a result of rapid population increase (Onifade *et al.*, 1999; Adu *et al.*, 2005). The semi-intensive system is dominated by small scale units (Colin and Lebas, 1996; Lukefahr, 2007), where the farmer keeps less than 10 does. Breeding management involves, servicing does 10 to 20 days after kindling and an average of 7 kits are weaned at four to five weeks, giving an average of 6 kindling per year and over 40 marketable fryers per doe per year (Lebas *et al.*, 1997).

Oseni *et al.*, (2008) reported that to house the rabbits, most farmers use assorted locally available materials such as wood, bamboo, sacks, wire mesh, worn out tires for the construction of rabbit cages with single tiering being the most predominant. Labor is provided by the family members and rabbits are fed on forages with minimal supplementation using kitchen wastes or purchased concentrates (Wilson, 1995). Adu *et al.*, 2005 described a similar feeding system in Nigeria.



2.5 Problems of Rabbit Production

In Nigeria, as is the case for most developing countries including Ghana, a major limitation to the development of smallholder rabbit production is the absence of reliable sources for quality genetic stocks of rabbits (Oseni *et al.*, 2008). Wilson (1995) pointed out that limited supply of high performance breeding stock retards rabbit production.

Sanford, (1996) stated that the most common diseases of rabbits are coccidiosis, ear and skin mange, snuffles, mastitis, inflammation of the eyes, epizootic hemorrhagic diseases and coenurosis.

Heat stress poses a serious limitation to rabbit production in the tropics (EL- Raffa, 2004). Heat stress reduces feed intake, impairs growth, decreases fertility and increases kit mortality (EL- Raffa, 2004). Finzi *et al.* (1992) reported on the results of experiments that evaluated heat stress under field conditions and noted that animal posture (which varied from normal and 'active' to 'stretched') gives some indication of the degree of heat stress in rabbits. High ambient temperatures can cause infertility in breeding rabbit's and 30°C is considered the threshold, beyond which infertility may result (Lukefahr and Cheeke, 1990). Adaptation to heat stress, particularly under hot and humid zones, has been extensively reviewed by El-Raffa (2004) who noted that heat stress is ranked as the most important problem facing the rabbit industry in the tropics and in arid regions, as compared to poor quality diets, diseases and/or parasites. Heat stress reduces feed intake, impairs growth, decreases fertility and increases kit mortality (El-Raffa, 2004).



population size of the animal genetic resource, its physical description, adaptations, uses, prevalent breeding systems, population trends, predominant production systems, description of environment in which it is predominantly found, indications of performance levels (milk, meat, growth, reproduction, egg, fibre, traction etc.), genetic parameters of the performance traits and information on genetic distinctiveness of the AnGR and its evolutionary relationship with other genetic resources in the species.

2.6.2 Types/Categories of Breed Characterization

Basically, there are two types of breed characterization in animal studies. These are:

1. Phenotypic characterization and
2. Molecular characterization

Phenotypic characterization is measuring **or** describing gross physical and physiological features of an organism by interaction of its genes and the environment (Madubi *et al.*, 2000; Vij *et al.*, 2006). It can also be termed as measuring or describing all the observable characteristics of an organism (e.g. shape, size, colour, and behaviour) and non-observable characteristics (e.g. blood group) that result from the interaction of its genotype with the environment.

Phenotypic characterization is concerned with the conservation and suitable use of farm animal genetic resources. According to ILRI (1997) it is essential for providing information on breed distribution, breed status (whether breeds are decreasing or increasing in population size or are stable), their production characteristics and the local uses. Breed-level statistics and characteristics are required, not only to quantify



the extent of phenotypic diversity, but also to classify individual livestock populations (breeds/strains) on the basis of potential risks of extinction.

Phenotypic characterization of interest can be classified into three main categories: (1) physical or morphological description or measurements; (2) performance characteristics; and (3) adaptation to the environment.

Morphology as a form of phenotypic characterization deals with the size, shape, and structure of an animal or one of its parts (Lindenfors *et al.*, 2007). Physical description of a breed should focus on characters which, in the view of keepers of the breed and local experts, facilitate identification of animals as being members of the breed or strain. Physical or morphological characteristics can be particularly useful in the classification of populations/strains/breeds within a species (Rege and Okeyo, 2006). Body shapes, measured objectively, could also improve selection for growth by enabling the breeder to recognize early-maturing and late-maturing animals of different size (Brown *et al.*, 1973; 1974).

Performance characteristics tend to be limited to such traits as growth and live weight, reproductive, maternal ability, carcass and behavioural traits. Adaptive traits include reaction to cold and heat stress, disease resistance or tolerance, endo- and ecto-parasite resistance and survival or mortality (Cartwright, 1982; Van Vleck *et al.*, 1987).



Molecular characterization refers to the complementary procedures used to unravel the genetic basis of phenotypes and their patterns of inheritance from one generation to the next, and to establish relationships between breeds (FAO, 2011a). FAO (2011a) further stated that the measurement of genetic relationships between breeds and genetic heterozygosity within breeds is the task of molecular characterization. Ideally, molecular characterization should be undertaken as part of a comprehensive national programme for management of AnGR that includes the strategy for meeting the country's needs for AnGR-related data (FAO, 2011b). According to FAO (2012), for maximum efficiency in characterization of AnGR, molecular characterization should be done in concert with phenotypic characterization. If molecular characterization is done independently, the following factors, according to FAO (2011b), should be taken into account to ensure a genetically diverse sample:

- consider the structure of the production system, geographic locations and pedigree relationships;
- preferably sample in the production areas that are closest to the site of the development of the breed;
- preferably cover the different agroclimatic zones where the breeds are found;
- typically no more than 10% of any one herd or village population should be sampled and in any case no more than five animals should be sampled from any herd;
- do not sample animals with the common grandparent;
- if there are indications of genetic subdivision within breed, seek to collect samples that represent all of the different subtypes and keep strict records of which animals and types have been sampled;



- for studies on mitochondrial DNA (mtDNA) and Y-chromosomal markers, sampling of animals with common maternal and paternal origins, respectively should be avoided;
- in situation where suitable breeding infrastructure exists, sampling can be done in conjunction with breeding associations or artificial insemination organizations, which may also be reliable sources of pedigree information.

Many research works have detailed the procedures, techniques, tools and methods of molecular characterization. Such techniques and tools have proven their value for studying variation within and across breeds. In principle, the most advanced technologies that are available for the species to be studied should be chosen, because these technologies are generally the most informative (FAO, 2011b). The merits of the current marker systems have been discussed by FAO, 2011b; Groeneveld *et al.*, 2010; Bruford *et al.*, 2003; Ajmone-Marsan *et al.*, 2010; Achilli *et al.*, 2008; Petit *et al.*, 2002.

A summary of all these studies indicate the following markers:

Microsatellites: so far most studies have analysed highly polymorphic microsatellite markers, which are repeated sequences of 1 to 6 base pairs (bp). Variability in terms of the number of repeated sequences has been observed. Microsatellites do not encode proteins and are thus assumed to be selectively neutral.

Single-nucleotide polymorphism (SNP): is a DNA sequence variation that occurs through a change in the nucleotide at a single location within the genome of a species or breed. SNP usually have only two alleles. Generally, SNP can occur throughout the genome and may represent either neutral or functional genetic diversity. A variety



of methods can be used for assaying SNP, including approaches based on hybridization, selective polymerization, and post-amplification analysis.

Copy number variations (CNV): genetic studies of the human genome indicate the presence of variation in copy number of certain chromosomal segments, as well as relationships between copy number and phenotypic variation. It is anticipated that this category of genetic variation will also prove to be relevant for studying the diversity of livestock.

Genome sequencing: genomic technologies have proof-of-principle stage, and will expand further the scope of molecular studies. Most notably, dense genetic maps allow the demarcation of "footprints" or "signatures" of selection, while knowledge on genotype-phenotype relationships will also reveal novel aspect of functional diversity.

Mitochondrial DNA (mtDNA) markers: these maternal markers have been instrumental in identifying wild ancestors, localizing domestication centres and reconstructing colonization and trading routes. Most studies with mtDNA target the hypervariable control region (D-loop), but complete mtDNA sequences add substantial information by establishing the relation between haplogroups.

Y-chromosomal markers: is a powerful tool with which to trace gene flow by male introgression. It is the most powerful marker in human population genetics and is used more and more in domestic animal studies.



2.6.3 Methods of Breed Characterization

There are basically three methods that can be used to characterize livestock breeds. These include on-farm surveys, on-station studies and molecular laboratory analyses of samples collected on-farm or on-station (FAO, 1998). Annor (2011) has given a detailed discussion of the three methods.

An on-farm study is the type of research carried out at the local site belonging to the fanner or farming community. An on-farm breed survey is organized to collect data on breed phenotypic characteristic, main uses and management of livestock in order to understand the reasons for the distribution and persistence of particular breeds (Mwacharo and Rege, 2002; Zerabruk and Vangen, 2005; Al-Amin *et al.*, 2007). It can also be designed to collect socio-cultural and indigenous knowledge data, which may be of value in understanding fanners' strategies for keeping specific breeds. Where breeds are known to occur in small numbers, a survey to gather this information may need to focus on the areas where they are.

Clear definition of objectives for collecting breed data is very important and careful consideration of the various different instruments that might be used for obtaining these data should be done. Summary of the objectives of a farm animal genetic resources (FAnGR) survey as outlined by ILRI (1997) are as follows:

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

determine breed status and trends;



- population numbers must be estimated;
- summarize performance characteristics;
- contribute to improved 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.

Procedures for the conduct of FAnGR survey have been described in detail by FAO (1992; 1998), ILRI (1997) and Ayalew and Rowlands (2004).

A controlled environmental study carried out at a research station or a nucleus breeding station is known as an on-station study. On-farm surveys can be useful for collecting basic information on production systems, population statistics, physical or morphological characteristics and performance characteristics of breeds. However, a more reliable compilation of data on characterization of livestock breeds can only be obtained from more detail on-station studies (FAO, 1998). Such studies may involve whole herd/flock as basic experimental units and require collection of data over relatively long period of time. Information such as livestock performance data, estimates of herd/flock structures and population trends essential for assessing rates of decline and identifying causes of such declines can be collected using on-station studies (Tibbo *et al.*, 2004).



The advantage of on-station breed characterization (and evaluation) is that the controlled experimental conditions ensure a high precision. Special adaptive attributes, which are difficult to measure at field level (on-farm), are also generally best studied on-station. The high precision to which on-station studies can be undertaken, as has been stated, makes them appealing for breed evaluation despite the fact that they are less accurate as indicators of performance in fanners' herds/flocks. According to Rege and Okeyo (2006), indeed, in the presence of genotype x environment interaction, conclusions drawn from on-station characterization could be misleading.

According to Ruane and Sonnino (2007) molecular biotechnology is the use of molecular markers to quantify genetic diversity, and relationships between and within livestock breeds, to investigate biological processes (e.g. mating systems) or to identify specific genotypes. Hetzel and Drinkwater (1992) reported that DNA techniques can be used to analyse the phylogeny of breed divergence, to follow gene segregation within populations, and to associate nucleotide variation with changes in gene function and expression of animal phenotype. Techniques for the analysis of variability are essential ingredients for animal conservation and active utilization programmes.

Zaid *et al.*, (2001) defined molecular markers as biomolecules (proteins, carbohydrates and DNA), whose heritable traits can be assayed for variation in organism or populations. Molecular markers can be thought of as constant landmarks in the genome of animals that give clues to identification of genes. They are



identifiable DNA sequences, found at specific locations of genome, and transmitted by standard laws of inheritance from one generation to the next.

Molecular markers can be used to estimate:

- population history of animals
- kinship and relationship among individuals in a population;
- the extent of genetic variability within and among populations;
- structures in distribution of variation, and
- inbreeding relationship within and among populations;

The appropriate techniques for assessing DNA variation in a variety of applications include Restriction Fragment Length Polymorphisms (RFLPs), Random Amplified Polymorphic DNA (RAPDs) markers, Amplified Fragment Length Polymorphisms (AFLPs), microsatellites and Single Nucleotide Polymorphisms (SNPs) (Ruane and Sonnino, 2007).

It must be noted that molecular characterization on its own is not adequate; characterization must be presented and undertaken in a broader context of utilization. Molecular characterization, therefore requires, a comprehensive integrated approach with continued emphasis on phenotypic recording programmes to enable gene detection, estimation and confirmation of effects, and use of estimates in selection (Ruane and Sonnino, 2007).



2.7.0 Non-Genetic Factors

2.7.1 Non-Genetic Factors Affecting Animals

Non-genetic factors are measurable environmental effects that affect animal performance (Annor, 2011). They include parity, age, sex, litter size, season of mating and of birth, and year of birth (Armor, 2011). In selecting animals to be parents of the next generation, comparison should be made between contemporary groups of animals. Therefore, to improve the rate at which genetic gain can be made, measured performance of an animal with respect to a particular trait should be adjusted for various known environmental or non-genetic factors which disguise or mask the genetic expression of that trait (Blair, 1989; Willis, 1991; Beffa *et al.*, 2009). For example, a kid reared in a litter size of five is likely to be somewhat lighter in weight than its counterpart that has been born and reared as a single. If the objective of the breeding programme is to improve pre-weaning growth rate, the kid from a litter of five has received an unfair handicap which has nothing to do with its genetic ability to grow. The slower growth may simply be due to the dam's inability to produce sufficient milk to adequately feed the five kids in the litter (Mattingly and McClure, 1985).

The influence of non-genetic factors on the performance of domestic livestock is very well documented in traditional livestock species reared in both temperate and tropical environments (Kabuga and Agyemang, 1983; Osei and Effa-Baah, 1989; Osei *et al.*, 1991; Ahunu *et al.*, 1993; Darko and Buadu, 1998; Baffour-Awuah *et al.*, 2005;



Beffa *et al.*, 2009). A summary of all these studies according to Annor (2011) indicate the following:

Herd-year-season: Animals in different herds perform differently because they are given different treatment or management. Animal performance varies with years due to differences in climatic variables in different years. The performances of animals in dry and rainy seasons are different. In the rainy season, there is adequate amount of grass, which is also of good quality, compared to what is obtained in the dry season. However, there are many diseases and pests that attack animals in the rainy season.

Sex of animal: Males tend to be bigger and also grow faster than females.

Age of animals: Animals of different ages have to be adjusted to a constant age.

Litter size: Animals in small litter grow faster than those in large litter.

Birth rank: Birth rank refers to the order of giving birth to individuals in a litter. In multiple births, animals born first are heavier and grow faster than those born last.

Parity of dam: Females giving birth for the first time, produce smaller litter that has low weights and growth rates than older females.

Dam age: Dam age is related to parity but it is a different factor altogether. Young dams produce offspring with smaller weights and growth rates than older dams.

2.7.2 Effects of Non-Genetic Factors on Rabbits

According to Sanford (1996), the environment of an animal consists of all those factors which influence it in any way but which are not inherited. The major group of environmental factors includes diet, housing, management and contact with disease, but there are many others. All factors that cause stress in any way are part of the environment of the animal and as such things as the size of the litter into which the



animal was born and so on. The importance of these environmental factors is little appreciated although they have a profound effect on the animal. Some characteristics of the rabbit are more affected by inheritance than by environment and others of more by environment than inheritance. For example, the coat colour of a rabbit is determined by its inheritance. Certainly, it may be slightly changed by some external influences (sunlight may fade it) but the colour and the pattern are fixed by the animals genetic constitution (Sanford, 1996). Such a character as milk — yield in does, although again influenced to some extent by inheritance, is affected by environment, especially diet, by the suckling of young and the parity of the litter.

The environment of animals may limit the expression of some inherited characteristics. For example, if the rabbit has genetic constitution for large size, that size cannot be fully attained unless the environment (particularly diet, housing and management) is sufficiently good. Nowhere is this relationship between environment and inheritance more clearly seen than in reproduction of rabbits. The broad pattern of fecundity, for example, is determined by inherited factors, but superimpose on this pattern are a number of limitations and modifications due to environment. The age of sexual maturity is a matter of both environment and inheritance. The larger the breed, the later it becomes sexually mature, but young born in the spring of the year have an older age of sexual maturity than do those of the same strain born in the late summer and autumn (Sanford, 1996). The genotype of both the mother and fetuses play a vital role in determining birth weight, while the consequent litter weights basically depend, beside the fetuses' genotype, on the suckled milk from the dam (Abdel-Azeem *et al.*, 2007). Litter weight at weaning is controlled by the number of kits



survived at weaning (Risam *et al.*, 2005). With the increase of litter size and decrease of mortality income becomes more elevated (Szendrő *et al.*, 1996).

2.8.0 Phenotypic Characteristics of Rabbits

2.8.1. Breeds Characteristics and Colour Varieties of Rabbits

The term 'breed' can be used in a number of different ways but in the rabbit world it is a group of animals, or populations which resemble each other (Sanford, 1996). Breeds of rabbits had been produced from these three ways; occurrence of mutation which is the mechanism which controls the inherited characters producing a particular colour or type of fur may be changed, thus producing an entirely new character. The second method is by combination of characters existing in two or more breeds. The third system is by selection for particular characteristics carried to such a degree that a strain differing greatly from the original stock is produced. All these ways, and variations of them, have been used or have occurred in the production of the present breeds and varieties of domestic rabbits (Sanford, 1996). Sanford (1996) further stated that the common breeds of rabbits are Angola white, Flemish giant, New Zealand white, New Zealand red, British giant, California white, Sussex, Smoke pearl, Chinchilla and Chinchilla giant, among others.

In 1972, eighty local rabbits were used as foundation stock for the National Rabbit Project (NRP). Foundation animals were purchased from backyard breeders throughout the country. Between 1972 and 1984, several hundred rabbits of various breeds: Alaskan, Blue Vienna, Californian, Champagne D'Argent, Chinchilla,



Checkered Giant, Creme D'Argent, Danish Giant, Danish White, Dutch, Flemish Giant, French Lop, New Zealand White and Thuringer, were generously donated or provided to the National Rabbit Project (NRP), Government of Ghana (GOG), by the Governments of Denmark, Switzerland and the United States (Lukefahr *et al.*, 1992 cited by Lukefahr, 2000). It was Mr. Mamattah, the managing director (M.D) of the project, who requested the importation of exotic breeds. The aim was to procure "good quality, beefy-giant types for crossing and up-grading the local animals" (Technoserve, 1975 cited by Lukefahr, 2000), despite the fact that these standard breeds were developed in temperate environments and were predominantly selected from commercial and (or) fancy herds. However, by 1975 the initial population of 80 rabbits had increased to nearly 4 000 rabbits. Unfortunately, the imported breeds were reported by Opoku and Lukefahr (1990) cited by Lukefahr, 2000) to acclimatise rather poorly (e.g. low fertility and depressed growth) to the stressful tropical environment in Ghana, in agreement with previous studies (Sundaram and Bhattacharyya (1991) cited by Lukefahr (2000) involving comparable breeds and environments.

According to the American Rabbit Breeders Association (ARBA) cited by NAFIS (2012), there are over 47 distinct rabbit breeds. Only about a dozen of these are reared in Kenya, the most common being New Zealand White, Californian white, Chinchilla, French lop, Dutch, Checkered Giant, Giant Flemish, Angora and Rex (NAFIS, 2012). A survey conducted by Animal Production Department of Kenya in November 2010 indicated that New Zealand White and Californian White breeds of rabbits are the most popular in Kenya. Other breeds that are popular in Kenya



include the Giant Flemish, the French Lop and Checkered Giant mainly because of their large size (NAFIS, 2012).

According to Sanford, (1996), closely coupled with the term breed is the term 'varieties'. The term 'variety' relates to colour. Thus, the Dutch breed has eight different colour varieties (Sanford, 1996). Redmond (2009) stated that at least 66 varieties of the domesticated rabbit were derived from a wild rabbit native to Europe and Africa. Some varieties are Angora, Belgian, Dutch, Himalayan, lop, Siberian, Patagonian, silver-tip, Polish, and Flemish. Sanford (1996) reported that difficulties, however, arise in some cases where there are more than two levels of breed or varieties. For example, the Rex is a breed having a number of different colours but Otto Rex, which is a variety of Rex, has four colours (Sanford, 1996).

The domesticated rabbit has extremely diverse characteristics, varying in colour through every grade, shade, and mixture, from pure white to all black; in coat from very short to long, silky hair capable of being woven; and in style of ears from the prick ear—erect, small and almost as stiff as metal—to the floppy, broad, soft-skinned lopped ear, which hangs to the ground (Redmond, 2009). Akugre (2010) reported white, red, black, ash and mixed colour varieties of rabbits from the Upper East region of Ghana. He noted that farmers use colour of fur and behaviour to classify rabbit. According to Sanford (1996), all domestic rabbits throughout the world are the same species, *Oryctolagus cuniculus*. Sanford (1996) again found that the domestic rabbit is the same species as the wild rabbit, and different characteristics of all domestic breeds arise through either mutations or by a combination of different inherited



characteristics. Selection thereafter modifies the breed or colour variety by an increase of the modifying genes (Sanford, 1996).

There have been attempts to produce breeds, or more accurately strains or families, having the best utilitarian characteristics, in particular for the production of meat. However, these attempts have lagged far behind the search for new fancy rabbits (Sanford, 1996). Robert *et al.* (2008) classified rabbits according to size, weight and type of fur/hair. Small rabbits weigh about 3 to 4 pounds (1.35kg-1.8kg) at maturity, medium breeds 9 to 12 pounds (4.05kg-5.4kg), and large breeds 14 to 16 pounds (6.3kg-7.2kg) (Robert *et al.*, 2008). Robert *et al.* (2008) further reported that based on this classification, two most popular breeds for meat production includes the New Zealand white and the Californian. These breeds are most popular because they combine white fur and good growth characteristics. The New Zealand rabbits are slightly larger than the Californian, 9-12 pounds (4.05kg-5.4kg) and 8-11 pounds (3.6kg-4.95kg) respectively. The New Zealand rabbit has a completely white, red or black body, whereas the Californian is white with colored nose, ears and feet. The two most popular rabbits for fur production are the Rex and the American Chinchilla. The Rex is slightly smaller than the American Chinchilla, 8-11 pounds (3.6kg-4.95kg) versus 9-12 pounds (4.05kg-5.4kg) (Robert *et al.*, 2008). Bergmann's Rule as stated by Kendeigh (1969), postulates that, geographic races of small size are generally found in the warmer parts of a species range and races of larger size in the cooler parts.



The various production traits such as fertility, growth and feed conversion rates when considered, under commercial conditions, New Zealand Whites and Californians are amongst the best breeds available for meat production (Robert *et al.*, 2008; NAFIS, 2012). New Zealand White and Californian White breeds of rabbits are the most popular in Kenya and these two medium sized rabbit breeds (3.6 - 5.9kg) are also rated the most popular for meat elsewhere in the world because of their good growth characteristics and high carcass dressing percentage (NAFIS, 2012). Baffour (2013) reported that majority of farmers keep a combination of the exotic, local and crossbreed (Table 1), and this could be due to the fact that, the combination produces hybrids with desirable features such as resistance to disease attack, ability to withstand local environmental conditions, good fathering and mothering ability, good bodily features, fast growth rate and increase in meat or carcass quality. Few of the farmers (22%) keep local breeds alone and this was due to their low price. None at all got them from a recognized breeding source (Baffour, 2013).



Table 1: Breeds of Rabbits in Ghana

Breed	Percentage (%)
Exotic breed	15.0
Local breed	22.0
Crossbreed	16.0
Exotic + Cross	1.0
Exotic + Local + Cross	46.0
Total	100.0

Source: Baffour, 2013

2.8.1.1: Description of Some Breeds of Rabbits

New Zealand White

The New Zealand White has a good growth characteristic and capable of attaining slaughter weight of 1.3-2.5kg live weight within 8-10 weeks depending on feeding regime. It is one of the best commercial breeds that grows to a weight of about 4-5.4kg and has all-white colour (Plate 1). Its fur is marketable. It is considered a dam breed because of its excellent mothering instinct (Sanford, 1996).



Plate 1: New Zealand White (Source: Sanford, 1996)

Californian White

This is another commercial breed developed in the US. It is a breed that has broad shoulders and meaty back and hips and hence is a good meat breed with good dressing percentage (Sanford, 1996). It is shorter and stockier and is white except for its ears, nose, feet and tail which are either dark grey or black (Plate 2). It is recognised by four colours- Normal (black points), Chocolate, Blue and Lilac. It is an ideal sire breed for interbreeding with other rabbit breeds for purposes of meat production (Sanford, 1996). Adults weigh between 3.5 and 4.75kg.

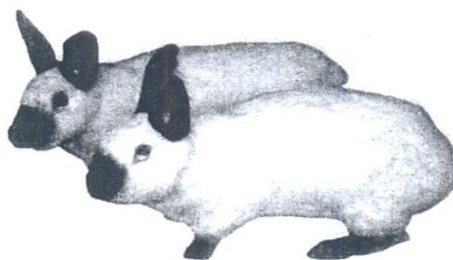


Plate 2: Californian White (Source: NAFIS, 2012)

Flemish Giant

This is one of the largest rabbit breeds (Plate 3), with adult bucks weighing not less than 4.9kg, nor adult does less than 5.4kg. Specimens up to 9.5 kg have existed but 6.3kg or more are of good size at the present time (Plate 3). Interbreeding it with other breeds yielded other Giants such as the British Giant and improved its characteristics (Sanford, 1996).



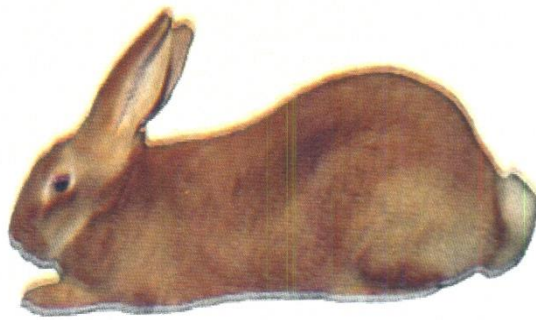


Plate 3: Flemish Giant (Source: NAFIS, 2012)

French Lop

Its outstanding characteristic is the large ears that droop around the head (Plate 4). They have short and stocky legs but are heavy - they weigh over 5.5kg. It has excellent carcass type, but also has other characteristics. Several other lops exist, including English lop (3.2kg), Dwarf lop (1.9kg), German lop (3-3.5kg), Danish lop, Miniature lop (1.5-1.6kg) (Sanford, 1996).

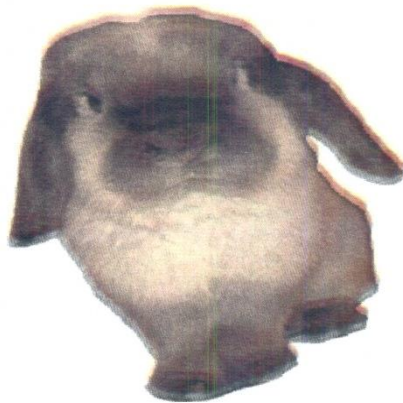


Plate 4: French Lop (Source: Sanford, 1996)

Chinchilla

Originally bred for fur and meat, they are short and stocky with a nice rounded back (Plate 5). There are 3 chinchilla breeds: Standard, American and Giganta Chinchilla (Sanford, 1996). It weighs between 2.5 and 3kg or more depending on the type. Pelts of the Chinchilla rabbit, which are impossible to imitate with dyes, usually fetched a better price than other normal fur-breed skins.

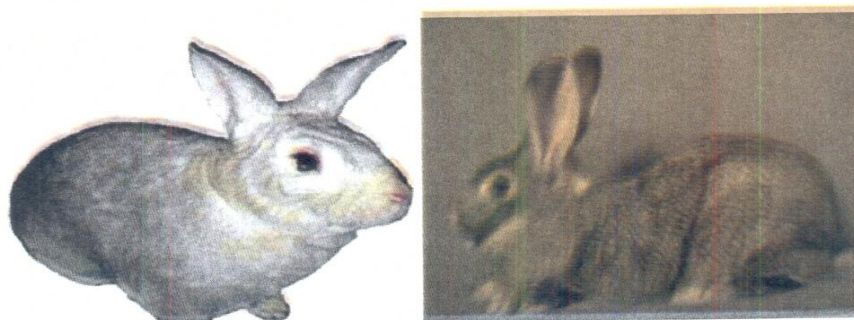


Plate 5: Chinchilla (Source: Sanford, 1996)

Angora

This rabbit is mainly bred for its wool (Plate 6). Because of the wool they produce, this rabbit requires regular grooming. It is therefore more suited as a pet than for meat the breed is recognized in white and twelve different colours, but majority of Angoras bred are white (albinos) (Sanford, 1996). It was at the beginning of the 18th century spoken of as White Shock Turkey rabbit, and later as the English Silk Rabbit. English Angora has much finer coat and weighing on average about 2.75kg as against 3.6kg or more for French Angora and slightly over 4kg for the larger German Angora.





Plate 6: Angora (Source: NAFIS, 2012)

The Dutch

Fairly small but compact rabbit with shorter forelegs (Plate 7). There are eight different colours of Dutch-Black, Blue (these two being most popular), Chocolate, Tortoiseshell, Pale Grey, Brown Gray, Steel Grey and Yellow. The breed, weighing under 2.25kg, had good meat properties, although on the small side. When other breeds are crossed with Dutch, traces of the Dutch pattern are liable to be exceedingly difficult to eradicate (Sanford, 1996).

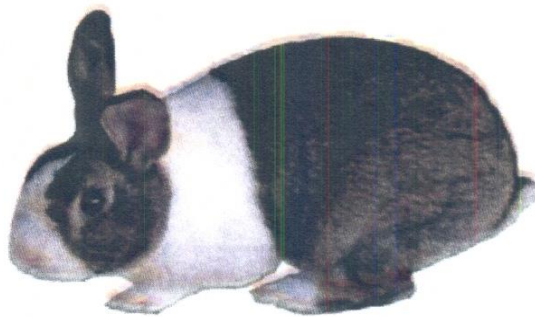


Plate 7: Dutch (Source: NAFIS, 2012)

2.8.2 Morphological Characteristics or Traits of Animals

Morphology deals with the size, shape, and structure of an animal or one of its parts (Lindenfors *et al.*, 2007). Lindenfors *et al.* (2007) reported that morphological characteristics or traits of animals are used for classification and identification of species or breeds. Lindenfors *et al.* (2007) again found that within species or breeds, morphological characteristics are used to differentiate between sexes. The differences in the morphological body measurements of the sexes are indications of sexual dimorphism (Lindenfors *et al.*, 2007). Morphological traits are often used to predict body weights in livestock, thereby enabling poor farmers who cannot afford expensive weighing scales to use measuring tapes to estimate body weights (Gueye *et al.*, 1998; Slippers *et al.*, 2000; Abdelhadi and Babiker, 2009). Body length and heart girth have long been recognized in livestock production as measures to predict body weight (Gueye *et al.*, 1998; Slippers *et al.*, 2000; Abdelhadi and Babiker, 2009).

Traditionally, animals are assessed visually, which is a subjective method of judgment especially in rural communities (Abanikannda *et al.*, 2002). The problem associated with this method is that it does not give a true reflection of each animal in terms of its body characteristics. Therefore, the development of objective means (linear body measurements) for describing and evaluating body size and conformation characteristics would overcome many of the problems associated with visual evaluation (Birteeb *et al.*, 2012; Yakubu and Ibrahim, 2011; Jimcy *et al.*, 2011). The linear body measurements of animals is an important factor associated with several management practices including selection for slaughtering or breeding, determining feeding levels and also it is a good indicator of animal condition (Ulutas



et al., 2001). According to Pundir *et al.* (2011), biometric traits are used to characterize the different breeds of livestock as they give an idea of body conformation and are also used for comparison of growth in different individuals. In addition, linear body measurements describe an individual or population in a better way than the conventional methods of weighing and grading. Body dimensions have been used to indicate breed, origin and relationship or shape and size of an individual (Pundir *et al.*, 2011).

Characterization of livestock breeds is the first approach to a sustainable use of its animal genetic resources (Lanari *et al.*, 2003). Delgado *et al.*, (2001) stated that the first step of the characterization of local genetic resources is based on the knowledge of variation in the morphological traits. Morphometric measurements have been used to evaluate the characteristics of various breeds of animals, and could provide useful information on the suitability of animals for selection (Yakubu *et al.*, 2010; Martins *et al.*, 2009; Araujo *et al.*, 2006; Mwacharo *et al.*, 2006; Rastija *et al.*, 2004; Nesamvuni *et al.*, 2000). The outcome of genetic improvement programmes could also be evaluated on morphological basis (Riva *et al.*, 2004). Although recent analyses have focused on molecular techniques, most mammalian species and subspecies originally were described on the basis of morphological characteristics (Feldhamer *et al.*, 2004). Previous efforts on the phenotypic characterization of breeds of livestock have been restricted to the use of analysis of variance, whereas the current trend in livestock classification involves the use of multivariate statistical tools (Yakubu and Akinyemi, 2010 and Traore *et al.*, 2008). This is because univariate statistical analysis according to Dossa *et al.* (2007), analyses each variable



separately and do not explain how the populations under investigations differ when all measured morphological variables are considered jointly.

Body measurements vary greatly due to some factors such as sex, age, breed, and type of the animal. It may also vary from one country to the other and even within regions. However some common body measurements of ruminants which have been explored by researchers are; chest girth, body length, wither height, chest depth, hip width, hip height, head length, head depth, ear length, body depth, rump height, height at withers and tail length (Birteeb *et al.*, 2012; Quaye, 2010; Yakubu, *et al.*, 2010; Ozkaya and Bozkurt, 2008;2009; Otoikhian *et al.*, 2008; Sowande and Sobola, 2008; and Khan *et al.*, 2006). A linear body measurement of cattle depends upon breed, age, type, size, condition and fattening level of the animals. Van Marle-KOster *et al.* (2000) described body measurements as selection criteria for growth in cattle and that body measurements can be used for characterization of breeds. Body weight measurement is used the most to evaluate body development in animals (De Brito Ferreira *et al.*, 2001); but it is not easily measured in the field. This is due to the time and energy expended while determining it. Regression equations have been established to estimate body weight from body dimensions (Birteeb and Ozoje, 2012; Oke and Ogonnaya, 2011; Gorgulu *et al.*, 2005). These regression models allow a fast evaluation of the body parameters of an animal; and are also used for the optimization of feeding, determination of optimum slaughtering age, and selection criteria. Besides, linear body measurements of meat animals have been found useful in quantifying body size and shape (Ayele *et al.*, 2006). The quantitative



measurements for size and shape are necessary for estimating genetic parameters in animal breeding programmes (Chineke, 2000).

2.8.3 Measuring Body Weight of Domestic Animals

Body weight is an important trait that is used in evaluating body condition (Erat and Arikan, 2010) and health status (Lund *et al.*, 2005), in computing dosages and in prescribing drugs in domestic animals. Body weight and condition score are also often used for assessing nutritional condition of dog and cat (Esfandiari and Youssefi, 2010). According to Latshaw and Bishop (2001), a lot of techniques, which are simple or sophisticated and expensive or inexpensive, are available to get information on animal's body traits. The easiest way to assess an animal's body mass is to weigh the animal. However, under some situations scale may not be available and prediction of body weight from body measurements could be preferred practically (Latshaw and Bishop, 2001).

2.8.4. Body Weight Characteristics of Rabbits

According to Philip (1990), body weight is regarded as a function of framework or size of the animal and its condition. Body weight is known to be moderately to highly heritable and hence the selection of heavier individuals in a population should result in genetic improvement of the traits.

According to Fielding and Matheron (1991), the weight of a rabbit at birth is about 30-40g. At birth, the kits average weight was 51.0 g in Kabyle rabbits (Zerrouki *et al.*, 2007). This weight increased progressively during the suckling phase to reach an average weight of 310 g at the end of the third week (Zerrouki *et al.*, 2007).



Similarly, according to Lebas (1969), live weight of Fauve de Bourgogne kits was 330 g at 21 days. On the other hand Khalil and Khalil (1991) found a weight at 21 days lower than the results of zerrouki *et al.* (2007) and Lebas (1969) with 222 g and 205 g for the Bouscat and the Egyptian Giza White rabbits, respectively. The mean weight of the rabbits at weaning (28 d) was 475 g with a daily weight gain of 15.7 g/d (Ifenychukwu, 2013). According to Brun (1990), the average weight of young at weaning (30 d) varied from 595 to 640 g in three INRA lines and their crossbred products.

Afolabi *et al.* (2012) found mean live body weight of 1.89kg (Table 2) in rabbits. The mean body weight of Chinchilla rabbits at 6 months of age was 2.05 kg (Table 3) (Ifenychukwu, 2013). Low adult weight of 2.9-3.1 kg was recorded in local Kabyle rabbit population (Zerrouki *et al.*, 2004). Zotte *et al.* (2012) conducted a study on the effects of age (20 weeks and 45 weeks) and gender on live weights and body measurements of dwarf rabbits. At both ages, they found that females showed heavier live weights than males (1,630 vs 1,542g and 1,953 vs 1,850g, at 20 and 45 wk of age, respectively). Small rabbits weigh about 3 to 4 pounds (1.35kg-1.8kg) at maturity, medium breeds 9 to 12 pounds (4.05kg-5.4kg), and large breeds 14 to 16 pounds (6.3kg-7.2kg) (Robert *et al.*, 2008). Alan *et al.* (2014) reported final mean live weight of 1196.0g (1.196kg) in local rabbits while Abugri (2014) noted live weight of 1.269kg, 1.241kg and 1.184kg respectively for local rabbits without night lighting, rabbit on six hours night lighting and rabbits on twelve hours night lighting regime. Pinna *et al.* (2004) reported 2167 ± 157 g (2.167 kg) live body weight in New Zealand White and California crosses at 77 days of age.



2.8.5 Morphometric Traits Characteristics of Rabbits

Tables 2 and 3 show some morphometric measurements of different breeds of rabbits in different environments.

Table 2: Descriptive Statistics of body weight (kg) and body measurements (cm) of rabbits reared under mature Rubber trees.

Body Parameters	N	Mean	Standard Deviation	SEM
Body Live Weight (BLW)	208	1.89	0.54	0.07
Body Length (BDL)	208	30.4	5.67	0.79
Head to pubic bone Length (HPL)	208	39.5	7.08	0.98
Leg Length (LL)	208	18.8	3.64	0.51
Thigh Length (THL)	208	10.4	1.84	0.26
Tail Length (TAL)	208	8.00	1.66	0.23
Heart Girth (HG)	208	25.8	4.07	0.57
Shoulder width (SW)	208	8.98	1.94	0.27

Source: Afolabi *et al* (2012)

Table 3: Descriptive statistics of body weight (kg) and linear body measurements (cm) of Chinchilla rabbits.

Traits	Mean	SD	CV
Body weight	2.05	0.30	14.80
Body length	43.68	2.17	4.96
Heart girth	24.98	2.00	8.00
Ear length	10.56	0.73	6.90

SD - standard deviation, CV - coefficient of variation % Source: Ifeanyichukwu (2013)



2.8.6 Reproduction in Rabbits

According to Robert *et al.* (2008), medium-weight breeds (4.05kg to 5.4kg) are able to start breeding at 6 to 7 months of age, with males maturing one month later than females. According to Stephen (2006), medium-weight rabbit breeds are mature and can be put into the breeding colony at 6 to 7 months of age. He further stated that given the same environmental conditions and breeding, bucks mature approximately 1 month later than does. Female rabbits usually attain puberty at 70-75% of adult weight and can breed at four months of age (Wilson, 1995). In the same litter, the does normally reach maturity from 2-4 weeks earlier than bucks. Robert *et al.* (2008) noted that because outward signs of heat are not always evident in mature does, one should follow a strict breeding schedule. When the doe is on heat, it is sent to the buck's cage for mating. A second mating is usually allowed 14 days after the first mating to ensure satisfactory service.

One buck can serve 8-10 does (Stephen, 2006). Robert *et al.* (2008) again found that one buck can service about 10 does but no more than two to three times a week. The average gestation period lasts 31 to 32 days (Robert *et al.*, 2008). Stephen (2006) indicated that the gestation period in rabbits is 30-32 days. The average commercial litter consists of 8 to 10 kits. The young are weaned in about 30 days, so you can expect an average of five litters annually per doe (Robert *et al.*, 2008).

Rabbits are characterized by high production traits, such as high fertility, prolificacy and early puberty (Kowalska, 2006; Zotte, 2002). Profitability of production depends on the reproduction intensity and the number of kits being weaned from one litter



(Castellini *et al.*, 2010; Gacek, 2010). Ajayi *et al.* (2005) reported that the combinations of these characteristics are unique. In addition to this, rabbits have a number of other characteristics that might be advantageous to subsistence farming system, such as their small body size, short generation interval with a relatively short gestation period averaging 30-31 days.

Iyeghe-erakpotobor *et al.* (2005) carried out an investigation to determine the effect of rebreeding interval on the reproductive performance and body changes of does during pregnancy and concluded that rebreeding does at 14 days post-partum increases the willingness of does accepting males which ultimately increases pregnancy rates and thus the number of rabbits produced at any one time. Mmereole (2009) stated that though rabbit may be re-bred within a wide range of intervals with measurable success, rebreeding interval of 7 days post-partum appears to give the best results in terms of high litter weight, high litter size, high conception rate and the total number of kit per doe per annum.

The decisive issue in reproduction is the efficiency of mating and litter size. Osei *et al.*, (2012) reported that litter size ranged from 1 to 10 with a mean of 4 kits per litter, which was lower than the average of 5 to 8 kits per litter obtained in Nigeria (Abu *et al.*, 2008). According to Osei *et al.*, (2012), with an average of 4 kindling per year and 4 kits per liter, a doe would produce 16 kits on the average per year, which, is lower than 20 marketable offspring per doe obtained in many developing countries (Lukefahr, 2007). Organised mating of rabbits results in 3 to 5 kindlings per year with an average of 4 kindlings per year (Osei *et al.*, 2012). This was lower than the



average of 5 kindlings per year in the Forest zone of Ghana (Karikari and Asare, 2008). According to Akugre (2010), two kindling per year recorded higher percentage as against 3 kindling per year in the Upper East region of Ghana which was attributed to poor nutrition. Wilson (1995) stated that poor feeding affects the number of times a rabbit will kindle in a year. Osei *et al.*, (2012) reported that attempts at achieving 6 kindlings per doe per year tended to result in high kit mortality. Three cases of double kindling per pregnancy were reported with almost all the kits dying within 2 weeks after birth (Osei *et al.*, 2012).

2.8.7 Mortality in Rabbits

Month of kindling effects were highly significant ($P < 0.001$) on preweaning mortality (Abd El-Moty *et al.*, 1991; El-Maghawry, 1993; Bhasin and Singh, 1995). Preweaning mortality was higher in hot months (May-June) which may be due to the direct effect of heat stress on the sensitive kits and reduction of dam's milk production (Ayyat *et al.*, 1995). The lowest percentage of preweaning mortality was found in rabbits born in March and January which may be due to the favourable conditions especially ambient temperature in these two months (Abdel-Azeem *et al.*, 2007).

2.8.8 Carcass Characteristics

Meat is defined as the muscle of slaughtered animal (Gunter and Hautzinger, 2007). Meat is a rich source of nutrients which human nutrition often lacks. It is a rich and important source of essential amino acids, vitamins, minerals and also long chain polyunsaturated fatty acids (Stephen, 2006; Wilson, 1995). One of the cheapest sources



of meat but which has been neglected in many West African Countries is the rabbit. Rabbit meat is classified as white meat, with low cholesterol level and nutrient elements absorption at 90%. It is also classified as functional foods (Kowalska, 2006; Zotte and Szendro, 2011). Rabbit's meat as a white meat is also relished by health conscious consumers, the elderly and the people living with debilitating disease conditions due to its low fat and cholesterol contents (Nworgu, 2007). According to Nguyen and Brian (2008), meat colour of animals fed concentrate is quite white which makes it not very attractive to the consumer, so the diet that the animals consume is very important. Most green feed are of good quality and high in carotene and xanthophylls, which are important in giving a deep yellow colour to egg and meat quality (Nguyen and Brian, 2008). Carcass traits are influenced by the adult weight and the maturity of rabbits at the age of slaughter (Pla *et al.*, 1996; Piles *et al.*, 2000). In an experiment conducted by Metzger *et al.* (2004), the carcass traits of *Hyplus* hybrid, purebred Pannon White rabbits and their crossbreds were compared; in this comparison the dressing out percentage of Pannon White x Hyplus female genotype was the highest. The effect of sex is significant on carcass traits and males have better carcass characteristics (Singh *et al.*, 1999; Baeza *et al.*, 2001). Singh *et al.* (1999) observed no differences in carcass traits between varieties of guinea fowls.

Sanford (1996) stated that the weight lost between live weight and carcass weight is known as the dressing loss, and is usually given as a percentage (the dressing-out percentage). This is the carcass weight as a percentage of the live weight. For mature rabbits the dressing-out percentage is about 60%, and for younger rabbits it may be reduced to 50% or even less (Sanford, 1996). Jennifer (2002) reported that the dress-

out percentage for fryers is between 50-60 percent resulting in a range of retail weights between 2.2 pounds (0.99kg) and 3 pounds (1.35kg). Pinna *et al.* (2004) reported 1294 ± 98 g (1.294 kg) for hot carcass weight, 1179 ± 96 g (1.179kg) for cold carcass weight, $59.7 \pm 8.1\%$ for dressing out percent (hot) and net bled weight of 2102 ± 110 g (2.102kg) in New Zealand White and California cross. Alan *et al.* (2014) reported 54.05% dress-out percent (hot) and 53.1% cold carcass dressing percentage for local rabbits. Slaughter weight and carcass weights were slightly lower and dressing percentages were higher in males than that in females, but these differences were not significant (Yalcin *et al.*, 2006). Similarly Trocino *et al.* (2003) also reported that females showed higher live weight ($p < 0.05$) but lower dressing percentage ($p < 0.01$) due to the higher incidence of the gut content. In contrast, according to the results of Pla and Cervera (1997) dressing yield was lower for males than for females. These differences might be due to the slaughter age, breeding, weaning age and feeding conditions (Deltoro and Lopez, 1986; Fernandez and Fraga, 1996).

Rabbits (*Oryctolagus cuniculus*) produce large quantities of tasty meat for domestic consumption (Wilson, 1995). Rabbit meat is high in protein, about 22 %, low in fat, 4 % and cholesterol, 5 % and thus possesses health promoting qualities (Aduku and Olukosi, 1990). According to Okorie (1997), rabbit is a suitable complement to poultry in terms of rapid growth rate and percentage of meat production. The meat has been found to be bristle, palatable, highly nutritious and good source of high quality protein (Okorie, 1997). In comparison with the meat of other species, rabbit meat has a low cholesterol level (50 mg — 100 mg), fewer calories, lower fat content and is richer in proteins than beef, pork, chicken or lamb (Kerry and David, 2002; Wilson, 1995).



Kerry and David (2002) and Wilson (1995) again reported that rabbit meat is also richer in certain vitamins and minerals, and is relatively rich in essential fatty acids. Rabbit meat offers an excellent nutritive and dietetic property (Zotte, 2004). According to Zotte (2004), rabbit meat is characterized by its low sodium (Na) content (37 and 49.5mg/100g for the loin and hind leg respectively), which makes it particularly appropriate for those with hypertension.

Rabbit meat is especially good for babies, elderly people and anyone with stomach disorders because it is easily digested. Rabbit fat contains less saturated fatty acids (stearic and oleic) than other species and higher proportions of the polyunsaturated linolenic and linoleic fatty acids (Kerry and David, 2002; Wilson, 1995). Unsaturated fatty acids have lower melting points than saturated fatty acids (Kerry and David, 2002). The carcass quality and meat chemical composition of broiler rabbits are influenced by breed (Ouhayoun, 1998; Singh and Prasad, 2005).

In South Africa, a large number of consumers of rabbit meat (79 %) do not like it to be presented in a whole carcass, as it resembles a cat or a human infant. This may be attributed to the fact that, although rabbit uses to be commercialized as a whole carcass in South Africa, a trend of selling rabbit in retail cuts is developing gradually (Piles *et al.*, 2000). Piles *et al.* (2000) noted that rabbit meat is available as flyers, roasters, stewers, and in rare cases, even capons. For the novice grower, an understanding of consumers' choice and reasons for their choice regarding this classification is essential for a successful rabbit meat business. A research conducted by Lamar (1998) showed that the greatest demand is for fryer rabbits that are young, tender and meaty.



These are rabbits that are not over 12 weeks of age, and for some processors they even prefer these fryers not to be over 10 or 11 weeks of age. Zotte (2002) reported that rabbit's meat production is strongly developed in Mediterranean countries of the European Union. The traditional consumers of the tropics consider rabbit meat to have positive sensory properties, being tender, lean and with delicate flavour. However, rabbit meat consumption depends heavily on cultural, traditional and religious believes (Zotte, 2002).

2.9. The Use of Body Measurements to Forecast Body Weight in Rabbits

In principle, the preeminent method of knowing the weight of an animal is to weigh the animal (Attah *et al.*, 2004; Goe, 2007). Unfortunately, this may not always be possible due to the lack of equipment and/or time. Other indirect methods have been identified in assessing body weight of farm animals without the use of a weighing scale. An example is the use of body measurements to predict body weight. A lot of work has been done in this regard in large animals, particularly cattle, sheep and goats (Attah *et al.*, 2004; Goe, 2007). In poultry, Oke *et al.*, (2004) related body weight with some egg production traits in the guinea fowl, Tegua *et al.*, (2008) reported significant association between body weight and body characteristics in the African Muscovy ducks. The use of linear body measurements to predict live body weight of animals is perceived more reliable compared to the use of weighing scales which could introduce biases as a result of feed in the gut. Moreover, weighing scales are not readily available in most rural African farming communities (Nesamvuni *et al.*, 2000). Multiple regression analysis has been used widely to describe quantitative



association between dependent (body weight) and independent variables (heart girth, body length and wither height etc.) in animal studies (Cankaya, 2009). Several studies on cattle, sheep and goat (Bagui and Valdez, 2007), dog and cat (Valdez and Recuenco, 2003), horse and donkey (Marante *et al.*, 2007), poultry (Grona *et al.*, 2009) and grasscutter (Armor *et al.*, 2011) have been conducted to predict body weight from body measurements. The relationship existing among linear body traits provides useful information on the performance, productivity and carcass characteristics of animals. Most of the linear measurements reflect primarily the length of the long bones of the animal and when taken sequentially over a period of time, they generally indicate the way in which the animal body is changing shape and have been used as predictors of live carcass composition (Oke *et al.*, 2004). Momoh and Kershima (2008) indicated that the relationship between body weight and linear measurements are important not only in predicting body weight but also useful in genetic improvement strategies.

According to Salako (2006), body measurements in addition to weight measurements describe more completely an individual or population than the conventional methods of weighing and grading. These body measurements have been used at various times for the estimation of weight when live weights are measured alongside these parameters. Chineke *et al.* (2002) reported that the relationship existing among body characteristics provides useful information on performance, productivity and carcass characteristics of animals and that these quantitative measures of size and shape are necessary for estimating genetic parameters in animal breeding programmes. Body dimensions have been used to indicate breed, origin and relationship through the



medium of head measurements (Itty *et al.*, 1997). Research has shown that the measure of a body part may relate significantly to body weight. Linear body measurements, therefore, have been used to predict live weight in poultry (Kabir *et al.*, 2006). Relating body weight to linear body measurements is one way of predicting body weight of rabbits (Shahin and Hassan, 2000). Body weight and body measurements are used to characterize rabbit breeds, contrast variation in size and shape (Shahin and Hassan, 2000) and estimate carcass and body weight (Oliveira *et al.*, 2005). This is relevant especially in rural communities where there is an evidence for absence of conventional weighing scales. In line with this, linear body measurements have been used to characterize breeds, evaluate breed performance and predict live body weight of animals (Ozoje and Herbert, 1997). This later report is attributed to the high genetic correlation between body weight and linear traits. For instance, Adeleke *et al.* (2004) observed that, chickens live weight is positively correlated with other linear body traits and gave breast girth as the best predictor of live weight. Linear body measurements have been used extensively to predict body weight in poultry and the ruminants both in the temperate and tropical regions. According to Chineke (2000) and Nwagu *et al.* (2000) such studies are few and/or non-existent for rabbits.

The relationships among quantitative traits such as body weight, body length, ear length, tail length and limb lengths etc have been investigated among domestic rabbits (Chineke *et al.*, 2002; Abdullahi *et al.*, 2003; Isaac *et al.*, 2011; Atansuyi *et al.*, 2011). Alcamo and Ibe (2005) reported genetic and phenotypic correlations among body measurements of rabbits. Chineke (2005) observed positive and significant relationship between body weight and body measurements in rabbit breeds and crosses.



Similar findings were reported by Chineke (2000), Tiamiyu *et al.* (2000), and Ebegbulem (2012). In the domestic rabbit, Oke *et al.* (2003) found height at withers as the best predictor of body weight at 20 weeks of age and body length at 16 weeks of age. In their study, Abdullahi *et al.* (2003) indicated shoulder-to-tail drop as the best single predictor of body weights for rabbits followed by body length and heart girth. According to Ozoje and Ngere (2002) and Salako and Ngere (2002), since the final body weight of an animal reflects the total of the weight of its component parts, predictive equations provide a readily available tool in estimating body weight especially in rural communities and in areas where standard weighing scales or balances are lacking or unavailable. Simple linear body measurements that can readily predict body weight without rabbit slaughter is highly desirable as it will ensure the selection of animals that will reach market weight and size at relatively faster rate. It will also serve as a tool for breeders in selecting animals destined for use as breeding stock (Isaac *et al.*, 2011). There are positive, strong and significant relationships between body live weight and morphometric structural measurements of rabbits reared under matured rubber plantation. The regression or prediction equations generated from body measurements are positive and strong and can be accurately employed to predict the relative body weight of rabbits in fields and markets with the use of tape rule (Afolabi *et al.*, 2012). A study conducted in Nigeria by Egena *et al.* (2012) indicated that linear body measurements and body weight of rabbit had significant association except for chinchilla pure breed at 35-days postpartum where no significant effect was observed and that body weight could be estimated accurately based on the value of the coefficient of determination (R^2), when R^2 values are high and positive.



2.10 Correlation among Morphometric Traits of Rabbits

Results of Oke *et al.* (2011) showed that the correlation among linear measurement in New Zealand white rabbits is positively very high and significant ($P < 0.01$). The correlation matrix showed that live weight was significantly ($P < 0.01$) and positively correlated with body length (0.818), tail length (0.865), head to shoulder (0.897), Height at wither (0.903), heart girth (0.934) and ear length (0.958). From the results of Oke *et al.* (2011), ear length proved the best indicator of body size for the New Zealand White. The interrelationship among the linear traits revealed that body length (shoulder to tail drop) was most correlated to head to shoulder. This implies that absolute length and head to shoulder are complementary (Oke *et al.*, 2011). Oke *et al.* (2011) further reported that correlation among linear measurement and body weight in the Dutch rabbits were positive, high and significant ($P < 0.01$). The work of Lawrence and Fowler (1997) supported this assertion. Specifically, the matrix indicates the live weight was significantly ($P < 0.01$) and positively correlated with heart girth (0.797), head to shoulder (0.872), tail length (0.898), body length (0.900), height at withers (0.947) and ear length (0.983). The result depicts ear length as the best predictor of body size. The result of the interrelationship among the linear traits show that body length and head to shoulder are most correlated (0.959) (Oke *et al.*, 2011). This would mean that genetic improvement on head to shoulder would most increase body length provided the correlation is due to genetic effects. Tiamiyu *et al.* (2000) observed that body length and heart girth were most correlated (0.95). The correlation between body size and linear trait measurements in the chinchilla was positive, high and significant ($P < 0.01$).



Body weight is significantly ($P < 0.01$) and positively correlated with head to shoulder (0.888), body length (0.988), height at withers (0.902) tail length (0.92) ear length (0.952) and heart at girth (0.967). Heart girth is the best predictor of body size in chinchilla (Oke *et al.*, 2011; Tihamiyu *et al.*, 2000). Body length and tail length (0.992) are best correlated, indicating that absolute body length and tail length are complementary and this means that selection of heavy breed rabbits that are long in body and tail may be practicable. These features are thus indicator of good conformation (Oke *et al.*, 2011). There is significant degree of linear association between the variables that is the linear body measurements (LBMs) and bodyweights (Okoro *et al.*, 2010; Alcamo and Ibe, 2006; Abdullahi *et al.*, 2003). Positive and significant ($p < 0.01$) correlations were observed between body weight and the five body dimension traits measured. Shoulder to tail length ($r = 0.931$ for New Zealand White -NZW and $r = 0.938$ for Chinchilla- CH) were found to have the highest correlation with body weight. The lowest correlation were those observed between nose-to-shoulder (NTS) and heart girth (HG) ($r = 0.723$ for NZW) and, tail length (TL) and ear length (LE) ($r = 0.713$ for CH). Generally, correlation between body weight and the five original interdependent variables were observed to be high in the two breeds of rabbit (Egena *et al.*, 2014). Fourie *et al.* (2002), Riva *et al.* (2004), Afolayan *et al.* (2006), Cam *et al.* (2010) and Birteeb (2011) also used HG to predict live weight in sheep. The high positive phenotypic correlation among morphological traits indicates that any one trait can be used to predict the other (Hohenboken, 1985). Similar results were reported in the sheep (Abbasi and Ghafouri-Kesbi, 2011) and grasscutter (Ikpeze and Ebenebe, 2004; Jayeola *et al.*, 2009).



CHAPTER THREE

3.0. MATERIALS AND METHODS

3.1. Location and Period of Study

The study took place in the Northern, Upper East and Upper West Regions (Figure 1). These three regions lie between latitude 8°N, 11°N and longitude 0°E 3°W (SARI, 2008). The vegetation of these areas consists of grassland dotted with small drought resistant trees. The areas experience one rainfall season annually, beginning in March and ending in September. The average temperature is 31°C with a minimum of 28.2 °C and a maximum of 42°C (SARI, 2008). The study was conducted between May, 2013 and January 2014.

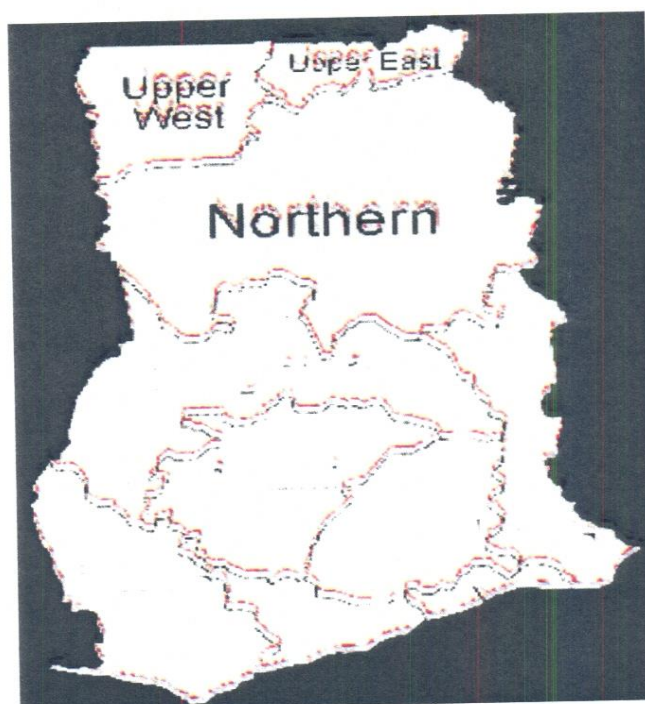


Figure 1: Map of Ghana showing the three regions of study
Source : Map of Ghana, 2009

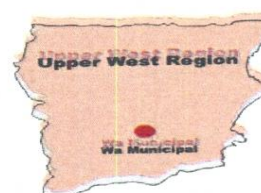


Figure 2



Figure 3



Figure 4



3.2 Study Population

One hundred (100) adult indigenous Ghanaian rabbits from each of the three northern regions were sampled. Morphological data were taken from the 300 rabbits. Ninety (90) local rabbits were purchased from the three northern regions and used for reproductive traits measurement. Twenty-four rabbits from six colour varieties obtained from northern region were used for carcass evaluation.

3.3 Sample Size and Sampling

Rabbit farmers in each of the regions were located using snowball sampling. In each region, 24 females and 6 males were reared for reproductive traits measurement. In all, 18 males and 72 females were used. The animals were purchased in the first week of May 2013 and housed for nine months in their respective regions under the care of selected rabbit farmers. For the first month, the rabbits were segregated according to sex, to allow the female rabbits to purge their systems of residual semen. After the first month, the rabbits were randomly grouped into families of one male to four females. Feed and water were administered *ad libitum*. After being allowed to mate, each female was kept in a separate cage to allow for easy identification of offsprings at birth. Within 12 hours after kindling, litters were checked, weighed and recorded.

Twenty-four rabbits from six colour varieties (12 males and 12 females) were purchased from Northern region only and used for carcass evaluation. Purposive sampling was used to locate rabbit sellers (farmers who want to sell). Then the animals on sale were stratified using sex with colour as a strata. Simple random



sampling was then used to draw animals from each strata. Animals were taken from this region alone due to accessibility and inadequate funds to reach the other regions.

3.4 Management of Experimental Animals

3.4.1 Housing

Animals were housed by the farmers in their various locations. Houses were made of locally available materials. Varied house types were used (Appendix). Walls of the houses were made of mud, wood, wire or iron sheets with the roof being thatch or iron sheets. The floors of the houses were made of concrete, wood or sand. Some holes were created in the houses to serve as nesting and hiding places for the rabbits. They were either made of concrete, wood or pipes. In some cases, pots, lorry tyres and rubber cans or empty gallons were used as nests and hiding places. In those with dust (sand) floors, rabbits created their own holes and nests by digging. Some of the house types are shown in appendix. Below (Plate 8 and 9) are samples of the cages used to house rabbits for reproduction evaluation.



Plate 8: Raised wooden cage roof ed with metal sheets

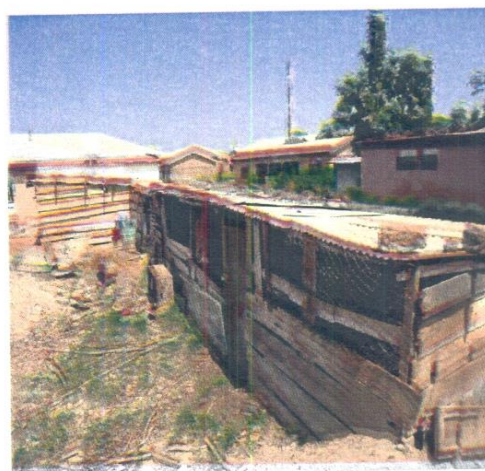


Plate 9: Sand floor wooden cage with roofed metal sheets



3.4.2 Feeding

Rabbits were fed with a wide range of leaves, grass and food wastes from household. Some of the feed materials include pito mash, corn chaff, groundnut leaves, acacia leaves, bean vines, sweet potato leaves, fig leaves, cassava and yam peels, plantain peels and grasses. These were freshly cut and fed to animals or dried before feeding.

Farmers' management practices were used with no intervention from the experimenter. The rabbits were fed mixture of concentrates with groundnuts. Feed and water were administered *ad libitum*. Water and feed were provided in troughs (Plate 11), but in some cases feed was kept on the floor for the animals (Plate 10). Animals were fed once, twice or three times daily.



Plate 10: Floor feeding of rabbits with fresh leaves



Plate 11: Dried leaves fed to rabbits in trough and floor



Plate 12: Corn chaff fed to rabbits

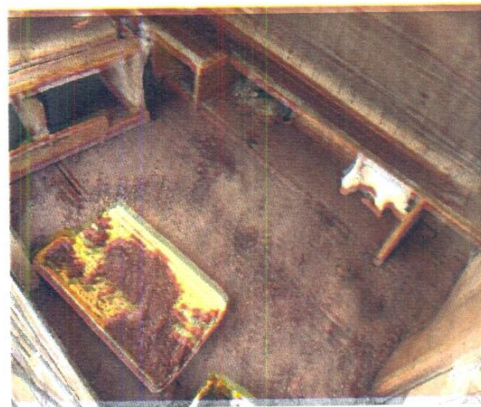


Plate 13: Pito mash fed to rabbits

Experimental animals for reproduction evaluation were fed in similar way as discussed above. They were however supplemented and alternately fed with standard mixed feed especially in the dry months. Although rabbit production in developing countries is based on low cost feeding using locally available forages/weeds (Mailafia *et al.*, 2010), rabbits should also be supplemented with concentrates either purchased or locally made as this improves the growth and breeding performance of the rabbits. The feed was always moistened before given to the animals. The table below contained detail of the supplementary diet.



Table 4: Standard Feed Composition of the Supplementary Diet

Feed	Inclusion level	CPC (%)	Estimated CP
Corn bran	63.5	20	12.7
soya bean meal (full fat)	15	37	5.55
Pito mash	10	23	2.3
groundnut haulms (hay)	10	13	1.3
Salt (iodated)	0.5	0	
Vitamin premix	0.5	0	
Dicalcium phosphate	0.5	0	
Total	100		21.85

CPC = crude protein content, CP = crude protein and % = percent

3.4.3 Health Care

Health care of animals was provided by farmers themselves due to limited number of veterinary personnel and cost of treatments. They buy drugs and administer to sick animals mostly in severe cases. Preventive measures were also observed by farmers to prevent influx of diseases on their rabbitaries.

3.5 Data Collection

The study was carried out in two phases. The first phase involved taking morphological and management data from the three northern regions. The second phase involved collection of reproductive performance and carcass data from rabbits. All rabbits sampled for phase one were above 8 weeks of age due to handling difficulties and safety of very young ones. Rabbits in the regions were not categorized based on age during the measurements.



3.5.1 Phase One

The following morphometric traits were measured across the three regions, using a Digital Kitchen Precision Scale, a tape measure, a digital camera, and a colour chart. Measurements were recorded in kilograms (kg) and centimeters (cm).

1. **Body weight (WT):** animals were weighed on a scale and their weights read and recorded.
2. **Body length (BL):** This is the distance between the point of the shoulder corresponding to the outer and central tuberosity of the left humerus to the left tuber ischium.
3. **The ear length (EL):** was taken as the length from the base of the ear to the tip.
4. **Heart girth (HG):** circumference of the body measured behind the forelimbs round the chest.
5. **Leg length (LL):** taken from the ball and socket joint of the pelvic girdle to the shank and the toe of the hind leg
6. **Thigh Length (THL) :** from the thigh to the hinge joint
7. **Head to pubic bone length (HPL):** the distance from the head to the posterior extremity or distal end of the pin or pubic bone)
8. **Shoulder to tail drop (STD):** length from shoulder to the base of the tail.
9. **Tail length (TL):** This is the distance from the base of the tail close to the body of the rabbit to the tip of the tail.



Each rabbit's sex was determined by holding the rabbit on its back, and put one finger on the tail side of the genital apparatus and one on the abdominal side. Then, pressed down gently and stretched the organ to show up a long slit for a doe, and a small curved penis for a buck (Schiere, 1990). Rabbits with a long slit were identified and tagged as females and rabbits without a long slit, but with a small curved penis were tagged as males. Tags with a unique identification number were fastened around the neck of all the animals. Even though this method of sexing was more complicated and time consuming than other methods, it may be the most accurate.

3.5.2 Phase Two

Reproductive performance and carcass characteristics data were taken during this phase.

Reproduction Performance

Reproductive traits were defined and measured as follows:

- 1. Litter size at birth:** the total number of kids born per doe at parturition.
- 2. Litter size at weaning:** the measure of the mothering ability and the impact of maternal genes until the kid's own genes for growth are switched on.
- 3. Mortality** of adult rabbits over the nine months.
- 4. Offspring characteristics:** Birth weight and weaning weight.
- 5. Littering interval:** how frequent a doe litters in a year

Carcass Measurements

Data on carcass characteristics were collected on 24 rabbits from six colour varieties (12 males and 12 females). Feed was withdrawn 24 hours prior to slaughter.



Slaughter of rabbits was done according to standard abattoir procedure (Grandin, 2009). All carcass measurements were taken at the University for Development Studies Meat LTD facility.

Measurements on the following carcass traits were recorded as follows:

1. **Live weight:** the final weight of the live rabbit.
2. **Bled weight:** the weight of the slaughtered rabbit after bleeding for 15 minutes.
3. **Skinned weight:** the weight of the bled carcass after the skin has been removed.
4. **Dressed weight:** the weight of the rabbit after the removal of viscera, shanks, and the head.
5. **Viscera (empty) Weight:** the weight of all internal organs.
6. **Meat and bone percentages:** this involved removing the flesh from bones and measuring the percentage of meat and bone in the total carcass.

3.6 Statistical Analyses

1. The frequencies of the various colour varieties were calculated using SPSS 17.0 (SPSS, 2008).
The top six colour varieties were used for further analysis since they formed over 95% of the population sampled.
2. To investigate the effects of variety, region and sex on body measurements the data were subjected to least squares analysis of variance using the GLM procedure of SAS (2000).



The model below was used;

$$Y_{ijkl} = \mu + V_i + R_j + S_k + VR_{ij} + VS_{ik} + SR_{kj} + VRS_{ijk} + e_{ijkl} \text{ -----(1)}$$

Y_{ijkl} = body weight, neck length, body length, hip width, shank length, and shank circumference

μ = the overall mean

V_i = the effect of the i^{th} variety of rabbit, $i = 1, 2, 3$ and 4

R_j = the effect of the j^{th} region, $j = 1, 2$ and 3

S_k = the effect of the k^{th} sex of rabbit, $k = 1$ and 2

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

VS_{ik} = is the interaction effect between i^{th} variety and the k^{th} sex

SR_{kj} = is the interaction effect between k^{th} sex and the j^{th} region

VRS_{ijk} = is the interaction effect between i^{th} variety, the j^{th} region and k^{th} sex

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

Significant means within an effect were separated using the PDIFF procedure of SAS

3. Stepwise Multiple Regression Procedure SPSS v 17 (SPSS, 2008) was used to test for the best prediction equation for body weight. The model used was:

$$BWT = a + \beta_{b1}X_1 + \beta_{b2}X_2 + \dots \beta_{bn}X_n \text{(2)}$$

Where,

BWT = body weight or dependent variable;

a = the intercept

b_1 - b_n = regression coefficients



X_1 - X_n = linear body measurements (independent variables) represented by BL, TL, HG, STD, EL, HPL, LL or THL

e_i = random error.

Body weight was then regressed individually on body measurements using SPSS v 17 (SPSS, 2008). The general simple linear regression equation was: $Y_i = \alpha + \beta X_i + e_i$, -----(3)

Where Y_i is body weight or dependent variable; α is the intercept or the value of Y_i when $X_i = 0$; β is the coefficient of regression or slope defined as the change in Y_i resulting from a unit change in X_i ; X_i independent variable represented by BL, TL, HG, STD, EL, HPL, LL or THL; and e_i is the random residual associated with Y_i . Orthogonal polynomials were fitted in SPSS for each morphological trait to determine the nature of response (linear, quadratic and cubic). Correlation coefficients between the various body measurements were estimated using the same SPSS v 17 (SPSS 2008).

Reproductive data collected was analyzed using SPSS version 17. Means were separated using LSD under the Post Hoc Multiple Comparison.

Carcass data were analyzed using the GLM Type III procedure of SAS (2000) to investigate the effect of variety and sex on carcass measurements. The model used was:

$$Y_{ijk} = \mu + V_i + S_j + VS_{ij} + e_{ijk} \text{ -----(4)}$$

Y_{ijk} = bled weight, dressed weight, visceral weight, carcass

μ = the overall mean

V_i = the effect of the i^{th} variety of rabbit, $i = 1, 2, 3$ and 4

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



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

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



CHAPTER FOUR

4.0. RESULTS

4.1. Morphological Description

From a sample of 300 rabbits from the northern sector of Ghana, thirteen colour varieties of rabbits were identified. The colour varieties identified were White, Red, Black, Brown, Ash, Black White, Brown White, Black Brown, Red Brown, White Red, White Ash, Ash Brown and Black Brown White. Some rabbits had white bellies besides their full body colours while in others, the colour of the belly was not different from the main body colour. The plates (8, 9, 10, 11, 12 and 13) below show the images of the six common clours in the study area.



plate 14: white rabbit



plate 15: brown rabbit



plate 16: black rabbit

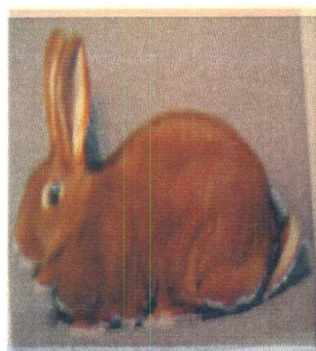


Plate 17: Red rabbit
rabbit



plate 18: black white rabbit



plate 19: brown white



4.2 Frequencies of Colour Varieties

Table 5: Frequencies of the Thirteen Colour Varieties of Rabbits

<i>Variety</i>	<i>No</i>	<i>Percent (%)</i>
White	84	28.0
Brown	50	16.7
Red	26	8.7
Black	27	9.0
Ash	3	1.0
Black Brown	1	0.3
Black White	34	11.3
Brown White	55	18.3
White Red	8	2.7
White Ash	6	2.0
Red Brown	2	0.7
Ash Brown	1	0.3
Black Brown White	3	1.0
Total	300	100

No = number

The frequencies of the various colour varieties encountered are presented in Table 5. The White rabbit colour variety had the largest representation in the three northern regions. The least represented were the Black Brown and Ash Brown. None of the Black Brown, Ash, Red Brown, White Red, White Ash and Ash Brown colour Varieties was found in the Upper West Region but the Black Brown White colour was found only in that region. Ash and the Ash Brown were found only in the Northern Region. The other six colour varieties cut across the three northern regions.



The numbers of the top six colour varieties of Rabbits sampled in the three northern regions are shown below in Table 6. These six colour varieties formed 92.0% of the entire population sampled (Table 5). The most common variety was the White (28.0%), followed by the Brown White (18.3%), then the Brown (16.37%), Black White (11.3%), Black (9.0%) and the least common was the Red (8.7%) (Table 5). This pattern was not applicable to any particular region. However, in the Upper East Region the Red and Black were of the same proportions.

Table 6: Percentages of the Top Six Colour Varieties of Rabbits in the Three Northern Regions

Variety	NR	UE	UW	Variety Totals
White	19	38.1	42.9	100
Brown White	41.8	21.8	36.4	100
Brown	28	30	42	100
Black White	47	20.6	32.4	100
Black	37.04	40.74	22.22	100
Red	46.2	42.3	11.5	100
Region Totals	91	88	97	276



NR= Northern Region, UE= Upper East, UW= Upper West

The white colour variety was the most popular colour of rabbits in both Upper East and Upper West regions, followed by the brown rabbit and then the brown white rabbit according to their colour frequencies (Table 6). This pattern, however, was not so for the Northern region. The rest of the colours have no consistent pattern.

4.3 Least Square Means of Traits of Rabbits in Northern Ghana

Mean body measurements for rabbits based on location (region) are presented in Table 7.

Table 7: Least square means and standard errors for body weight and linear body measurements of rabbits in northern Ghana

Variable	Region				<i>P Value</i>
	Northern	Upper East	Upper West	Mean	
BWT(kg)	1.219±0.070 ^a	1.516±0.070 ^b	1.950±0.070 ^c	1.696±0.060	0.001
BL(cm)	26.910±0.340 ^b	28.375±0.340 ⁸	28.60±0.340 ⁸	28.082±0.305	0.001
EL(cm)	10.627±0.069 ^a	10.688±0.069 ^a	11.021±0.069 ^b	10.88±0.060	0.001
HG(cm)	19.505±0.253 ^a	20.450±0.253 ^b	22.128±0.253 ^G	20.957±0.219	0.001
STD(cm)	35.025±0.356 ^a	36.475±0.356 ^b	36.560±0.356 ^b	36.184±0.317	0.003
TL(cm)	7.695±0.113 ⁸	8.20±0.113 ^b	9.048±0.113 ^c	8.338±0.103	0.001
HPL(cm)	36.626±0.365 ^a	38.070±0.365 ⁴	37.488±0.365 ^{8b}	37.425±0.320	0.020
LL(cm)	23.80±0.216	24.330±0.216	23.742±0.216	24.191±0.194	0.107
THL(cm)	15.715±0.135	15.890-10.135	15.820-10.135	15.857±0.122	0.655
No.	100	100	100	300	

P-Value = probability value, BWT= body weight, BL= body length, EL= Ear length, HG = heart girth, STD= shoulder to tail drop, TL= tail length, HPL= head to pubic length, LL= leg length and THL= thigh length.

NB: Means between regions with different superscripts are significantly different ($p < 0.05$).

Location had profound influence ($p < 0.01$) on body measurements of rabbits in most traits.



For body weight, heart girth and tail length, rabbits in the Upper West region had the highest ($p < 0.01$) body measurements, followed by those in Upper East, with the Northern region recording the lowest values. For body length and shoulder-to-tail drop, Upper East and Upper West recorded similar ($p > 0.05$) values and these were higher ($p < 0.01$) than values recorded in the Northern region. Ear length of rabbits in the Northern and Upper East were similar ($p > 0.05$) and these were lower ($p < 0.01$) than values recorded in the Upper West region. Head-to-pubic length of rabbits in the Upper West was similar ($p > 0.05$) to that recorded in the other two regions but the Upper East recorded higher ($p < 0.05$) than Northern. In leg and thigh lengths similar ($p > 0.05$) values were recorded in all regions.



Mean body measurements for rabbits based on sex are presented in Table 8.

Table 8: Least square means and standard errors for body weight and linear body measurements of rabbits based on sex in northern Ghana

Variable	Sex		
	Male	Female	<i>P Value</i>
BWT(kg)	1.559±0.078	1.563±0.053	0.971
BL(cm)	27.349±0.352	28.250±0.242	0.036
EL(cm)	10.819±0.072	10.760±0.049	0.504
HG(cm)	20.211±0.278	20.922±0.191	0.036
STD(cm)	35.271±0.366	36.373±0.251	0.014
TL(cm)	8.394±0.128	8.277±0.088	0.453
HPL(cm)	36.546±0.370	37.80±0.254	0.006
LL(cm)	23.951±0.222	23.960±0.152	0.973
THL(cm)	15.743±0.138	15.839±0.095	0.565
No.	96	204	

P-Value = probability value, BWT= body weight, BL= body length, EL= Ear length, HG = heart girth, STD= shoulder to tail drop, TL= tail length, HPL= head to pubic length, LL= leg length and THL= thigh length.

Both sexes had the similar ($p > 0.05$) WT, EL, TL, LL and THL. Female rabbits were superior ($p < 0.05$) for the rest of the morphometric traits than their male counterparts.



Mean body measurements for rabbits based on colour variety are presented in Table 9.

Table 9: Least square means and standard errors for body weight and linear body measurements of rabbits based on colour variety

Variable	Colour Variety							P Value
	White	Brown	Red	Black	Black & white	Brown & white	&	
BWT(kg)	1.63±0.084	1.80±0.095	1.43±0.146	1.43±0.146	1.48±0.132	1.52±0.110		0.194
BL(cm)	28.27±0.324 ^{ac}	29.05±0.305 ^a	26.33±1.126 ^b	27.93±0.720 ^{ab}	27.44±0.457 ^{bc}	27.91±0.480 ^{ac}		0.028
EL(cm)	10.88±0.078	10.85±0.089	10.59±0.120	10.63±0.099	10.88±0.123	10.74±0.091		0.222
HG(cm)	21.35±0.315 ^a	21.39±0.276 ^{ac}	19.77±0.483 ^b	20.21±0.550 ^{ab}	20.06±0.489 ^b	20.38±0.342 ^{bc}		0.010
STD(cm)	36.45±0.375 ^a	37.23±0.354 ^a	35.94±0.703 ^{ab}	34.72±0.610 ^b	34.81±0.648 ^b	35.92±0.522 ^{ab}		0.009
TL(cm)	8.72±0.130 ^a	8.61±0.137 ^a	7.90±0.169 ^b	7.84±0.196 ^b	8.0±0.193 ^b	8.11±0.130 ^b		< 0.001
HPL(cm)	37.56±0.397	38.57±0.377	36.88±0.700	36.46±0.709	37.13±0.561	37.18±0.570		0.141
LL(cm)	23.85±0.290	24.24±0.253	23.92±0.298	24.11±0.463	23.91±0.345	23.85±0.263		0.935
THL(cm)	15.85±0.151	16.01±0.170	15.79±0.257	15.74±0.259	15.74±0.244	15.69±0.178		0.880
No.	84	50	26	27	34	55		

P-Value = probability value, BWT= body weight, BL= body length, EL= Ear length, HG = heart girth, STD= shoulder to tail drop, TL= tail length, HPL= head to pubic length, LL= leg length and THL= thigh length.

NB: Means between colour varieties with different postscripts are significantly different ($p < 0.05$).

The various colour varieties of rabbits were different ($p < 0.05$) in terms of BL, HG, TL and STD (Table 9). Except the superiority of the brown rabbit in all these traits, there was no clear pattern of superiority or inferiority in the other colours. The rabbits recorded similar ($p > 0.05$) values for the rest of the morphological parameters (Table 9).





BWT(kg)	1.50±0.047 ^b	1.885±0.108 ^a	0.001
BL(cm)	27.788±0.217 ^b	28.875±0.498 ^a	0.046
EL(cm)	10.715±0.044 ^b	11.117±0.10 ^a	< 0.001
HG(cm)	20.478±0.170 ^b	21.829±0.390 ^a	0.002
STD(cm)	35.778±0.226 ^b	37.292±0.517 ^a	0.008
TL(cm)	8.285±0.079	8.469±0.181	0.353
HPL(cm)	37.198±0.230 ^b	38.468±0.531 ^a	0.029
LL(cm)	23.824±0.135 ^b	24.656±0.310 ^a	0.015
THL(cm)	15.740±0.085 ^b	16.167±0.1 ^a	0.045
No.	252	48	

P-Value = probability value, BWT= body weight, BL= body length, EL= Ear length, HG = heart girth, STD= shoulder to tail drop, TL= tail length, HPL= head to pubic length, LL= leg length and THL= thigh length.

The exotic breeds of rabbits and their crosses were superior ($p < 0.05$) in all morphometric measurements than the local breed of rabbits in northern Ghana, except in tail length in which both local and exotic had similar ($p > 0.05$) values (Table 10). The superiority was highly significant ($p < 0.01$) for body weight, ear

length, heart girth and shoulder to tail drop. The significance however reduced ($p < 0.05$) for head-to-pubic length, thigh length and body length.

4.4 Interaction effects of fixed factors on morphometric traits

Interaction effects of fixed factors on morphometric traits are presented in Table 11.

Table 11: Interaction effects of fixed factors on morphometric traits

Type of Interaction	WT	BL	EL	HG	STD	TL	HPL	LL	THL
Region*Colour	*	ns	ns	ns	ns	ns	ns	ns	ns
Region*Sex	ns	ns	ns	ns	ns	ns	ns	ns	ns
Region*Breed	ns	ns	ns	ns	ns	ns	ns	ns	ns
Colour*Sex	ns	ns	*	ns	ns	**	ns	ns	ns
Colour*Breed	ns	ns	ns	ns	ns	ns	ns	ns	ns
Sex*Breed	ns	ns	ns	ns	ns	ns	ns	ns	ns
Region*Colour*Sex	ns	ns	ns	ns	ns	ns	ns	ns	ns
Region*Sex*Breed	ns	ns	ns	ns	ns	ns	ns	ns	ns
Colour*Sex*Breed	ns	ns	ns	ns	ns	ns	ns	ns	ns

* = $P < 0.05$; ** = $p < 0.01$; not significant (ns)

BWT = body weight, BL = body length, EL = Ear length, HG = heart girth, STD = shoulder to tail drop, TL = tail length, HPL = head to pubic length, LL = leg length and THL = thigh length.

Region * colour interaction effects on body weight was significant ($p < 0.01$). Colour * sex interaction effects was significant on ear length ($p < 0.05$) and tail length ($p < 0.01$). All other interaction effects on all traits were not significant ($p > 0.05$) (Table 11).



4.5 Ranking of colour varieties for various traits

Table 12: Ranking of Colour Varieties for body weight in the three regions

Region	Variety	No.	LSM(kg)	±SE
Northern Region	Brown	14	1.68 ^a	0.111
	Red	12	1.30 ^b	0.178
	Brown and white	23	1.19 ^b	0.116
	Black	10	1.16 ^b	0.152
	Black and white	16	1.02 ^b	0.084
	White	16	1.01 ^b	0.106
	<i>Probability</i>		<i>0.004</i>	
Upper East	Brown and white	12	1.89 ^a	0.247
	Black and white	7	1.66	0.278
	White	32	1.62	0.149
	Brown	15	1.43	0.158
	Red	11	1.34	0.232
	Black	11	1.11 ^b	0.214
	<i>Probability</i>		<i>0.204</i>	
Upper West	Black	6	2.47	0.242
	Red	3	2.33	0.384
	Brown	21	2.15	0.154
	Black and white	11	2.05	0.258
	White	36	1.92	0.110
	Brown and white	20	1.69	0.206
	<i>Probability</i>		<i>0.190</i>	

No. = number of observations, LSM = least squares mean and SE = standard error

NB: Means within regions with different superscripts are significantly different ($p < 0.05$).



4.5.1 Ranking of colour varieties for body weight

In the Northern Region, the Brown Rabbit was significantly ($P < 0.01$) heavier than the other colour varieties. The rest of the rabbits had similar ($P > 0.05$) body weights though there were slight numerical differences among them (Table 12).

In the Upper East and Upper West Regions, there was little weight difference ($P > 0.05$) among the various colour varieties of the rabbits (Table 12).

4.5.2 Ranking of colour varieties for body length

Rankings of the various colour varieties body length are presented in Table 13.

In each of the regions (Northern, Upper East and Upper West Region), there was minor ($p > 0.05$) difference among the various colours in terms of body length (Table 13).



Table 13: Ranking of Colour Varieties for Body length in the three northern regions

Region	Variety	No.	LSM(cm)	±SE
Northern Region	Brown	14	29.3	0.372
	Black	10	28.40	1.267
	White	16	26.72	0.658
	Black and white	16	26.50	0.532
	Brown and white	23	26.39	0.662
	Red	12	24.96	2.233
	<i>Probability</i>		<i>0.057</i>	
Upper East	Brown and white	12	29.96	1.129
	Brown	15	29.43	0.709
	White	32	28.61	0.588
	Black and white	7	28.14	0.962
	Red	11	27.64	1.049
	Black	11	27.00	1.079
	<i>Probability</i>		<i>0.267</i>	
Upper West	Black	6	28.83	1.579
	White	36	28.65	0.435
	Brown	21	28.57	0.461
	Brown and white	20	28.43	0.697
	Black and white	11	28.36	0.956
	Red	3	27.00	0.577
	<i>Probability</i>		<i>0.949</i>	

LSM = least squares mean and SE = standard error

NB: Means within regions with different superscripts are significantly different ($p < 0.05$).



4.5.3 Ranking of colour varieties for heart girth

Rankings of the colour varieties in heart girth for the three regions are presented in Table 14. Brown Rabbit in the Northern Region had the widest heart girth ($p < 0.05$) than the other colour rabbits except the Black Rabbit, which had similar heart girth ($p > 0.05$) with the Brown Rabbit. All colour varieties of rabbits in each of the Upper East and Upper West Regions were similar ($p > 0.05$) with respect to heart girth (Table 14).

4.5.4 Ranking of colour varieties for shoulder-to-tail drop

Table 15 presents the Shoulder-to-Tail Drop rankings of the colour varieties in the three regions.

In the Northern Region, there was little difference ($p > 0.05$) between the Brown Rabbit and the Red Rabbit in their Shoulder-to-Tail Drop length. However, the Brown Rabbit had significantly longer Shoulder-to-Tail Drop ($p < 0.05$) than the rest of the rabbits in that region. There was no difference ($p > 0.05$) in Shoulder-to-Tail Drop among all colour varieties of rabbits in Upper East and Upper West Regions (Table 15).



Table 14: Ranking of Colour Varieties for heart girth in the three regions

Region	Variety	No.	LSM(cm)	±SE
Northern Region	Brown	14	21.25 ^a	0.441
	Black	10	19.90 ^{ab}	0.702
	White	16	19.53 ^b	0.667
	Brown and white	23	19.28 ^b	0.488
	Red	12	18.88 ^b	0.663
	Black and white	16	18.44 ^b	0.610
	<i>Probability</i>		<i>0.033</i>	
Upper East	Brown and white	12	21.13	0.634
	Brown	15	20.97	0.610
	White	32	20.89	0.489
	Black and white	7	20.43	0.369
	Red	11	20.09	0.765
	Black	11	18.95	0.718
	<i>Probability</i>		<i>0.253</i>	
Upper West	Black	6	23.02	1.236
	White	36	22.56	0.433
	Black and white	11	22.18	0.856
	Red	3	22.17	0.441
	Brown	21	21.79	0.400
	Brown and white	20	21.21	0.576
	<i>Probability</i>		<i>0.419</i>	

LSM = least squares mean and SE = standard error

NB: Means within regions with different postscripts are significantly different ($p < 0.05$).



Table 15: Ranking of Colour Varieties for Shoulder-to-Tail Drop in the three regions

Region	Variety	No.	LSM(cm)	±SE
Northern Region	Brown	14	37.61 ^a	0.393
	Red	12	35.83 ^{ab}	0.958
	Brown and white	23	34.54 ^b	0.713
	White	16	34.47 ^b	0.715
	Black	10	34.40 ^b	0.581
	Black and white	16	34.31 ^b	0.568
	<i>Probability</i>		0.009	
Upper East	Brown	15	37.47	0.839
	Brown and white	12	37.38	1.317
	White	32	37.14	0.561
	Black and white	7	36.07	1.373
	Red	11	35.86	1.299
	Black	11	34.41	1.281
	<i>Probability</i>		0.281	
Upper West	Brown	21	36.81	0.544
	White	36	36.71	0.608
	Red	3	36.67	1.481
	Brown and white	20	36.63	0.802
	Black	6	35.83	1.167
	Black and white	11	34.73	1.651
	<i>Probability</i>		0.681	

LSM = least squares mean and SE = standard error

NB: Means within regions with different postscripts are significantly different ($p < 0.05$).



Table 16 presents the ear length rankings of the colour varieties in the three regions. Even though location was generally a significant ($p < 0.01$) source of variation in ear length in the entire northern Ghanaian rabbits (Table 6), rabbits in each of the regions were similar ($p > 0.01$) in terms of ear length with respect to colour varieties.

4.5.6 Ranking of colour varieties for tail length

The colour variety rankings for tail length in the three regions are presented in Table 17.

In the Upper West, the White, the Brown and the Red rabbits had the similar ($p > 0.05$) tail length. The White rabbit, however, had longer tail ($p < 0.001$) than the rest of the colour varieties. All colour varieties of rabbits in the other two regions were similar ($p > 0.05$) in tail length.



Table 16: Ranking of Colour Varieties for ear length in the three regions

Region	Variety	No.	LSM(cm)	±SE
Northern Region	Black and white	16	10.84	0.162
	Brown	14	10.74	0.126
	Red	12	10.68	0.152
	Black	10	10.60	0.169
	White	16	10.56	0.127
	Brown and white	23	10.46	0.086
	<i>Probability</i>		<i>0.286</i>	
Upper East	White	32	10.97	0.131
	Brown and white	12	10.93	0.197
	Brown	15	10.69	0.163
	Black and white	7	10.57	0.167
	Black	11	10.50	0.141
	Red	11	10.39	0.217
	<i>Probability</i>		<i>0.091</i>	
Upper West	Black and white	11	11.14	0.897
	Brown	21	11.05	0.152
	White	36	10.95	0.124
	Brown and white	20	10.95	0.182
	Red	3	10.93	0.233
	Black	6	10.92	0.221
	<i>Probability</i>		<i>0.978</i>	

LSM = least squares mean and SE = standard error

NB: Means within regions with different postscripts are significantly different ($p < 0.05$).





Table 17: Ranking of Colour Varieties for tail lengths in the three regions

Region	Variety	No.	LSM(cm)	±SE
Northern Region	Brown	14	8.18	0.145
	Red	12	8.00	0.163
	Brown and white	23	7.67	0.128
	Black and white	16	7.66	0.231
	White	16	7.63	0.221
	Black	10	7.25	0.335
	<i>Probability</i>		<i>0.069</i>	
Upper East	Brown and white	12	8.46	0.226
	Black and white	7	8.29	0.264
	White	32	8.28	0.110
	Brown	15	8.17	0.205
	Black	11	7.95	0.247
	Red	11	7.68	0.318
	<i>Probability</i>		<i>0.178</i>	
Upper West	White	36	9.60 ^b	0.181
	Brown	21	9.21 ^{bc}	0.220
	Black	6	8.60 ^a	0.311
	Brown and white	20	8.40 ^{ac}	0.268
	Red	3	8.33 ^{ab}	0.667
	Black and white	11	8.32 ^{ac}	0.454
	<i>Probability</i>		<i>0.001</i>	

LSM = least squares mean and SE = standard error.

NB: Means within regions with different postscripts are significantly different ($p < 0.05$).



4.6 Correlations between body measurements

Phenotypic correlations among morphological traits and between the morphological traits and body weight of rabbits in the three regions (below diagonal) and in the northern region (above diagonal) are shown in Table 18.

Table 18: Correlations matrix of body measurements in the three regions (below diagonal) and correlation among morphometric traits (above diagonal) in the Northern Region alone.

	Bwt	BL	EL	HG	STD	TL	HPL	LL	THL
Bwt		0.615**	0.329**	0.704**	0.715**	0.212**	0.740**	0.395**	0.422**
BL	0.589**		0.416**	0.673**	0.681**	0.122	0.763**	0.556**	0.557**
EL	0.408**	0.509**		0.461**	0.575**	0.190**	0.526**	0.680**	0.669**
HG	0.663**	0.738**	0.539**		0.740**	0.171**	0.838**	0.595**	0.590**
STD	0.580**	0.792**	0.575**	0.690**		0.499**	0.896**	0.684**	0.701**
TL	0.380**	0.352**	0.387**	0.451**	0.466**		0.291**	0.262**	0.272**
HPL	0.554**	0.819**	0.538**	0.703**	0.839**	0.322**		0.688**	0.707**
LL	0.364**	0.533**	0.463**	0.423**	0.579**	0.126*	0.619**		0.883**
THL	0.442**	0.672**	0.587**	0.595**	0.742**	0.270**	0.749**	0.744**	

**significant ($p < 0.01$), * significant ($P < 0.05$), Bwt= body weight, BL= body length, EL= Ear length, HG = heart girth, STD= shoulder to tail drop, TL= tail length, HPL= head to pubic length, LL= leg length and THL= thigh length.

In most cases, there was positive moderate to high correlation between the various body measurements in the three regions (Table 18). The highest correlation was recorded between head to pubic length and shoulder to tail drop. Correlation between leg length and tail length even though positive, was the lowest. Body weight had the highest correlation with heart girth (Table 18) in the three regions.

In the northern region, phenotypic correlations among morphological traits ranged from low (0.122) to high (0.896). Body weight had the highest correlation with head-to-pubic length and the lowest correlation with tail length in the region (Table 18). Table 18 shows phenotypic correlations among morphological traits and between the morphological traits and body weight of rabbits in Upper West (below diagonal) and in the Upper East region (above diagonal).

Table9: Correlations matrix of body measurements in the Upper West region (below diagonal) and correlation among morphometric traits (above diagonal) in the Upper East Region.

	Bwt	BL	EL	HG	STD	TL	HPL	LL	THL
Bwt		0.747	0.453	0.698	0.682	0.307	0.721	0.620	0.624
BL	0.408"		0.583"	0.863"	0.912"	0.376"	0.938"	0.729"	0.821"
EL	0.267"	0.550"		0.568"	0.566"	0.327"	0.580"	0.477"	0.582"
HG	0.452"	0.727"	0.469"		0.803"	0.369"	0.873"	0.648"	0.753"
STD	0.379"	0.810"	0.579"	0.551"		0.362"	0.873"	0.675"	0.827"
TL	0.202*	0.460"	0.385"	0.422"	0.530"		0.350"	0.219*	0.287"
HPL	0.309"	0.772"	0.553"	0.499"	0.744"	0.337"		0.698"	0.849"
LL	0.242*	0.444"	0.436"	0.289"	0.473"	0.061	0.535"		0.749"
THL	0.349"	0.710"	0.584"	0.565"	0.698"	0.310"	0.674"	0.696"	

**significant ($p < 0.01$), * significant ($P < 0.05$), Bwt= body weight, BL= body length, EL= Ear length, HG = heart girth, STD= shoulder to tail drop, TL= tail length, HPL= head to pubic length, LL= leg length and THL= thigh length.



In the Upper West region, phenotypic correlations among morphological traits ranged from low (0.06) to high (0.810). Body weight had the highest correlation with head-to-pubic length and the lowest correlation with tail length in the region. Phenotypic correlations between body weight and all morphological traits range from low (0.202) to medium (0.452) in the Upper West region (Table 19).

Phenotypic correlations among morphological traits in the Upper East region ranged from low (0.219) to as high as 0.938. Body weight had the highest correlation with body length in the region. Phenotypic correlations between body weight and all morphological traits were high except tail length and ear length which were medium (Table 19).

4.7 Prediction of Body Weight from Linear Body Measurement

With the stepwise multiple regression, heart girth (HG) was the best predictor of body weight with R^2 of 0.349. The R^2 increased a bit to 0.466 for heart girth (HG) together with shoulder-to-tail drop (STD). The rest of the variables did not yield any equation. The two equations obtained were :

$$\text{BWT} = -2.239 + 0.184\text{HG} \dots\dots\dots (5)$$

$$\text{BWT} = -3.091 + 0.139\text{HG} + 0.050\text{STD} \dots\dots\dots (6)$$

The prediction equations (linear, quadratic and cubic) comprising the intercepts and the slopes of the regression line for various body measurements are presented in Table 20.

Table 20: Prediction of body weight from linear body measurements

Nature of Response	Equation	R ²	Probability Value				
			Model	α	β ₁	β ₂	β ₃
Body length							
Linear	-2.043 + 0.129X	0.347	< 0.001	< 0.001	< 0.001		
Quadratic	0.288 – 0.061X + 0.004X ²	0.376	< 0.001	0.673	0.239	< 0.001	
Ear length							
Linear	-3.175 + 0.439X	0.166	< 0.001	< 0.001	< 0.001		
Quadratic	-1.448 + 0.117X + 0.015X ²	0.167	< 0.001	0.802	0.913	0.763	
Heart girth							
Linear	-2.239 + 0.184X	0.439	< 0.001	< 0.001	< 0.001		
Quadratic	-4.201 + 0.378X + 0.005X ²	0.442	< 0.001	0.009	0.017	0.217	
Cubic	-3.602+0.285X-7.890-E5X ³	0.442	< 0.001	0.001	< 0.001	< 0.001	0.193
Shoulder-to-tail drop							
Linear	-2.830 + 0.122X	0.337	< 0.001	< 0.001	< 0.001		
Quadratic	0.130 - 0.051X + 0.003X ²	0.340	< 0.001	0.957	0.716	0.219	
Tail length							
Linear	-0.349 + 0.230X	0.144	< 0.001	0.202	< 0.001		
Quadratic	-2.246+ 0.656X - 0.023X ²	0.165	< 0.001	0.003	0.006	< 0.001	
Cubic	1.979- 0.681X + 0.110X ² -0.004X ³	0.173	< 0.001	0.464	0.416	0.182	0.105





<i>Head-to-pubic length</i>							
Linear	$-2.736 + 0.115X$	0.307	< 0.001	< 0.001	< 0.001		
Quadratic	$-3.544 + 0.160X + 0.000X^2$	0.308	< 0.001	0.272	0.367	0.801	
Cubic	$-3.390 + 0.142X - 6.696E-6X^3$	0.308	< 0.001	0.122	0.115	< 0.001	0.762
<i>Leg length</i>							
Linear	$-1.497 + 0.128X$	0.364	< 0.001	< 0.001	< 0.001		
Quadratic	$3.290 - 0.294X + 0.009X^2$	0.148	< 0.001	< 0.128	0.116	0.024	
<i>Thigh length</i>							
Linear	$-2.368 + 0.249X$	0.195	< 0.001	< 0.001	< 0.001		
Quadratic	$-8.880 + 1.097X - 0.027X^2$	0.202	< 0.001	0.033	0.042	0.115	

Dependent variable (X); Co-efficient of multiple determination (R^2); Intercept (α);

Slope of regression line ($\beta_1, \beta_2, \beta_3$)

The best prediction equation (linear, quadratic or cubic) was given by heart girth, followed by body length/shoulder-to-tail drop, head-to-pubic length and thigh length, with the poorest being leg length, tail length and ear length. The orthogonal polynomial contrasts (linear, quadratic and cubic) indicated highly significant ($P < 0.01$) effects for some of the models, intercepts and slopes of regression lines (Table 20), only where the nature of response was linear, indicating that all the morphological traits increased with increasing body weight in a linear fashion. Cubic equations were impossible for some variables.

4.8 Carcass characteristics of rabbits

Carcass characteristics are presented in Table 21.

Table 21: Carcass characteristics expressed as a percentage of live weight.

Carcass characteristics	Percentage of live weight
Bled weight	97.0
Dressed weight (hot)	48.99
Dressed weight (cold)	45.80
Skinned weight	87.4
Lung weight	0.64
Heart weight	0.26
Liver weight	3.30
Kidney weight	0.72

The indigenous rabbits lost about 3% of their live body weight after bleeding. The edible internal organs (lung, heart, liver and kidneys) constituted 4.92 % of the live body weight of the rabbit (Table 21).



Table 22: Effect of colour variety on carcass characteristics of rabbits

Parameter	White	Brown	Red	Black	Black & white	Brown & white	Mean	P-value
LW (kg)	1.23±0.2	1.33±0.03	1.34 ± 0.1	1.34 ± 0.1	1.35 ± 0.1	1.35 ± 0.1	1.32±0.035	0.94
BLW (kg)	1.19 ± 0.2	1.29±0.03	1.30 ± 0.1	1.30 ± 0.8	1.31 ± 0.2	1.32 ± 0.1	1.28 ± 0.04	0.93
SW (kg)	1.07 ± 0.1	1.18±0.02	1.19 ± 0.1	1.15 ± 0.1	1.17 ± 0.1	1.19 ± 0.1	1.16 ± 0.03	0.89
HCDW (kg)	0.60 ± 0.1	0.65±0.01	0.67± 0.04	0.67 ± 0.1	0.66 ± 0.1	0.65 ± 0.02	0.65 ± 0.02	0.93
HCD (%)	48.65± 0.9	48.71±0.8	49.74± 1.0	49.79± 1.2	48.76± 1.5	48.36± 2.0	48.99± 0.5	0.95
CCDW (kg)	0.55 ± 0.1	0.62±0.01	0.63± 0.04	0.63 ± 0.1	0.61 ± 0.1	0.62 ± 0.02	0.61 ± 0.02	0.89
CCD (%)	44.38± 1.0	46.09±0.4	46.71± 1.1	46.45±1.1	45.34± 1.1	45.84± 2.6	45.80± 0.5	0.86
DCW (g)	290.2±43.3	353.9±9.5	328.4±16.4	368.5±30.2	306.3±12.3	357.5±14.2	334.2±10.6	0.20
BW (g)	249.9±25.2	256.3±9.3	296.5±25.0	251.5±22.4	299.9± 48	246.8 ± 7.6	266.8±10.6	0.53
LW* (g)	8.74 ± 1.1	8.21 ± 0.2	8.93 ± 0.4	7.80 ± 1.6	8.70 ± 1.7	8.1 ± 0.4	8.42 ± 0.4	0.97
HW(g)	3.41 ± 0.4	3.40 ± 0.4	3.26 ± 0.5	3.70 ± 0.2	3.27 ± 0.2	3.44 ± 0.6	3.41 ± 0.2	0.97
LVW (g)	43.76±5.4	43.47±3.2	41.28± 2.5	41.1±7.98	46.755± 2.5	45.378±4.8	43.63 ± 1.8	0.95
KW (g)	8.8 ± 0.9	8.79 ± 0.4	9.66 ± 0.2	9.8 ± 0.5	10.6 ± 1.4	9.15 ± 0.4	9.46 ± 0.3	0.54
EIW (g)	85.1±11.6	88.49±3.9	98.67± 8.7	87.77± 6.9	103.1±15.1	97.35 ± 8.0	93.41 ± 3.8	0.73

P-value = probability value, kg = kilograms, g = grams and % = per cent

LW = live weight, BLW = Bled weight, SW = Skinned weight, HCDW = Hot carcass dress weight, HCD% = Hot carcass dressing per cent, CCDW = Cold carcass dressing weight, CCD% = Cold carcass dressing per cent, DCW = Deboned carcass weight, BW = Bones weight, LW* = Lung weight, HW = Heart weight, LVW = Liver weight, KW = Kidney weight and EIW = Empty intestine weight.

Colour varieties had little effect ($p > 0.05$) on all carcass characteristics (Table 22).

Observations from the in the raw data indicated that hot carcass dressing percent ranged from 43.42 to 53.16 while cold carcass dressing percent ranged from 39.47 to 49.37.



Table 23: Effect of sex on carcass characteristics of rabbits

Parameter	Male	Female	Mean	P-value
LW (kg)	1.290 ± 0.041	1.355 ± 0.056	1.322 ± 0.035	0.362
BW (kg)	1.253 ± 0.041	1.313 ± 0.056	1.283 ± 0.035	0.399
SW (kg)	1.117 ± 0.036	1.193 ± 0.050	1.155 ± 0.031	0.225
HCDW (kg)	0.653 ± 0.025	0.643 ± 0.019	0.648 ± 0.019	0.795
HCD (%)	50.57 ± 0.491 ^a	47.431 ± 0.556 ^b	48.99 ± 0.488	<0.0001
CCDW (kg)	0.608 ± 0.024	0.605 ± 0.029	0.607 ± 0.019	0.931
CCD %	47.04 ± 0.641 ^a	44.56 ± 0.677 ^b	45.80 ± 0.525	0.014
DCW (g)	343.122 ± 15.44	326.183 ± 14.70	334.15 ± 10.55	0.462
BW (g)	264.94 ± 11.99	268.71 ± 18.13	266.82 ± 10.64	0.864
LW* (g)	8.10 ± 0.531	8.73 ± 0.610	8.416 ± 0.401	0.444
HW (g)	3.258 ± 0.170	3.563 ± 0.238	3.410 ± 0.147	0.308
LVW (g)	40.121 ± 2.289 ^a	47.130 ± 2.418 ^b	43.63 ± 1.785	0.047
KW (g)	9.173 ± 0.272	9.714 ± 0.546	9.455 ± 0.312	0.398
EIW (g)	82.784 ± 2.547 ^a	104.032 ± 5.690 ^b	93.41 ± 3.77	0.003

p-value = probability value, kg = kilograms, g = grams and % = per cent

LW = live weight, BLW = Bled weight, SW = Skinned weight, HCDW = Hot carcass dress weight, HCD% = Hot carcass dressing per cent, CCDW = Cold carcass dressing weight, CCD% = Cold carcass dressing per cent, DCW = Deboned carcass weight, BW = Bones weight, LW = Lung weight, HW = Heart weight, LVW = Liver weight, KW = Kidney weight and EIW = Empty intestine weight.*

An important carcass characteristic for commercial rabbit production is the dressing percentage. The effect of sex was found to be a highly significant ($p < 0.01$) source of variation for hot carcass dressing percentage and intestine (empty) weight. But this significance reduced to $p < 0.05$ for cold carcass dressing percentage and liver weight.



The males had higher ($p < 0.01$) dressing percentages (hot and cold carcass) than the females. However, the liver weight and empty intestine weight of females were higher than that of males. All other carcass parameters were not influenced ($P > 0.05$) by sex (Table 23).



4.9 Reproduction Performance

Table 24: Descriptive statistics of reproductive traits of rabbits in Northern Ghana

Litter size	% of adults nursing in 1 st kindling		% of adults nursing in 2 nd kindling		% of adults nursing in 3 rd kindling	
	Birth	Weaning	Birth	Weaning	Birth	Weaning
<i>Upper West Region</i>						
1	13	18.2	8.7	8.7	9.1	9.1
2	39.1	50.0	21.7	30.4	22.7	22.7
3	30.4	31.8	13	21.7	18.2	27.3
4	13		21.7	21.7	18.2	18.2
5	4.3		17.4	13	13.6	9.1
6			13	4.3	9.1	13.6
7			4.3		4.5	
8					4.5	
No	23		23		21	
<i>Upper East Region</i>						
1	21.7	30.4	10.0	20.0	11.1	23.5
2	43.5	60.9	15.0	15.0	16.7	17.6
3	21.7	8.7	15.0	25.0	16.7	11.8
4	13		25.0	20.0	22.2	23.5
5			15.0	15.0	11.1	5.9
6			15	5.0	22.2	17.6
8			5			
No	23		20		18	

No = number of adults in each kindle (nursing mothers); % = percentage



Table 24: Descriptive statistics of reproductive traits of rabbits in Northern Ghana

(Continued)

Litter size	% of adults nursing in kindling		% of adults nursing in 2 nd kindling		% of adults nursing in 3 rd	
	Birth	Weaning	Birth	Weaning	Birth	Weaning
<i>Northern Region</i>						
1	27.3	25.0	4.8	9.5	22.2	27.8
2	31.8	55.0	23.8	19.0	11.1	16.7
3	22.7	20.0	23.8	38.1	33.3	33.3
4	13.6		14.3	4.8	16.7	16.7
5	4.5		14.3	28.6	11.1	5.6
6			14.3		5.6	
7			4.8			
No	22		21		18	

No = number of adults in each kindle (nursing mothers); % = percentage

Litter size range between 1 to 5 kits at the first kindle (parity) in all the regions. It however increased to between 1 to 8 kits in the second and third parity (kindle). Litter size between 1-6 survived up to weaning in the first and second kindles. This reduced to 1-5 in the third kindle (Table 24).



The Rabbit reproduction characteristics are presented in Table 25.

Table 25: Least Square Means of Reproductive Traits

Variable	Region	1 st kindling	P-Value	2 nd kindling	P-Value	3 rd kindling	P-Value
GS	UWR	30.00±0.427	0.462	30.9±0.360	0.435	30.17±0.308	0.634
	UER	30.71±0.427		30.8±0.341		30.50±0.267	
	NR	30.13±0.40		30.3±0.382		30.17±0.308	
LSB	UWR	3.571±0.337	0.824	5.1±0.495	0.824	5.67±0.595 ^a	0.117
	UER	3.286±0.337		4.7±0.470		4.00±0.516 ^b	
	NR	3.500±0.316		5.0±0.525		5.17±0.595 ^{ab}	
BWT (g)	UWR	42.62±1.255 ^a	0.003	43.78±1.420 ^a	0.012	46.85±1.598 ^a	0.019
	UER	36.01±1.255 ^b		37.65±1.347 ^b		43.59±1.384 ^{ab}	
	NR	36.85±1.174 ^b		38.87±1.506 ^b		39.65±1.598 ^b	
LSW	UWR	2.00±0.250	0.488	3.56±0.437	0.667	4.50±0.612 ^a	0.087
	UER	1.71±0.250		3.2±0.415		2.63±0.530 ^b	
	NR	2.13±0.234		3.75±0.464		3.83±0.612 ^{ab}	
WWT (g)	UWR	322.05±14.88	0.202	454.35±19.33 ^a	<0.0001	466.0±25.21 ^a	0.025
	UER	310.32±14.88		341.70±18.34 ^b		372.09±21.83 ^b	
	NR	347.25±13.92		335.71±20.51 ^b		378.54±25.21 ^b	

P-Value = probability value, GS= gestation, LSB= litter size at birth, BWT=birth weight, LSW= litter size at weaning, WWT= weaning weight, UWR= Upper West Region, UER= Upper East Region and NR= Northern Region.

NB: Means between/among regions with different postscripts are significantly different ($p < 0.05$; $p < 0.01$).

Region had significant effect ($p < 0.05$) on birth weight during the first kindle but not gestation, litter size at birth, litter size at weaning and weaning weight ($p > 0.05$). In the second kindling, region had influence on weaning weight ($p < 0.01$) and birth weight ($p < 0.05$). Birth weight and weaning weight were again, significantly ($p <$



0.05) influenced by location (region) of the rabbits in the third kindling. Animals in the Upper West region weighed heavier than those in the other regions except weaning weight in the first kindle. Birth weight in northern region was lower ($p < 0.05$) than that of Upper West region but similar ($p > 0.05$) to that of the Upper East region. The rest of the variables were not significantly affected ($p > 0.05$) by region (Table 25). Slight differences between mean values recorded were apparent.

4.10 Mortality in Rabbits

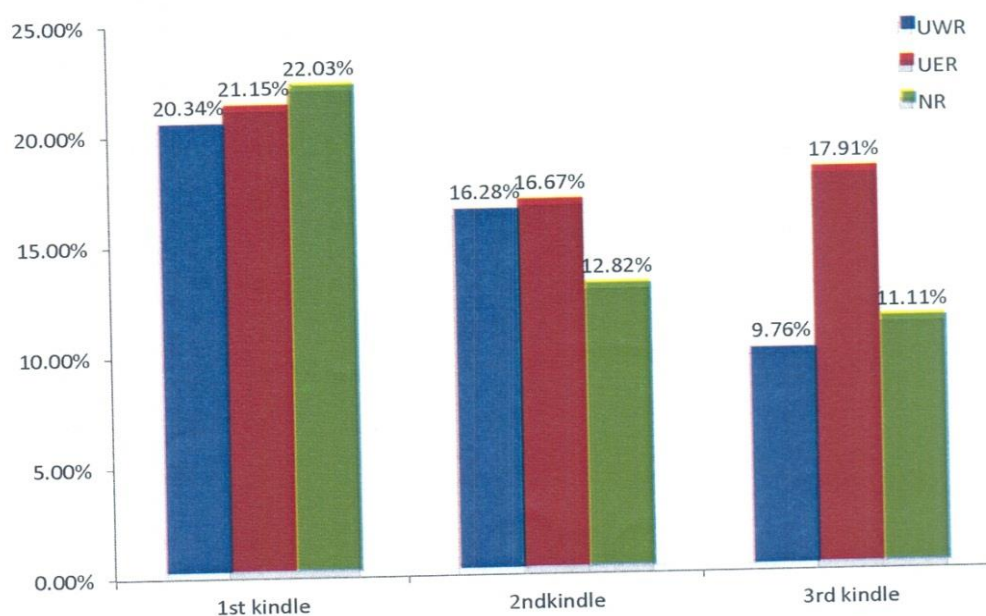


Figure 5: Mortality Rate in Young Rabbits (birth to weaning) in Northern Ghana

(UWR = Upper West region; UER = Upper East region; NR = Northern region)

Mortality was high (above 20%) during first kindle across all regions. Reduction in mortality was then observed right from the second kindle and continued in the third kindle in descending order with exception of the Upper East region (Figure 5). At the end of the experiment, 5 (2 in UER and 3 in NR) out of 72 adult animals (does) died, representing 6.94 percent.



CHAPTER FIVE

5.0 DISCUSSION

5.1 Morphological description

The rabbits encountered in northern Ghana fell into the local and exotic/cross rabbit category. The local rabbit was generally small in size or body weight as compared to their exotic counterparts as well as their crosses. Similar finding has been reported by Baffour (2013) from southern part of Ghana on the presence of local and exotic breeds of rabbits in Ghana. The sheer ease of encountering different breeds of rabbits in the various homesteads in the three northern regions confirms statements made by Galal *et al.*, (2000) that the different breeds of rabbits found are the locally adapted Ghanaian rabbit and exotic breeds like the Flemish giant, Chinchilla, Californian and New Zealand White.

5.2 Coat (Fur) Colour Characteristics

The colour varieties encountered were the White, Red, Black, Brown, Ash, Black White, Brown White, Black Brown, Red Brown, White Red, White Ash, Ash Brown and Black Brown White. This finding corroborates the work of Akugre (2010) who reported that white, red, black, ash and mixed colour varieties of rabbits from the Upper-East region of Ghana. This study agrees with the statement made by Redmond (2009) that the domesticated rabbit has extremely diverse characteristics, varying in colour through every grade, shade, and mixture, from pure white to all black. Sanford (1996) found eight different colour varieties in the Dutch. Redmond (2009) stated that



at least 66 varieties of the domesticated rabbit were derived from a wild rabbit native to Europe and Africa. The most frequently encountered colour variety was the white and the least was the Black Brown and Ash Brown with similar frequencies.

NAFIS (2012) also observed some of these colour varieties, namely white, black white and brown white. They also reported the Red and White Ash colour varieties which were observed in this study. Sanford (1996) has also reported similar varied colours in rabbits. The diversity of colour varieties found in this study lends credence to historical evidence mentioned by Redmond (2009) listing Africa as one of the centre of origin for the domestic rabbit.

Overall, more than one colour variety was found in each region. This agrees with the results of Akugre (2010) who found similar colour varieties in the Upper East region. The Ash and the Ash Brown were encountered only in the Northern Region. According to Sanford (1996), colour and pattern are fixed by the animal genetic constitution. The Northern Region is the largest region (70,384 km²) in Ghana. With such a large land mass the probability of having different colour varieties increases. Further, the region shares boundaries with the Upper East, Upper West and Brong-Ahafo Regions internally. Externally the Region shares boundaries with Togo and Ivory Coast. This exposes the Region to introduction of different Colour variety of Rabbits from several geographic locations. None of the Black Brown, Ash, Red Brown, White Red, White Ash and Ash Brown colour varieties was found in the Upper West Region but the Black Brown White colour was found only in this region.



These differences in the colour variety in the regions may be due to geographical locations because some external influence such as sunlight can reflect (fade) the colour of rabbit though the colour and pattern are fixed by the animal's genetic constitution (Sanford, 1996). It may also be due to the breed of rabbits being kept by farmers and farmers' objective for keeping such breeds.

5.3 Body Measurements

The mean body weight of the indigenous Ghanaian rabbit found in the northern sector was 1.696 ± 0.060 kg. This weight was lower than the 2.05kg reported by Ifeanyichukwu (2013) in chinchilla, 1.89 kg reported by Afolabi *et al.*, 2012, but higher than the 1196.0g (1.196 kg) which Alan *et al.* (2014) reported for local rabbits in Ghana and 1.269 ± 0.171 kg, 1.241 ± 0.171 kg and 1.184 ± 0.171 kg which Abugri (2014) reported for local rabbits without night lighting, with six hours night lighting and twelve hours night lighting respectively in northern Ghana. Thus the weight of rabbits in this study was similar to that reported for small rabbits but lower than the weight mentioned for medium and large Rabbits in the temperate zones. The small size of the Ghanaian rabbit agrees with Bergmann's Rule as stated by Kendeigh (1969) who postulates that, geographic races of small size are generally found in the warmer parts and races of larger size in the cooler parts.

Effect of region was highly significant ($p < 0.01$) on all morphometric measurements except LL and THL. Upper West recorded the highest ($p < 0.01$) body weight and other measurements with the northern region recording the least. These differences in body weight and morphometric traits across the regions may be due to different



environmental effects such as management, nutrition, and climate or differences in the genetic constitution. Animals in different herds perform differently because they are given different treatment or management. Animal performance varies with years due to differences in climatic variables in different years (Kabuga and Agyemang, 1983; Osei and Effa-Baah, 1989; Osei *et al.*, 1991; Ahunu *et al.*, 1993; Darko and Buadu, 1998; Baffour-Awuah *et al.*, 2005; Beffa *et al.*, 2009).

The mean body length in this study was 28.082cm. This was lower than 43.68cm reported by Ifeanyichukwu (2013) and 30.4cm reported by Afolabi *et al.* (2012). Also, the 39.95cm and 25.8cm observed by Afolabi *et al.* (2012) for head to pubic bone length and heart girth respectively were higher than what was noted (37.425cm) and (20.957cm) for head to pubic bone length and heart girth respectively in the present study. Ifeanyichukwu (2013) reported 24.98cm for heart girth which was also higher than that in the present study. The 10.88cm observed for ear length in this study near the 10.56 cm reported by Ifeanyichukwu (2013) for same variable. The mean leg length, thigh length and tail length in this study were 24.191cm, 15.857cm and 8.338cm respectively. These values were higher than 18.8cm, 10.4cm and 8.0cm reported for leg length, thigh length and tail length respectively by Afolabi *et al.* (2012). These differences between the values for the various morphometric traits in this study and what has been reported by other researchers may be due to variation in measurements of the variables, locations, the breed or nutrition of the animals.

Sex had significant ($p < 0.05$) effect on BL, HG, STD and HPL. This means that those measurements could be considered in sexing rabbits as sexual dimorphism. It



however had no significant effect ($p > 0.05$) on BWT, EL, TL, LL and THL. In this study, female rabbits had higher body measurements than their male counterparts except body weight, tail and ear lengths, leg length and thigh length. The high body measurements encountered in females than males could be due to the fact that most of the females were adults and many of the males were young ones. This is because farmers usually sell the adult males leaving only the young ones for breeding purposes. This is different from the finding of Zotte *et al.* (2012) who reported that females are heavier (1,630g (1.63kg)) than males (1,542g (1.542kg)) at the age of 20 weeks in dwarf rabbits. Zotte *et al.* (2012) again reported 1,953g (1.953kg) for females and 1,850g (1.85kg) for males which, again, is different from the results of this study, which indicated that females showed no difference in live weights from males.

Colour variety had a significant ($p < 0.05$) effect on BL, HG, STD and TL. In all these traits, the Brown rabbit was superior ($p < 0.01$). Even traits in which all colours were similar ($p > 0.05$), the brown had higher absolute values. Generally, the Brown colour variety was apparently the heaviest (1.80 ± 0.095 kg) and the Red colour and the Black colour varieties were absolutely the lightest ($1.43 \pm 0.146/0.157$ kg) among the six common colour varieties in northern Ghana. It was significant to note that the lightest (apparent) rabbit colour variety in the Upper West region (Brown White - 1.69 kg) was heavier than the highest ranked (absolute) colour variety in the Northern (Brown 1.68 ± 0.111 kg) and the second highest (apparent figures) ranked colour variety in Upper East (Black White 1.66 ± 0.278) regions. These suggest that colour is basically controlled by genes (Sanford, 1996) but environmental effects such as nutrition, housing and healthcare may influence the body weight.



The effect of the brown colour could be due to heterosis incase its origin is traced to exotic breed. This is because its origin was not established by molecular studies in this work and so it is likely to be traced to any exotic breed when molecular studies is conducted.

The absolute differences in rankings of the colour varieties in the various regions and the significant effect of variety as well as region on most measurements indicate that the measurement of the colour varieties depends on the region in which they were measured. This is a case of genotype-environment interaction (Mogre, 2009). This implies that selection for improvement of body weight and size should be done within regions (Mogre, 2009), provided the same genotypes exist in the regions.

Breed had significant ($p < 0.05$) effect on all the variables except TL. Regarding this, from a morphological point of view, it is important to consider the type of breed(s) to use in any genetic improvement programme and formulation of the breeding objectives. The outcome of genetic improvement programmes could be evaluated on morphological basis (Riva *et al.*, 2004). This is because body measurements reflected the influence of genetic selection used to produce dwarf rabbits, which yields useful information about the investigated breed (Zotte *et al.*, 2012).

5.4 Correlations among morphometric traits of Ghanaian Rabbits

Correlations among body traits are very important in the study of morphometric characters because they (the correlations) serve as indicators of the magnitude and direction of change in one trait as affected by another. In the present study, the



pearson correlation coefficient among most traits were moderate to high positive. This agrees with results of Oke *et al.* (2011) who stated that the correlation among linear measurement in New Zealand White rabbits was positively very high and significant. The highest observed correlation (0.839) was between head-to-pubic bone length (HPL) and shoulder-to-tail drop (STD). If genetic correlation would be in the same direction, then this means that selection for improvement in the head to pubic bone length would mean increased shoulder to tail drop and subsequent body size increase. This also implies that absolute head-to-pubic bone length (HPL) and shoulder-to-tail drop (STD) are complementary. This disagrees with Oke *et al.* (2011) who stated that the interrelationship among the linear traits revealed that body length (shoulder to tail drop) was most correlated to head to shoulder. Tihamiyu *et al.* (2000) observed that body length and heart girth were most correlated (0.95).

In most researches, particular interest is paid to the correlations between live (body) weight and other body dimensional traits. This is because linear body trait approaches to weight estimation is a laudable knowledge discovery to livestock researchers and farmers, due to its role in decision making processes in the areas of selection and breeding, feeding, medication, production and marketing of livestock. The moderate to high phenotypic correlation between live body weight and most morphological traits indicates that one trait can be used to predict the other (Ikpeze and Ebenebe, 2004; Jayeola *et al.*, 2009; Abbasi and Ghafouri-Kesbi, 2011). Body weight is significantly ($P < 0.01$) and positively correlated with head to shoulder (0.888), body length (0.988), height at withers (0.902) tail length (0.92) ear length (0.952) and heart girth (0.967) (Oke *et al.*, 2011; Tihamiyu *et al.*, 2000). These values are higher than the values of this study. Likewise, Lawrence and Fowler (1997) supported this assertion.



Specifically, they stated that the matrix indicates the live weight was significantly ($P < 0.01$) and positively correlated with heart girth (0.797), head to shoulder (0.872), tail length (0.898), body length (0.900), height at withers (0.947) and ear length (0.983). The high relationship of HG with Live Weight proved HG as the indicator of body weight which confirms the findings of other works such as Oke *et al.* (2011) and Tihamiyu *et al.* (2000) who found heart girth as the best predictor of body size in chinchilla and Fourie *et al.* (2002); Riva *et al.* (2004); Afolayan *et al.* (2006); Cam *et al.* (2010); Birteeb (2011) who also used HG to predict live weight in sheep. Egena *et al.* (2014) found Shoulder to tail length ($r = 0.931$ for NZW and $r = 0.938$ for CH) to have the highest correlation with body weight which contradicts the present study.

5.5 Prediction of body weight using body measurements

The live body weight of rabbit is one of the single most important growth and economic trait that most producers and processors of rabbit products give special attention to. Accurate knowledge of live weight and ways of predicting it are therefore imperative for maximization of its benefits by farmers and livestock processors. Even though using conventional weighing scales is the best way of determining the Live Weight of an animal, the use of linear body measurements have become a laudable alternative (Fourie *et al.*, 2002; Riva *et al.*, 2004; Afolayan *et al.*, 2006; Cam *et al.*, 2010; Birteeb, 2011).

Heart girth was found to be the best predictor of body weight because it is part of tissue measurements, while other measurements are related to skeletal measurements (Blackmore *et al.*, 1958).



This was followed by body length and then shoulder-to-tail drop. This corroborates the findings of Oke *et al.* (2011) and Tihamiyu *et al.* (2000) who stated that heart girth is the best predictor of body size in chinchilla. This findings are also in agreement with results in sheep (Thys and Hardouin, 1991), poultry (Gueye *et al.*, 1998), goats (Slippers *et al.*, 2000), cattle (Abdelhadi and Babiker, 2009) and grasscutter (Annor *et al.*, 2011). In the domestic rabbit, Oke *et al.* (2003) found height at withers as the best predictor of body weight at 20 weeks of age and body length at 16 weeks of age. In another study, Abdullahi *et al.* (2003) indicated shoulder-to-tail drop as the best single predictor of body weights for rabbits followed by body length and heart girth which though had the same variables like this work as weight predictors, is different in order of superiority in weight prediction as found in this work.. Relating body weight to linear body measurements is one way of predicting body weight of rabbits (Shahin & Hassan, 2000).

The requirements (measuring tape and/or calibrated stick) for linear body measurements for livestock weight prediction (estimation) are economically viable, technically sound and warrant sustainability. Obviously, the use of body traits to predict weight will also help livestock farmers in carrying out all animal production and marketing practices and as well save them the hustle of the unavailability, unaffordability, inconvenience and huge task of carrying weighing scales.

5.6 Carcass Characteristics of Rabbits

The indigenous rabbit lost about 3% of its live body weight after bleeding. This is similar to the result in poultry (Mogre, 2009), but differs slightly from work by Sah (2008), who reported that guinea fowls in northern Ghana lost 8% of the live weight after bleeding. The average hot carcass dressing-out percentage was 48.99 ± 0.488 .



The low dressing-out percentage may be due to poor nutrition because there was no planned management and balancing of the diets, as reported by Sanford (1996) that an animal which has been reared on a low level of nutrition will, before it reaches maturity, have a lower dressing-out percentage than one reared on a high level of nutrition. The low dressing-out percentage could also be due to the small size of indigenous rabbits. The present finding is lower than 50-60% range reported by Sanford (1996) and Jennifer (2002), the $59.7 \pm 8.1\%$ reported by Pinna *et al.* (2004) and the 54.05% reported by Alan *et al.* (2014) for local rabbit on control diet. The cold carcass dressing percentage of 53.1% reported by Alan *et al.* (2014) for local rabbits on control diet is higher than the 45.80 ± 0.525 recorded in this study. The difference between hot carcass dressing percentage and the cold carcass dressing percentage is due to moisture losses as a result of freezing. About 3.19% was lost to freezing. The values 8.416 ± 0.401 , 3.410 ± 0.147 , 43.63 ± 1.785 , 9.455 ± 0.312 and 93.41 ± 3.77 which were respectively recorded for lung weight, heart weight, liver weight, kidney weight and empty intestine weight in this study were higher than the figures reported by Alan *et al.* (2014) for the same internal organs except kidney weight. These differences might be due to variation in measurements between the researchers or due to the higher incidence of the gut content or more so, the breeds used.

The similarities ($p > 0.05$) in carcass characteristics including dressed weight, among all colour varieties suggest that colour may be strongly controlled by genes.



This is different from findings (in poultry) recorded by Mogre (2009) who observed significant effect of colour variety on carcass characteristics of local guinea fowls in northern Ghana. The effect of sex was also significant ($p < 0.05$). The difference may be due to the higher incidence of the gut content (Trocino *et al.* 2002; Yalcin *et al.*, 2006). It might also be due to the slaughter age, breeding, weaning age and feeding conditions (Deltoro and Lopez, 1986; Fernandez and Fraga, 1996). Slaughter weight, bled and skinned weights were slightly lower and dressing percentages were higher ($p < 0.05$) in males than that in females. In contrast, according to the results of Pla and Cervera (1997) dressing yield was lower for males than for females. Singh *et al.*, (1999) and Baeza *et al.*, (2001) in India, also found sex to be a significant source of variation for carcass traits.

5.7 Reproduction Performance of Rabbits

Litter size recorded in the study ranged 1-8 kits per kindle depending on the parity of the doe. This result is higher than the 1-6 range recorded by Akugre (2010) in the Upper East Region but lower than the average of 8 to 10 kits per litter reported by Robert *et al.* (2008). The findings is similar to that of Osei *et al.*, (2012) that litter size ranged from 1 to 10 with a mean of 4 kits per litter but lower than the average of 5 to 8 kits per litter obtained in Nigeria (Abu *et al.*, 2008). Adjare (1985) stated that the conditions which prevailed in West Africa do not permit fanners to have a large (7-15 kits) litter size which is not in line with this finding.

Average gestation in this study was 30 days in all the regions in northern Ghana with average of 3 kindlings within the 9 months period. This suggests that gestation



obviously is strongly controlled by genes though environmental factors such as nutrition could affect it. This is similar to the average gestation period of 31 to 32 days reported by Robert *et al.* (2008). The finding corroborates the report by Ajayi *et al.* (2005) that rabbits have short generation interval with a relatively short gestation period average of 30-31 days.

In a study conducted by Akugre (2010), two times kindling per year recorded higher percentage as against 3 times kindling per year which was attributed to poor nutrition. This assertion may be true as the feeding in this study was improved as compared to the ordinary feeding by local farmers, hence improved number of kindling. Wilson (1995) stated that poor feeding affects the number of times a rabbit will kindle in a year. There was significant ($p < 0.05$) effect of region on both birth and weaning weights across all phases of kindling except weaning weight in the first kindle (Table 21). Kits' weights increased with increasing age or parity of the does. This differences may be due to influence by non-genetic factors such as feeding, housing, parity, climate and management as stated by Kabuga and Agyemang (1983); Osei and Effa-Baah (1989); Osei *et al.* (1991); Ahunu *et al.* (1993); Darko and Buadu (1998); Baffour-Awuah *et al.* (2005); Beffa *et al.* (2009). Animals in different herds perform differently because they are given different treatment or management. They further asserted that animal performance varies with years due to differences in climatic variables in different years. According to Sanford (1996), such a character as milk — yield in does, although influenced to some extent by inheritance, is affected by environment, especially diet, by the suckling of young and the parity of the litter. Females, giving birth for the first time, produce smaller litter that has low weights



and growth rates than older females (Kabuga and Agyemang, 1983; Osei and Effa-Baah, 1989; Osei *et al.*, 1991; Ahunu *et al.*, 1993; Darko and Buadu, 1998; Baffour-Awuah *et al.*, 2005; Beffa *et al.*, 2009). The average birth weights recorded for the various regions in this study agree with the finding of Fielding and Matheron (1991), that the weight of a rabbit at birth is about 30-40g but lower than the kits average weight of 51.0 g reported by Zerrouki *et al.* (2007).

High kit mortality was recorded during the first kindle (June) in all regions. The lowest percentage of preweaning mortality was found in rabbits born in September and November which may be due to the favorable conditions especially ambient temperature in these two months. This contradicts with the report by Abdel-Azeem *et al.* (2007) that the lowest percentage of preweaning mortality was found in rabbits born in March and January which may be due to the favourable conditions especially ambient temperature in these two months. This difference may be due to regional differences in climate or weather and/or difference in the breeds of rabbits used with respect to the locality. In the Upper East region, mortality in the third kindle increased instead of decreasing. This was due to diseases but could also be due to adverse environmental effects. This is because climate/weather conditions in the region are generally similar to that of the tropics.



CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Based on results of this study, the indigenous Ghanaian Rabbits:

- Are generally small in body conformation with Upper West region having the heaviest rabbits.
- Have wide range of colours and mixture of different colours. The white colour was the largest, followed by the brown rabbit which appears to be superior in most of the morphological traits to the other colours.
- Are moderately prolific, short gestation (30 days) and medium to large litter size .
- Heart girth was the best predictor of body weight. It can therefore be used by farmers to predict body weight of rabbits. High degree of reliability of regression estimates of body weight in the domestic rabbit could aid in the selection of both breeder and meat type rabbits for improved reproductive and production performance, particularly in rural areas or where weighing scale is not readily available.
- Could have more than three kindles in a year with improve nutrition.
- Face problem of kit mortality in young does especially in young does and hot months.



6.2 Recommendation

- The breed of the brown rabbit and others should be established by molecular genetic studies.
- There is the need to break the seasonal kindling behaviour of rabbits using concentrate supplements and provision of quality feed. This can increase litter size and number of kindles in a year and thereby enhances incomes of farmers.
- There is little to be gained from measuring several body components in predicting body weight. Heart girth alone appeared to provide the best single measurement predicting body weight. It is recommended that where labour is expensive heart girth be used alone to predict body weight using the equation below:

$$\text{BWT} = -2.239 + 0.184\text{HG}$$

- More research works should be conducted on characterization of the indigenous rabbit including phenotypic, genetic, molecular, and immunological characterization and genetic parameter estimation. This will aid breeding and conservation decisions.
- Selection and breeding programs should be carried out to improve the production performance of the rabbit. The specific areas that require immediate improvement are body weight, kit survivability, litter size at birth and weaning and to make the rabbits year round kindlers.
- For improvement of body weight selection should be done within regions.



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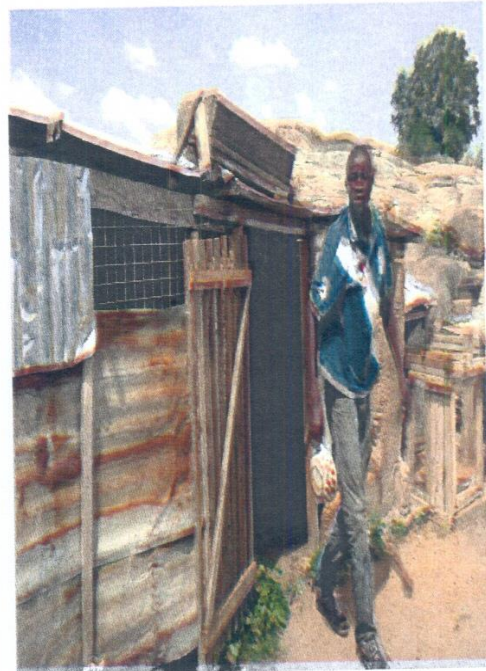
APPENDIX



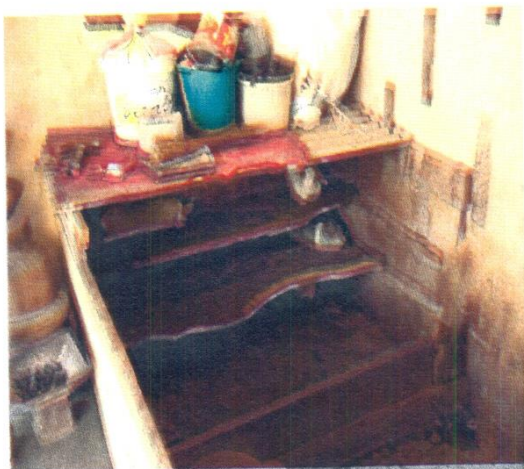
Raised floor cage made of wire and wood with zinc roof (left) and mud walls with concrete floor roofed with zinc (right)



Mud walls with thatch roof house



Zinc and concrete walls roofed with zinc



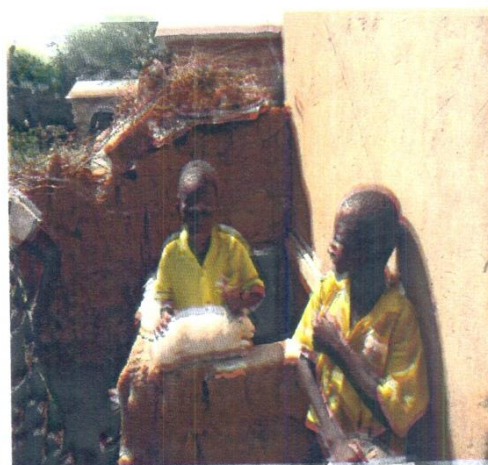
Wooden house with concrete floor kept under shade



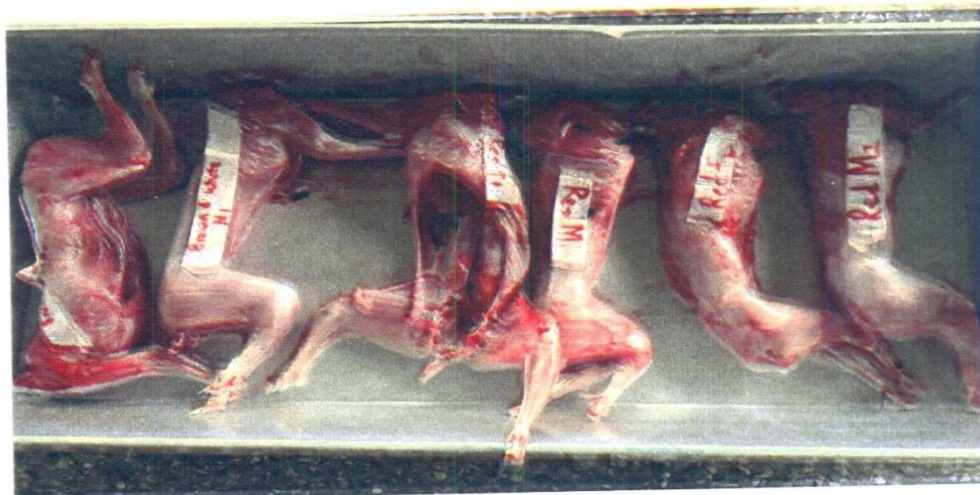
Concrete and pot nests



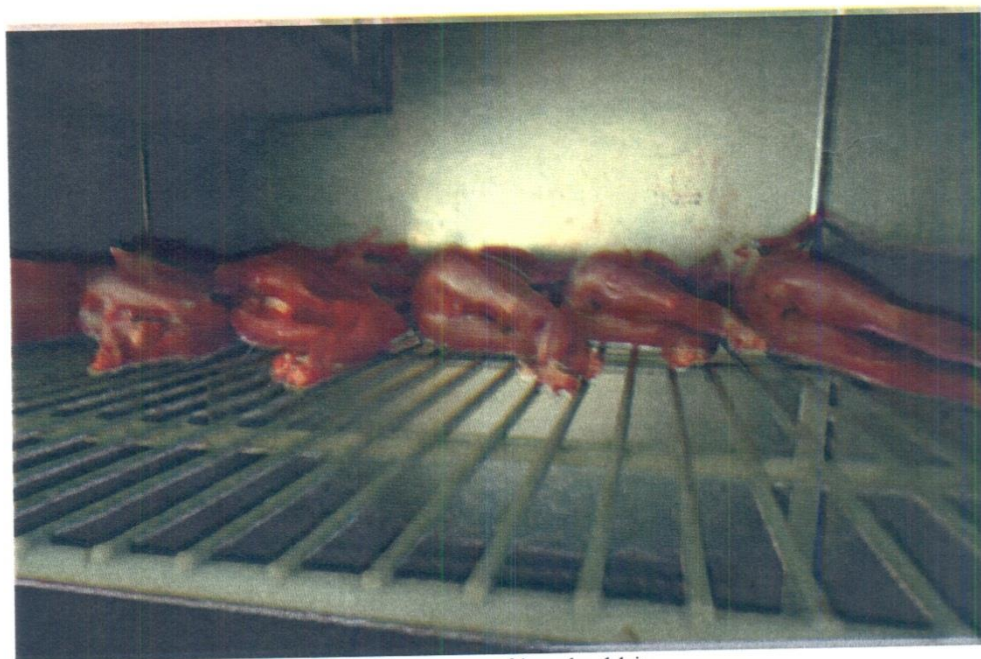
A coop used for rabbits



Lorry tyre, pot and empty gallon used as nests



Hot carcass of local rabbits



Cold carcass of local rabbits

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