THE EFFECT OF THE NAKED NECK (*NA*) AND FRIZZLING (*F*) GENES ON THE FERTILITY, HATCHABILITY, EGG QUALITY AND PTERYLOSIS OF LOCALLY DEVELOPED COMMERCIAL LAYER PARENT LINES

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DEDICATION

This work is dedicated to my parents Mr. Joseph F. Kamara and Mrs. Mary S. Kamara and to my loving wife Nyepu Kollie Dunga for their love, financial support and care throughout my education. I also dedicate it to my late father old man Gregory Tamba Dunga Sr. may his soul rest in serenity and to all relations particularly Wata Akoi, Christine Dunoh, Agnes Paylay, Amos Konneh, Karen Kamara and Catherine, Eve, Isatu and Agnes Dunga respectfully.

May God almighty bless you all!

CERTIFICATION

I, Gregory Tamba Dunga, hereby confirm that the work herein submitted as a dissertation for the Master of Science(Animal Breeding and Genetics) degree has neither in whole nor in portion been presented nor is being concomitantly submitted for any other degree elsewhere. However, works of other researchers and authors which served as sources of information were appropriately acknowledged by references of the authors.

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ABSTRACT

The effect of the naked neck (*Na*) and frizzling (*F*) genes on the fertility and hatchability of eggs of 24 week- old locally developed layer parent lines (brown and white) were examined. Three feather genotypes were used, namely, the naked neck (*Nanaff)*, frizzle (*nanaFf*) and the normal feathered birds (*nanaff*). A total of 3,196 eggs were set in the study. Fertility values in the naked neck (71.98%) and the frizzle birds (70.29%) were significantly higher ($p<0.05$) than those in the normal feathered bird (63.17%). Hatchability of eggs from the frizzle (76.81%) was significantly higher ($p<0.05$) than the 65.07% and 59.64% obtained for the naked neck and normal feathered birds respectively. The weights of the day-old chicks obtained from the different lines did not differ significantly ($p>0.05$). In the second phase of the study, 2,430 eggs were used to determine the effect of the feather genotypes on egg quality traits. There were no significant differences ($p>0.05$) among the three genotypes with respect to egg length, egg width, shell thickness and shape index. There was a significant difference ($p<0.05$) in egg weight between the naked neck and the normally feathered birds but no difference ($p>0.05$) was observed between *Nanaff* and *nanaFf*. The naked neck and frizzled birds laid eggs that had significantly higher ($p<0.05$) yolk weight compared to their normal feathered sibs. The *Nanaff* also produced eggs with significantly higher ($p<0.05$) diameters than eggs from their sibs while, the normal feathered birds showed a significantly higher ($p<0.05$) yolk index than the *Nanaff* and *nanaFf* genotypes. There was no significant ($p>0.05$) difference in yolk weight and yolk colour score among all three genotype. Average values for albumen diameter, albumen height, albumen index and Haugh unit were significantly higher ($p<0.05$) in eggs from *Nanaff* (naked neck)

compared to the frizzle (*nanaFf*) and normal feathered (*nanaff*) birds while there was no significant ($p>0.05$) difference in albumen weight for the three feather types. A study was also conducted on the feather pattern exhibited by birds with the naked neck and Frizzle genes compared to normal feathered birds. The pterylosis of the dorsal, ventral and lateral regions were evaluated as to the number of lines and follicle for each region. Twenty seven birds nine from each genotype naked neck, frizzle and normal feathered were slaughtered for the determination of the pterylosis of the three regions dorsal, ventral and lateral. The birds were de-feathered carefully to avoid damage to the skin. Lines and follicles in each tract were then counted and recorded for each genotype. The study showed that the numbers of lines and follicles of the three regions were significantly reduced ($p<0.05$) in the naked neck as compared to their frizzle and normal feathered counterparts. The frizzle and naked neck genes could be incorporated in layer parents in hot humid areas to improve performance in fertility, hatchability and some egg quality traits.

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CHAPTER ONE

1.0 INTRODUCTION

Naked neck and frizzle chickens are two mutant birds kept in many parts of the world including Liberia and Ghana (Tadelle, 2003). To the poor majority in urban and rural areas, these mutant fowls serve as a source of meat and income when money is needed for crucial family requirements (Ekue *et al.*, 2002). The mutant chicken makes a substantial contribution to human livelihood and contributes pointedly to food security (Gondwe, 2004). Sometimes women and youths are frequently involved in the keeping of these chickens.

These mutant chickens are recognized for various qualities. They are economically reared as scavenging flocks, feeding on household leftovers. They need a small house or shelter to spend their night while free ranging during the day, and their meat and eggs are preferred over those of exotic chickens (Roberts, 1999; Dessie and Ogle, 2001). They are known for their adaptation superiority in terms of their resistance to endemic diseases and other harsh environmental conditions. However, mutant chickens are poor performers in terms of growth rate (hence meat production) and egg production. Most of them are of small adult size and lay small sized eggs when compared to improved commercial broiler or layer birds respectively (Pedersen, 2002; Gondwe, 2004).

What is generally referred to as local chickens is a pool of heterogeneous individuals. They are of several ecotypes that are distinct. Their performance vary considerably and no single ecotype meets the attributes of good egg traits, fertility, hatchability, survivability, high growth rate, heavy weight at slaughter and high egg production

(Msoffe *et al.*, 2001; Fayeye *et al.*, 2005). Fortunately, their genetic diversity could be exploited to improve their productivity. It is therefore a laudable proposition that more attention should be given to the genetic improvement and development of the local chicken in order to improve the present acute animal protein shortage in many poor societies around the globe.

One way of improving the local chicken is by crossbreeding with improved commercial breeds. In Liberia, crossbreeding local fowls to improved commercial chickens that will produce good-ecotype chickens that are superior to other local ecotypes in terms of egg traits, hatchability, growth performance and live weight has not been carried out. There is a need for such improvements which will provide potentially good ecotypes for meat and egg production and, could thus help to develop and improve local strains thereby contributing significantly to food security. In spite of the many problems involved in poultry keeping, almost all poor households in the villages keep poultry; and poultry production is therefore considered an excellent tool in poverty alleviation due to its quick turn over and low investment. Thus, if production could be improved, village poultry production would create an opportunity for the development of the poor segments of society (Quisumbing *et al.*, 1995; Todd, 1998; Permin *et al.*, 2000; Gueye, 1998). Stemming from the importance of local mutant chickens to the economy of the poor majority in Liberia, this study is designed to gather preliminary information on the performance of the improved local parent stock.

Objectives

The general objective of the study therefore was:

To assess the hatchability, fertility, egg quality and pterylosis of two lines of locally developed commercial layer parent stock.

The Specific objectives were:

1. To determine the influence of three feather cover genotypes *Nanaff* (Naked Neck), *nanaFf* (Frizzling) and *nanaff* (normal feathered) on the hatchability and fertility of the eggs of two lines of locally developed commercial layer parent stock.
2. To determine the effect of the three feathered cover genotypes on the external and internal egg quality traits.
3. To assess the influence of the *Na* (Naked neck) and *F* (frizzling) genes on the numbers of feather follicles and lines.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 ORIGIN OF THE LOCAL CHICKEN

According to modern ornithology, there are four species of the jungle fowl and the red jungle fowl (*Gallus gallus)* is found to be the major contributor or an ancestor to the domestic fowl (Crawford, 1990).

It is believed that the other three wild species (*G. sonnerati, G. lafayettei and G. varius*) interbred with *Gallus gallus* and those domestic fowls are carriers of the inheritance to these three species. These fowls give rise to variety of domestic hens of all kinds. These 'fancy' breed are of important value. It is very important that these breeds are maintained in the future as 'gene bank' because they may comprise major genes that could be exploited cost-effectively (Smith, 1990). Indigenous chickens of today resulted from many cross-breeding with exotic breeds and random breeding within flocks of indigenous fowl. As a consequence, it is not possible to homogenize the characteristics and performance of indigenous chickens (FAO, 1998).

Mutant genes such as the frizzled feathers, naked neck, pea, rose and walnut combs are widespread within local birds (Anonymous, 2007). The Naked neck mutation originated in Transylvania, Romania and spread across Europe many centuries ago; while the frizzle feathered chicken was first described by Western explorers in Fiji during the seventeenth century (FAO, 2000).

2.2 LAYING PERFORMANCES OF THE INDIGENOUS CHICKEN

The egg laying ability of the indigenous chicken varies with the type of management system. Peters (2000) discovered that naked neck and frizzle feathered birds laid more eggs than the normal feathered birds. Sonaiya and Olori (1990) indicated that an average of 9 eggs was laid within a period of 12 days. Nwosu (1979) observed that the indigenous chicken produces 100 eggs per year under the extensive management system and 124 to 128 eggs per year under the intensive management system. Omeje and Nwosu (1988) discovered that the average egg weight at age at 1st lay was 25.75g and at 52weeks the average weight was 40.36g. Oluyemi *et al*, (1979) classified the indigenous chicken as white egg layers while Sonaiya and Olori (1990) reported that the indigenous laid both brown and white eggs.

2.3 ADAPTATION OF THE CHICKENS IN THE TROPICAL ENVIRONMENT

The strong nature of the local chicken as manifested in their resistance to certain diseases and their ability to thrive well under harsh condition had helped in their adaptation in the tropical environment which is characterized by heat stress (Horst, 1989).

Peters (2000) reported that the naked neck chicken has the highest egg weight followed by frizzle feathered and lastly normal feathered chickens. Variation in egg weight/size, egg length and breadth is said to be influenced by the possession of major genes, dam's genotype and environmental factors. The possession of major genes influences the utilization of available food reserve for egg production as determined by Peters (2000). Peters (2000) attributed the superior performance of the naked neck and the frizzle

feathered birds when compared to the normal feathered birds in terms of feed efficiency to the thermoregulatory roles of the genes they possess.

2.4 LOCAL POULTRY AS SOURCES OF PERTINENT GENETIC MATERIALS

Modern breeding strategies for profitable poultry centre on dedicated production lines derived by vigorous selection from a few breeds and a very large population with a great genetic uniformity of traits under selection (Ac amovic *et al*., 2005). There are fancy breeds throughout the world that are characterized by medium or low performance and are often maintained in small populations (Horst, 1999). The genetic erosion of these local breeds may lead to the loss of valuable genetic variability in specific characteristics that are momentarily unimportant in commercial breeding strategies (Ladokun *et al*., 2008). It can be assumed that local breeds contain the genes and alleles pertinent to their adaptation to particular environments and local breeding goals. Local breeds are needed to maintain genetic resources permitting adaptation to unforeseen breeding requirements in the future and a source of rich material (Notter, 1999).

2.5 OVERVIEW ON MARKER AND MAJOR GENES IN POULTRY

The genetic resources base of the indigenous chickens in the tropics is rich and should form the basis for genetic improvement and diversification to produce a breed adapted to the tropics. Horst (1987) described nine major genes of the indigenous chicken (Table 1) that can be used in genetic improvement programs. There is little information on the genetic make-up of the indigenous chickens of Africa. Mathur and Horst. (1988) reported an increase in egg production through incorporating naked neck (*Na*) genes in a

crossbreeding program of local Fayoumi. Similarly, Horst and Mathur (1994) reported favorable effects of naked neck (*Na*) and frizzle (*F*) genes on egg production and egg weight, and the dwarf gene (*dw*) on feed efficiency of chickens under heat stress.

Table 1: Major and marker genes in local fowl population, with side-effects on tropical tolerance

Gene	Inheritance	Direct effects	Indirect effects
Dw: dwarf	Recessive, sex-linked, Multiple allelic	Reduction of body size10 30%	Reduced metabolism, improved fitness and disease tolerance
Na: naked neck	Incomplete dominant	Loss of neck feathers, reduction of pterlae width, reduction of secondary feathers.	Improved ability for convection, reduced embryonic livability (hatchability), improved adult fitness
F: frizzle	Incomplete dominant	Curling of feathers, reduced feathering	Decreased fitness under temperate conditions, improved ability for convection
h: silky	Recessive	Lack of hamuli on the barbules, delicate shafts, long barbs at contour feathers	Improved ability for Convection
K: slow	Dominant, sex-linked, multiple allelic	Delay of feathering	Reduced protein requirement, reduced fat deposition during juvenile life, increased heat loss during early growth, reduced viability
id: non-inhibitor	Recessive, se-linked, Multiple allelic	Dermal melanin deposition in the skin and shanks	Improved ability for radiation from shanks and skin
Fm: fibro-melanosis	Dominant with multi-factorial modifiers	Melanin deposition: all over the body; sheaths of muscles and nerves, tendons, esenterium; blood vessel walls	Protection of skin against UV radiation, improved radiation from the skin, increased pack-cell volume and plasma protein
P: pea comb	Dominant	Change of skin structure: compact comb size; reduction of pterlae width; development of breast ridges	Improved ability for convection, increased frequency of breast blisters, sex-limited (*o*) improvement of late juvenile growth
O: blue shell	Dominant, sex-linked	Deposition of blue pigment (bilverdin IX) into egg shell	Improved egg shell stability

Based on, Horst, 1987.

2.6 THE NAKED NECK (*NA*) GENE

Naked neck chickens look like a cross between a turkey and a chicken with their completely featherless necks and faces. They are often referred to as turkens, Transylvania Naked necks, bare necks, Hackle-less and Rubber necks and are characterized by the naked neck trait, caused by a single autosomal dominant gene (Davenport 1914). The naked neck gene (*Na*) is incompletely dominant and the heterozygote (*Nana*) can be identified by a tuft of feathers on the ventral side of the neck above the crop. The homozygous dominant chickens (*NaNa*) however, either lack this tuft or it is reduced to just a few pinfeathers or small feathers (Crawford, 1976). Scott and Crawford (1977) demonstrated that the presence or absence of the tuft could be used to identify the two genotypes accurately at hatching. The resulting bare skin becomes reddish, particularly in males as they approach sexual maturity (Somes, 1990).

The naked neck chicken is thought to have originated from Transylvania, Romania and was spread all over the world by a Dutch East Indian Company in the course of trading around the 17th century (Ramsey *et al*., 2000). The *Na* gene is associated with significantly less plumage cover than chickens not carrying the gene (Nthimo, 2004). They are very colorful – white, red, brown and black feather combinations are found. The autosomal incompletely dominant naked neck (*Na*) gene is not only responsible for de-feathering the neck region, but it also restricts the feathered area around the body by 20 to 30% in heterozygous (*Nana*) and up to 40% in homozygous (*NaNa*) genotypes because of the incomplete dominance of the *Na* gene (Islam and Nishibori, 2009).

The *Na* gene received greater attention in the recent past in broiler production because of its association with heat tolerance (Merat, 1986; Cahaner *et al*., 1993); which is considered to be the most important inhibiting factor for poultry production in hot tropical climate (Horst, 1987). In broiler chickens, the '*Na*' gene results in a relatively higher growth rate and meat yield than the normal birds at normal temperature and the effect is more pronounced at high temperature (Cahaner *et al*., 1993). Higher meat yields were reported for *Na* genotypes (Younis and Cahaner, 1999; Galal and Fathi, 2001; Patra *et al*., 2002; Fathi *et al*., 2008).

In expression of sex differences, *Nana* females have 4.8% greater naked area compared to *Nana* males (Howlider *et al*., 1995). Bordas *et al*. (1978) reported that the *Nana* birds tend to have more feather cover as compared to their *NaNa* counterparts (41 to 27%) and (33 to 22%) for males and females respectively. Normally, the apterium carry scattered down and semi-plume feathers, but the apterium of the naked neck birds contain no feathers.

The feather tracts themselves are also either absent or reduced in area so that birds have greatly reduced feather cover (Greenwood, 1927). Feather pterylae are absent from the head and neck except around the comb, the anterior spinal tract and two small patches on each side around the comb. Islam *et al*. (2004) suggested that the *Na* gene and its effects on heat dissipation positively affect appetite and this happens for two opposing reasons; in cool climates, because of higher energy demands, and in hot climates because of an increase in the upper limits of the critical body temperature. Under such conditions, feed

intake increases, resulting in improved body weight, egg sizes and livability. The introduction of the *Na* gene in chicken breeds seems to improve the resistance of the birds to heat stress (Islam and Nishibori, 2009).

The incorporation of this gene in commercial breeds might contribute to the production of birds with a high genetic potential and better performance at high temperatures. The relationship between the presence of the *Na* gene and the resistance of the naked neck bird to heat stress is due to the fact that the gene reduces feathering by about 30% in the heterozygous birds (*Nana*) and 40% in homozygous birds (*NaNa*). The homozygous naked neck *(NaNa*) is slightly superior in most tests to the heterozygote (*Nana*) for body-weight and feed efficiency (Gowe and Fairfull, 1995). Eberhart and Washburn (1993) stated that feather reduction in naked neck birds probably caused their greater ability in dissipating heat through exposed areas compared to birds not carrying the gene. Singh *et al*. (2004) reported that in India, the naked neck and frizzle birds were not liked by most people because of their unfamiliar look but demand is increasing year after year realizing the advantage of these genotypes in tropical adaptation and productivity.

2.7 EFFECT OF THE NAKED NECK GENE ON PERFORMANCE OF BIRDS

Merat (1986) and Horst and Rauen (1986) studied the effect of temperature variation on the egg production performance of two genotypes (naked-neck and normally feathered birds). Their studies showed that there was a different response of the naked-neck and normally feathered genotypes to high environmental temperature.

2.7.1 EGG PRODUCTION

Egg numbers at moderate temperature were not affected by the naked-neck gene. At high temperature, the naked-neck hens had an improved laying rate. Under constant heat stress the heterozygous naked neck (*Nana*) layers have significantly higher egg number, egg weight, egg mass, body weight and productivity index than the normal feathered ones (Somes, 1988; Hareen-Kiso, 1991; Mathur, 2003).

However, according to Mathur (2003) under natural conditions there were large differences in the performance of naked neck birds in terms of egg number, egg weight, egg mass, body weight and productivity index at different locations (Turkey, Egypt, Cuba, Burundi, Bolivia and Malaysia).

2.7.2 CARCASS CHARACTERISTICS

The reduction of plumage (20 - 40%) gives 1.5 - 3.0% more carcass yields to the naked neck genotypes than their normal feathered counterparts regardless of the temperature. Due to the higher proportion of muscle in the pectoral region of naked neck birds, there is 1.8-7.1 percent more meat in them than normal feathered birds when their carcasses are dressed (Merat, 1986). Fathi *et al.* (2008) reported that the naked neck genotypes (*NaNa* or *Nana*) exhibited higher relative weight of dressed carcass, drumstick and breast muscles compared to normally feathered individuals (*nana*) and that the proportion of abdominal fat was decreased in both naked neck genotypes compared with normally feathered ones. Intramuscular and subcutaneous fat in naked neck birds is low due to the utilization of a larger fraction of energy for thermoregulation (Merat, 1990). N'Dri *et al*. (2005) observed that slow growing homozygous and heterozygous naked neck birds under fluctuating temperature, tended to reach the weight of 2 kg 3.3 days sooner than

normally feathered birds and that carcass yield of *Na* birds was higher than that of normally feathered birds (81.6 % vs. 80.0 %). Singh *et al.* (1996) reported that heterozygous naked neck broilers gained about 3% more weight than their normally feathered counterparts under commercial conditions during the spring and summer months, and that this advantage was almost tripled at high ambient temperature of about 32°C.

2.7.3 BODY WEIGHT AND GROWTH RATE

At 20°C, adult body weight was lower in naked-neck hens, especially the homozygote, than in hens with complete plumage cover, but the trend reversed when the temperature increased above 30°C (Cahaner *et al*., 1993). The reduction of feather coverage provides relative heat tolerance and therefore, in high ambient temperature, heterozygous naked-neck chickens are superior to their normally feathered counterparts (Cahaner *et al*., 1993). The naked-neck gene has been associated with increased laying rate, egg size and egg mass in hot environments (Garces *et al.*, 2001; Younis and Galal, 2006). Abdel-Rahman (2000) researched into the effect of the naked-neck gene on the egg production performance of Sharkasi chickens under subtropical conditions and reported that the naked-neck birds showed significant increases in egg production, 90-day egg number and egg mass by 9.0, 17.80 and 13.30% for *Na/na* and 3.70, 7.30 and 7.30% for *Na/Na* respectively compared with the *na/na* genotype. Garces *et al.*, (2001) and Younis and Galal, (2006) observed that the naked-neck birds also reached sexual maturity significantly earlier than the normally feathered birds by about 5 days. The naked-neck birds were also heavier at 24, 40 and 72 weeks than normally feathered birds ($P<0.05$ at

40 and 72 weeks of age). The average mortality rate during the laying season was less in naked-neck birds than normally feathered (*na/na*) ones; however, the differences were not significant. Garces *et al.,* (2001) and Younis and Galal, (2006) stated that the *Na* gene also reduced feed intake by 12.40 and 13.60% in *Na/na* and *Na/Na* genotypes, respectively. The naked-neck birds had a significantly better feed conversion than *na/na* genotypes. The *Na* gene led to a significant reduction in egg yolk and shell percentages. Eggs produced from naked-neck birds had a lower breaking strength and egg shell thickness compared with the *na/na* genotypes.

Other effects of this gene on productivity noted by other researchers include reduced effect of high ambient temperature on fertility, (Ladjali *et al*., 1995), less body weight loss under heat stress and superior levels of heat shock protein, Hsp 70 (Hernandes *et al*., 2002). Similarly, Fraga *et al*. (1999) observed the lowest incidence of diseases such as cloaca cysts, ascites, prolapse, Marek's disease, Coccidiosis, Osteodystrophy and Salmonellosis in the naked-neck birds studied. According to Yushimura *et al*. (1997) among the indigenous chickens, the naked-neck is found superior in terms of egg production, egg size and body weight in a hot and humid environment. Other positive effects associated with this gene on broiler stocks are increased body weight and meat yield, higher body weights, lower fat content and better feed efficiency (Merat, 1986).

A study by Njenga (2005) on productivity and socio-cultural aspects of local poultry phenotypes in coastal Kenya showed that the naked-neck phenotypes had significantly higher body weights compared to the normally feathered counterparts. Egg weights ranged from 38±2.9 g to 45±4.5 g, with the naked-neck phenotypes having the highest.

The overall mean eggshell thickness for the birds was 0.31mm. The naked-neck had the highest average daily gain among the other four phenotypes. The author concluded that the naked-neck phenotype is superior in productivity when compared to the other phenotypes. Barua *et al*. (1998) showed that among the indigenous chickens of Bangladesh, the naked-neck fowl performed better in terms of egg and meat production, and were more resistant to diseases than their fully feathered counterparts. They observed that the crosses between the indigenous naked-neck fowl and the exotic standard breeds performed better than similar crosses using fully feathered indigenous fowl.

2.7.4 ADAPTATION

According to Islam and Nishibori (2009) the naked-neck chicken has a good heat dissipation mechanism, is well adapted to the harsh tropical environment and poor nutrition, and is highly resistant to disease and superior to indigenous full-feathered and exotic egg-type or exotic naked-neck counterparts in terms of growth rate, egg production, egg quality and meat yield traits. It can produce double the standard number of eggs under improved nutrition and management conditions. Crossbreds of indigenous naked-neck with exotic chicken can perform even better than that of exotic chicken in respect of productive and reproductive traits. Consumers prefer the meat and eggs of indigenous naked-neck chickens for reasons of pigmentation, leanness, taste, firmness, and they are also used in special dishes. Indigenous naked-neck chicken prices are typically higher compared with those of products from exotic stocks (Islam and Nishibori, 2009).

Naked-neck birds were inferior at 20°C or lower but superior to their normally feathered counterparts at 30°C or higher temperature for body weight, feed conversion efficiency, egg production and carcass yield (Horst and Rauen, 1986; Merat, 1986; Rauen *et al*., 1986; Cahaner *et al*., 1993). Reduced feathering intensity and feather structure can increase heat loss, and so indirectly increase feed intake and productivity, which may lead to an improved productive adaptability of laying hens under hot-environmental conditions (Rauen *et al*., 1985). Furthermore the *Na* gene reduces mortality due to heat stress, and naked-neck birds can thrive under adverse environments like poor feeding, poor housing, poor management, sudden change of feeding or nutrients and variable temperature and humidity (Barua and Howlider, 1990).

2.8 FRIZZLE GENE

The frizzle gene was first described by Aldrovandi in 1600, but it was Davenport who first suggested that it is a dominant gene in 1906 (Somes, 1990). According to Horst (1989) the frizzle condition is caused by a single incompletely dominant autosomal gene, symbolized *F*. The frizzle gene which controls frizzling is situated on chromosome 6. The gene is infrequently restricted by an autosomal recessive modifier (*mf*). As described by Somes (1990), in unmodified homozygous frizzled birds, the rachises of all feathers are extremely curved. These feathers are easily broken and therefore the birds appear quite bare. The modifying gene lessens the extreme aspects of the homozygote so that they appear less woolly. The unmodified heterozygotes have the feather shafts and barbs of contour feathers curved, to a much lower extent than the homozygote. The action of the frizzling gene has been shown to be localized in the feather follicle and does not

result from a metabolic disorder (Somes, 1990). He further stated that the modifying gene modifies the heterozygotes making them less different from the normally feathered ones.

2.9 EFFECTS OF THE FRIZZLE GENE ON PERFORMANCE OF BIRDS

There is not as much information on the effects of the frizzle gene on productivity as there are in the naked-neck gene. Nevertheless, there is evidence to indicate that the gene may be useful in stocks that have to perform under hot humid conditions (Gowe and Fairfull, 1995). Gowe and Fairfull, (1995) stated that the gene was capable of reducing the insulating properties of the feather cover thereby making it easier for the bird to radiate heat more efficiently from their body. Merat (1990) showed that the frizzling gene resulted in an increase in egg number and mass, alongside reducing mortality under hot and humid conditions. Work by Haaren-Kiso *et al.* (1988) on *F/f* and *f/f* progenies compared under two temperatures, (18-20°C) and (32°C), revealed that the birds carrying the *F* gene laid 24 more eggs over a 364 day laying period in the hot (32°C) environment. On the other hand, the *F* gene birds laid only 3 eggs less on average in the cooler (18°C) environment. There was also an increase in egg weight, feed efficiency and viability under the hot environment for the frizzled birds.

According to Horst (1988) the *F* gene is associated with increases in egg number, egg mass and reduction in mortality when the birds are raised under hot and humid conditions. Haunshi *et al.* (2002) worked on the effect of the naked-neck and frizzle genes on immune-competence in chickens and reported that there were significantly higher haemolytic complement levels in serum observed for the frizzle feathered birds

than their normally feathered sibs. Younis and Cahaner (1999) suggested that when reared at high ambient temperature (32°C), birds with frizzle genes perform better in terms of weight gain from 4-7 weeks than their counterparts which are normally feathered. The results indicated that the reduction in feather coverage by the frizzle gene provided relatively better heat tolerance, and therefore, under hot climates the *F/f* broilers were superior to their normally feathered counterparts. They concluded that frizzled broilers should be preferred in hot climates. Nwachukwu *et al.* (2006) also observed that the birds with the frizzle gene outperformed their sibs which were either naked-neck or normal feathered in body weights and most of the egg traits evaluated, thus indicating that the frizzle gene may be advantageous in poultry production in the humid tropics.

2.10 THE INTERACTION BETWEEN THE NAKED-NECK (*NA*) AND FRIZZLE (*F*) GENES

According to Gowe and Fairfull (1995) some major genes like naked-neck and frizzling are used to improve heat tolerance and are often incorporated in breeding programs with local chickens to increase poultry production. Studies by Younis and Cahaner (1999) have shown that combining the naked-neck allele with another heat tolerant gene like frizzling resulted in a favourable additive effect on various productive parameters. Mathur and Horst (1992) reported that the three genes *Na*, *F* and *dw* interact so that the combined effects of two genes are lower than the sum of their individual gene effects. Mukherjee (1992) observed a positive additive effect on performance when Dahlem Red naked-neck strains were crossed with Dahlem White frizzle strains. Horst (1988) also advocated the use of the naked-neck and frizzling genes in combination to develop stocks specifically for the hot and humid environments.

It is therefore clear that the use of the double heterozygote (*Na/naF/f*) is very advantageous especially for stocks that are to be reared in hot humid environments. Horst (1989) and Haaren-Kiso *et al.* (1988) proposed the use of the double heterozygous condition of naked-neck and frizzling for a favourable egg laying performance under hot and humid conditions, that is, above 30˚C. Younis and Cahaner (1999) suggested the incorporation of the naked-neck and frizzle genes in birds that are to be reared under high ambient temperature conditions due to the positive additive effects of the two thermoregulatory genes on body weights and growth rates.

The advantage of heterozygous naked-neck (*Na/na*) broilers over their normally feathered (*na/na*) counterparts under heat stress was only one-half of that of homozygous (*Na/Na*) ones (Cahaner *et al.*, 1993), but producing *Na/Na* broilers is not commercially feasible because of their poor hatchability (Merat, 1986). Therefore, instead to reducing feather number from 20% (*Na/na*) to 40% (*Na/Na*), the insulation efficiency of the feather coverage of *Na/na* birds could be further reduced by the frizzle gene (*F*). The *F* gene curls the feathers and reduces their size, thus increasing the heat conductivity of the feather coverage (Somes, 1990). The effects of frizzled feathers on the performance of layers were reported by Haaren-Kiso *et al.* (1995). Combining the naked neck and frizzling genes at the heterozygous state (*Na/naF/f*) resulted in a better heat tolerance compared with that of fully feathered birds and with that of heterozygous birds only for one of these genes (Pech-Waffenschmidt, 1992). When layers of the four genotypes (*na/naf/f, na/naF/f, Na/naf/f,* and *Na/naF/f*) were exposed to a constant high ambient

temperature of 34°C, the double heterozygous birds (*Na/naF/f*) exhibited the highest feed consumption, body weight and egg production among the four genotypes.

According to a report by Mahrous *et al*. (2008), it was observed that the combined naked-neck frizzle (*Na/naF/f*) genotypes attained sexual maturity earlier than their normally feathered counterparts by about 4.3 days, while the age at sexual maturity was not significantly affected by the frizzle gene. The presence of the naked-neck and frizzle genes in combination significantly increased egg mass, egg number and egg weight compared to the fully-feathered genotype (Mahrous *et al*., 2008). Egg albumen percentage and Haugh units of *Na/naf/f, na/naF/f* and *Na/naF/f* genotypes were higher than that of *na/naf/f* ones. The presence of the *Na* gene in combination with the *F* gene significantly increased egg shell weight, egg shell percentage and egg shell thickness compared to their normally feathered counterparts (Mahrous *et al*. 2008). According to them the breaking strength of eggs of hens with the naked-neck frizzle genotype were significantly higher than that of normal feathered (*na/naf/f*) ones. Mahrous *et al*. (2008) concluded that combining the two alleles in a heterozygous state (*Na/naF/f*) resulted in a better performance of laying hens compared to normally feathered (*na/naf/f*) birds

The importance of the heat-tolerant genes on egg production of birds reared under tropical conditions cannot be overemphasized. Results obtained on the effect of genotype on egg production from a work by Hagan *et al.* (2010) showed that birds expressing the genes either in the single or double segregation state laid significantly ($P<0.05$) more eggs than their counterparts which were normally feathered Hagan *et al.* (2010).

It is more profitable to rear the naked neck birds followed by the frizzles and normal feathered birds respectively; due to the positive influence of the naked neck gene on body weight, egg production traits and survivability under tropical conditions (Adumako 2009).

The birds with thermoregulatory genes in the double heterozygous state are able to convert feed into egg production than the single heterozygote and normal feathered (Hagan *et al.*, 2010). They reported that the naked neck and frizzle genes when they interact confer on bird's better feed efficiency especially under warm humid environment.

2.11 FERTILITY AND HATCHABILITY

According to Peters *et al*. (2004), fertile eggs are eggs that are capable of hatching. They are eggs that have been fertilized and have formed embryos while fertility is the fertile status of groups of eggs laid over a period of time by single hens, by a small group of hens or by a commercial flock. Fayeye *et al*. (2005) reported that the Fulani ecotype birds has a fertility of 76% with a significantly lower hatchability (56%) recorded for the normal feathered chicken.

While hatchability refers to the proportion of fertile eggs that continue development and produced viable chicken (Peters *et al*. 2005). Hatchability also refers to the percentage of hatched eggs reported either as percentage of fertile eggs hatched; or percentage of chicks hatched from all eggs in the incubator.

Ajayi *et al.* (2008) reported that percentage hatchability was higher for naked neck chicken (73.1%) while lower hatchability was recorded for the normal feathered chicken (58%). They also noted that the superiority of the naked neck genotype with respect to hatchability could be attributed to the greater efficiency of thermoregulation that is associated with their gene.

Asuquo and Okon, (1993) established that egg size has a marked effect on hatchability. They also reported that hatchability is at a maximum when eggs of medium size are set for hatching. They stressed that there was a significant difference between medium and large size eggs, with average percentage of 88.24% and 84.79% respectively. The different in hatchability they claimed was probably due to embryonic mortality.

Avigdor *et al.* (1986) submitted that among the factors causing differences in hatchability of eggs among chickens was the effect of breed differences. Oluyemi and Robert (1998) reported that fertility and hatchability of eggs are both functions of breed and environment. Peters *et al.* (2008) confirmed that the strain of the dam had prominent effect on fertility and hatchability of eggs.

Peters (2000) observed that the effect of strain and breed differences do affect fertility of eggs and reported that normal feathered local chickens laid more fertile eggs than frizzle feathered birds which performed better than naked neck chickens. The superior fertility demonstrated by normal feathered local chickens was influenced by sire strain effect, which may be due to the quality of their semen which had a higher sperm concentration, mobility and livability.

Hatchability to a large extent is a derivative of fertility except for the presence of major genes and strain/breed differences that affect embryonic livability (Avigdor *et al.*, 1986; Peters *et al.*, 2005). Peter *et al.* (2008) opined that the strain of the dam affects fertility and hatchability of eggs.

Meijerhof (1992) reported that during storage, hatching is influenced by the length of storage period, temperature, humidity, general environment and the orientation of the eggs. Storage temperature should be lower for prolonged storage of eggs. Meijerhof (1992) reported that humidity during storage improved hatchability, probably due to a reduction in water loss.

Sarda-Jova (1992) reported that storage of eggs for up to 7 days had no significant effect on the hatchability of the egg. He added that there was a highly significant deterioration in egg quality with increasing length of storage. The quality of fresh eggs was higher than that of eggs stored in a refrigerator or at ambient temperature and the quality of refrigerated eggs was higher than that of eggs stored at ambient temperature.

2.12 EGG QUALITY TRAITS OF NAKED NECK AND FRIZZLES

The effect of *Na* gene on egg quality measurements under moderate or high ambient temperatures was studied by Bordas *et al*. (1980) who reported that the homozygous naked neck (*NaNa*) genotype had significantly more albumen than those of *Nana* and *nana* genotypes at both temperatures. Albumen height was significantly higher for *nana* genotype (6.81 mm) than for *NaNa* (6.06 mm) and *Nana* (6.28 mm) birds. The

heterozygous genotype was intermediate for most traits, but was closer to the *nana* for yolk to albumen ratio. Under hot environmental conditions (31^{o}C), Bordas *et al*. (1980) showed that egg weight, yolk weight, albumen weight and albumen height for *nana* and *Nana* genotypes were 48.7 vs. 53.2g, 14.6 vs. 16.1g, 29.4 vs. 31.5g and 7.05 vs. 6.22 mm, respectively.

The heterozygous genotype was generally intermediate but closer to *NaNa* birds for albumen height. Under Egyptian environmental conditions, Zein El-Dein (1981) concluded that the egg shell weight for the *Nana* genotype was superior to that of *NaNa* (6.25 vs. 5.84 g), while the *nana* genotype was intermediate (6.16 g). Egg shell percentage and egg shell weight exhibited the same trend. Fathi (1987) found that albumen and shell percentages were higher for *Nana* hens than for the normal feathered. Conversely, under natural and improved environmental conditions, Abdel-Rahman (1990) showed that the *Na* gene reduced egg shell percentage by about 0.8% and 4.4%, for *Nana* and *NaNa* genotypes respectively. Fathi (1992) stated that there were differences among *NaNa*, *Nana* and *nana* genotypes for most of the egg quality measurements. Shell thickness was higher for *nana* genotype than for *NaNa* and *Nana*. Shell percentage was lower for both *NaNa* and *Nana* genotypes. There was no advantage associated with *Na* allele for yolk height. Zulkifli *et al*. (1992) reported that the combination of *Na* and *F* genes within dwarfed genotype (*dw-Ff-Nana*) did not significantly affect albumen height at 60 and 76 weeks of ages, yolk weight at 76 weeks and shell breaking strength at 60 weeks. They added that the combination of *Na* and *F* in non-dwarfed genotype background (*Dw-Nana-Ff*) appeared to have a positive interactive

effect on several egg quality traits. Galal (1995) found that the highest values of albumen weight occurred in the *Nana* genotype in Mandara, Golden Montazah and Gimmizah strains when compared with their normal plumage counterparts.

Under Bangladesh condition, Islam *et al.* (2001) reported that the Desi naked neck genotype produced better quality eggs than their Desi full feathered sibs. Alvarez *et al.* (2002) showed that the specific gravity, Haugh units, albumen height and shell thickness were significantly better ($p>0.05$) in the *Nana* genotype compared with *NaNa* and *nana*. Under the subtropical climatic conditions (30.1°C) of Maputo, Garces and Casey (2003) found that the *Na* gene increased yolk weight and reduced albumen height compared to its recessive allele *na*.

2.13 MEASUREMENT OF CHICKEN EGG QUALITY

Egg quality is based on characteristics of the egg that affect its acceptability. Each of the main components of the egg (shell, albumen and yolk) has a natural variability which is not in line with the modern requirements (De Ketelaere *et al*., 2004). Nowadays, concern about egg quality is growing steadily (Kemps *et al*., 2006).

The overall quality of the chicken egg is determined by the egg external and internal qualities. Both of them are of paramount importance to the egg industry (Roberts, 2004). The appearance of the egg is important for consumer appeal. In fact, egg shell quality is based on egg size, egg specific gravity, shell colour, shell breaking strength, shell deformation, shell weight, percentage shell, shell thickness and shell ultra-structure

(Roberts, 2004). For table eggs, shells must be strong enough to prevent failure during packing and/or transportation (Narushin *et al*., 2004). For hatching eggs, shells must be initially thick and strong to preserve the embryo and then it must become thin and weak later during incubation in order to allow gas exchange as well as easier cracking when hatching (Narushin and Romanov, 2002). Interior egg quality is based on albumen quality, yolk quality and the presence of blood or meat spots (Jacob *et al*., 2000).

2.13.1 Shell Thickness

Apparently, birds are affected by stress thus affecting egg formation and the quality of the egg. The feather reduction in the naked neck bird enhances heat loss thereby preventing stress and eventually egg quality parameters According to Njenga (2005), among the birds of Kenya (naked neck dwarf normal feathered), the naked neck bird was superior in term of eggshell thickness. Eggshell in many studies show a significantly higher in the naked neck which confirms the findings of Njenga (2005) and Sharifi (2006), who concluded that the indigenous naked neck birds were significantly higher in shell thickness compared to the frizzle and normal feathered sibs. The reduction in feather coverage of the naked neck birds enables them to receive more solar radiation, which may facilitate vitamin D3 synthesis and in turn, contribute to better shell guality (Akhtar-Uz-Zaman, 2002)

2.13.2 Yolk Colour

The colour of the yolk is determined by the presence or absence of xanthophylls, some of which are precursor of vitamin A. If the feed has plenty of yellow plant pigments, known as xanthophylls, it will be deposited in the yolk. Therefore, yolk colour is influenced by

nutrition and dark yellow colour can be produced by feeding laying birds on green forage meal (smith, 1996).

According to Pavlovski (1981); hens fed mashes containing yellow corn and alfalfa meal lay egg with yellow colour yolks while those eating barley or white corn lay eggs with light colour yolks.

According to Sergeyeva (1986) local chicken under intensive management system laid eggs with thicker shell, which is an important bio-economic trait during egg storage since it encouraged the best use of the nutrients in the egg by the developing embryo. Thick eggshell also reduced the ability of bacteria to penetrate the egg (Fisinin *et al.,* 1990), preventing the egg from dehydration (Rogue and Soares, 1994), and providing protection from damage (Sergeyeva, 1986).

2.14 ALBUMEN QUALITY

Albumen quality has a major influence on overall interior egg quality and thinning of the albumen can point to a quality loss (Mathews, 1986). He also stated that egg with a good albumen quality should be free from internal blemishes such as blood spots, pigment spots and meat spots. The albumen consists of thick and thin material, which in the fresh egg alternatively surrounds the yolk sphere in three concentric layers, the thin layer, the thick fibrous layer, and the outer thin layer (Mathews, 1986). Thick albumen is a gel and thin albumen is a fluid (Brooks and Hale, 1959). The thick albumen forms a capsule around the yolk that is impenetrable in fresh eggs. During storage, the gelatinous structure of thick albumen changes its physical and chemical characteristics and

gradually breaks down into a clear liquid, loosing consistency (Robinson and Monsey, 1972). Albumen quality is measured in terms of Haugh Unit (HU) calculated from the weight of the intact egg and the height of the albumen (Haugh, 1937).

Many factors are reported to affect the albumen quality: storage time, temperature, hen age, strain of bird, nutrition and disease.

2.14.1 EFFECT OF STORAGE TIME AND TEMPERATURE

Egg storage time and conditions are the major factors that affect albumen quality. After the egg is laid, the carbon dioxide (CO_2) evaporates through the shell causing an increase of albumen pH. This loss is faster at higher temperature. The increase in albumen pH can be a reason for the change in viscosity of the albumen. Kemps *et al*. (2007) reported that 65% of the variation in HU is accounted for by an increase in albumen pH. With storage, albumen pH increased and albumen height decreased (Li-Chan and Nakai, 1989). These changes led to a decrease in the HU.

Scott and Silversides (2000) reported that there was no effect of storage time on eggshell weight. However, the principal changes that occur with storage were the decrease in albumen and egg weights. Schäfer *et al*. (1999) reported that with time, the isoelectric point of ovalbumin becomes slightly acidic and this change is in accordance with the formation of S-ovalbumin. They concluded that these changes are related to temperature rather than storage time. Kröckel *et al*. (2005) reported that the microbial growth in the egg increases with age. This growth is related strikingly to storage temperature and time.

2.14.2 CAUSES OF DECREASING ALBUMEN QUALITY

Many mechanisms lead to the liquefaction of egg white including: protease enzyme action, de-polymerization by hydroxyl ion at increasing pH values, reduction by thiol type reducing agents and interaction with lysozyme (Wells and Norris, 1987). Proteolytic enzymes, hydroxyl ion and disulphide bond de-polymerize ovomucin and hence lead to the liquefaction of the albumen (Wells and Norris 1987). However, these substances are not solely responsible for the natural liquefaction of the egg white gel or the natural de-polymerization of ovomucin (Beveridge and Nakai, 1975). In addition, in view of the existence of O-glycosidically linked trisaccharides, specifically in β-ovomucin, enzymatic hydrolysis of this glycosidic link may also be responsible for the liquefaction of the thick egg white gel (Robinson, 1987). This chemical reaction takes place during the natural liquefaction of thick egg white gel at the relatively high pH value of 9.2 in egg white. The destruction of the gelatinous nature of thick egg white can occur due to ovomucin-lysozyme interaction as the pH of the albumen changes after being laid (Robinson and Monsey, 1972).

2.15 FEATHER STRUCTURE AND DISTRIBUTION

Several genes affect plumage condition in the chicken, irrespective of the physiological status of the bird. Some mutations modify feather structure such as frizzle or stringy (Somes, 1988). Frizzle is a mutant in the chicken in which the feathers grow so that they curve outward, instead of lying smoothly along the birds' body. Others affect feather distribution such as the naked neck gene which reduces the surface of feathered areas by 30% to 40% in the homozygous state (*NaNa*) (Touchburn et al., 1980).

Crawford (1977) reported that heterozygous naked neck (*Nana*) can be identified by an isolated tuft of feathers on the ventral side of the neck. This tuft is lacking or reduced to few feathers in homozygous naked neck (*NaNa*). The naked neck gene, *Na*, is a genetic mutant with approximately 30% to 40% reduced feather covering in homozygous *(NaNa*) and approximately 30% reduced covering in heterozygous (*Nana*) (Bordas *et al*., 1978). Likewise, Touchburn *et al*. (1980) suggested that reduced feathering associated with *Na* gene (40% in *NaNa* and 30% in *Nana*) results in increased flexibility in regulating their body temperature (BT) at high ambient temperature.

The main effect of naked neck gene is the reduction of the whole feather percentage especially in neck and breast areas by about 30-40% as compared with the normal chickens (Mérat, 1986; Horst and Rauen, 1986). Accordingly, naked neck chickens can tolerate low dietary protein level more than normal chickens (Monnet *et al*., 1979). The *Na* gene significantly reduced the feather percentage by about 33% either under 16 or 18% crude protein diets. Increasing the dietary protein level significantly elevated the feather percentage for both genotypes (El-Attar *et al*., 1986). Bordas *et al*. (1978) reported that the reduction in total plumage weight by the incompletely dominant (*Na*) gene could not be caused by the plumage lacking in the neck region only. Fewer pterylae were observed in the heterozygous than in the homozygous (27 and 22% for *Nana* and 33% for *NaNa* females and males, respectively). Mérat (1990) concluded that the naked neck gene reduces feather coverage in the chicken by about 20 and 40% in the heterozygous (*Nana*) and homozygous (*NaNa*) states, respectively. Cahaner *et al*. (1993**)** showed that the single dose of the *Na* allele reduced fresh feather mass by 1.25g/100g

body weight, as compared to the normal birds. Furthermore, the double dose caused a reduction of about 1.6g/100g body weight.

Frizzling is a modified plumage conditions arising from the curving of the rachis of all feathers, with curling of the barbs. Action of the frizzling gene has been shown to be localized in the feather follicle and does not result from a metabolic disorder (Landauer and Aberle, 1935). The inheritance of this gene was studied as early as 1906, when Davenport suggested that it was controlled by a dominant gene. However, subsequently, Hutt (1930), Landauer and Dunn, (1930) proved that it is governed by a single autosomal incompletely dominant gene, for which symbol (*F*) was assigned. A recessive modifier gene, restricting the effect of *F* gene, was reported by Landauer (1933) and the symbol *mf* was assigned also to it (Hutt, 1936). The action of the (*F*) gene has been shown to be localized in the feather follicle and does not result from a metabolic disorder (Landauer and Aberle, 1935). It is also not due to the presence of different proteins, but to changes in the spatial distribution of common structural elements (Brush, 1972). Haaren-Kiso *et al*. (1988) showed that the endowment of medium heavy hens with *F*-gene significantly reduces the feathering intensity.

Independent of environmental temperature, Haaren-Kiso *et al*. (1994) reported that the frizzle gene reduced feather intensity (feather weight at slaughter) by more than 40% in the heterozygous (*Ff*) genotype and slightly increased body temperature.

The combination of naked neck and frizzle genes led to a plumage reduction (60%) in *NanaFf* genotype when compared with normally feathered (*nanaff*) (Rauen, 1985).

2.16 THERMOREGULATION AND RESISTANCE TO HEAT STRESS

The Hen's body temperature lies in the range of 41-42°C and remains constant within certain ambient temperature. Touchburn *et al*. (1980) suggested that reduced feathering associated with *Na* gene (40% in *NaNa* and 30% in *Nana*) results in increased flexibility in regulating their body temperature (BT) at high ambient temperature. Bordas and Mérat (1984*)* showed that the increase in heat production in the *Nana* genotype compared to *nana* is relatively low, even at 10°C and is absent at 30°C. There is a slight reduction of body temperature in *Na* birds compared with controls in broiler-types as well as layers (Herremans *et al*. 1988) at low ambient temperatures. Mérat (1986) indicated that either there is no difference in body temperature between naked neck and normal birds or there is a slightly lower BT (0.1 to 0.2°C) for naked neck birds. An increase in the rate of heat loss by naked neck birds, as with a decrease in ambient temperature, should increase protein retention and decrease fat deposition (Leenstra and Cahaner, 1991). This mechanism could also contribute to the higher meat yield of broilers with reduced plumage. Heterozygous naked neck (*Nana*) broilers exhibited about one half of the heat tolerance of homozygous (*NaNa*) ones, but the latter are not commercially feasible (Cahaner *et al*., 1993). Naked neck birds seemed to have a greater change in body temperature than normal birds when exposed to 40.5°C (Eberhart and Washburn, 1993). The same authors found that the lighter body weight birds had a higher basal BT and a smaller change in BT when exposed to acute heat stress than heavier body weight birds.

The increase in body temperature in high ambient temperatures was higher in normally feathered than in naked neck broilers. Consequently, the naked neck broilers exhibited

higher feed intake, growth rate, and meat yield than their normally feathered counterparts (Deeb and Cahaner, 1994). Reduced feather coverage should improve and enhance heat dissipation and consequently alleviate the effects of heat on chickens reared in hot climates (Yahav *et al*., 1996). Likewise, Yalcin *et al*., (1997) reported that the reduction in feather coverage provided relative heat tolerance, and therefore, under hot climates the Nana broilers were superior to their normally feathered counterparts. At 28°C ambient temperature, Benedict *et al*. (1932) found that the heat production of frizzle was greater than in normal fowls. At 17°C the difference was more pronounced, as the homozygous frizzle produced heat twice as much as normal fowls. The frizzle gene appears to increase heat conductivity of the feathers by affecting their structure (Somes, 1990). Haaren-Kiso *et al*. (1992) stated that the combination of *Na* and *F* genes in the heterozygous state may increase heat tolerance compared to only one dose of genes. At 34°C ambient temperature, the surface temperature of normal (*nana ff*), naked neck (*Nana ff*), frizzle (*nana Ff*) and the frizzled-naked neck combination type (*Nana Ff*) were 34.4, 39.9, 39.5 and 40.3°C which helped the adaptation process through increased sensible heat loss from the body surface (Manner, 1992). The combination of *F* and *Na* alleles, and possibly of other genes affecting feathering, may facilitate the breeding of commercial broilers better adapted to hot climates (Cahaner *et al*., 1993).

The effects of *Na* and *F* genes on feathering seem to improve the adaptability through improving physiological buffering capacity, decreasing basal energy metabolism and a general increasing of critical temperature (Horst and Mathur, 1994). After exposing four genetically different feathering types, fully feathered (*nanaff*), fully frizzle feathered

(*nanaFf*), naked neck (*Nanaff*) and naked neck-frizzle (*NanaFf*) to heat stress (34°C), Pech- Waffenschmidt *et al*. (1995) suggested that plumage reduction led to higher body surface temperature, improved heat loss and consequently, lower body temperatures. The reduced feathering in broilers enhances direct heat dissipation by a reduction of insulation plumage and improved thermoregulation of physiological responses under high ambient temperature (Jianxia, 2002).

2.17 PTERYLOSIS OF THE LOCAL CHICKEN

The arrangement of feathers in definite areas on the bird's body is known as pterylosis Birds in general appear to be covered with feathers over their entire body, except for the feet, beak, and eyes. Naked or seemingly naked skin in birds, such as the head region of turkey and vultures, attracts attention because it is atypical. Yet a continuous distribution of feathers over the avian body is found almost exclusively in the "ratitle" cassowaries, emu and ostrich birds. (DeMay., 1942 as cited by Lucas and Stettenheim, 1972).

Among the "carinate" birds, the penguins have almost a complete feather coat but in all others the plumage is interrupted. The feathers are segregated into tracts or groups intermingle with featherless spaces over the body. (DeMay., 1942 as cited by Lucas and Stettenheim, 1972).

The pattern of the feather tracts and the featherless spaces was presented by Nitszsch (1867) as cited by Lucas and Stettenheim (1972). As a result of this extended studies, a basic plan was formulated for Pterylosis of birds in general. He established criteria for the identification of pteryla and for an apterium, the former was to be based on the presence

of contour feathers only, and all the feathers were to be visible on the external surface of the plumage. The latter was identified by the absence of feathers or by the existence of down or semi-plume feathers. (Comptom, 1938) as cited by Lucas and Stettenheim, (1972) was one of the few who indicated boundary lines for each tract.

Although Nitzsch's classification was used as a guide in compiling the key feather tracts (pterylae), the key contains some additions and changes in terminology established by common usage since 1900. In the past, the need for subdividing most pterylae, especially the capital, spinal, and ventral tracts, has brought about the naming of tracts according to the region of the body on which the tract occurs. (Boulton, 1927 as cited by Lucas and Stettenheim, 1972).

The distribution of a group of feathers is often but not always identical with the body region of the same name, chiefly because the feathers may occupy only a small part of the particular region, the remainder being a featherless area. Also, a feather group having the name of one region may extend into an adjacent region. Therefore, it is clearly understood that the feathered region is called tracts and the featherless regions are called apteria. (Nitszsch, 1867 as cited by Lucas and Stettenheim, 1972).

2.18 SOME TRACTS OF THE CHICKEN

The body of bird contains tracts. There are several tracts that contain follicles from which feathers grow. These tracts are located on the body of the bird in regions like the dorsal,

ventral and lateral regions. (Lucas and Stettenheim, 1972). The following are some tracts in the bird;

Capital tracts: The capital tract was named by Nitzsch (1867), who regarded it as a single tract. This tract covers the region of the bird's head.

Caudal tracts: The caudal tracts include 10 groups of feathers; among them are three rows of upper tail coverts and three rows of under tail coverts.

Ventral tracts: Nitzsch (1867) described the ventral tract and its subunits. He recognized three major divisions: a gular portion on the ventral side of the neck, a truncal portion on the breast and belly that is divided longitudinally, and a lateral offshoot of the truncal portion that he named the "lateral tract". To the first two the name ventral cervical tract has been given, to the second "sternal and abdominal tracts" and to the third, "pectoral tract."

Sternal tract: The sternal tract lies on each side of the keel, sometimes close to it and sometimes far laterally. It may be narrow or wide, and it may have continuity with the pectoral tract, but in most species of birds, it does not.

Pectoral tract: The pectoral tract is often stronger than the sternal tract. In most species of birds, the pectoral tract is single, but in the Great Horned Owl this tract has two parts, which are designated the medial and lateral pectoral tracts.

Lateral body tract: The lateral body tract is composed of feathers found on the lateral body surface. The feathers of the lateral body tract are covered by the folded wings.

CHAPTER THREE

3.0 MATERIALS AND METHODS

The first phase of the study was to determine the effect of the Naked Neck (*Na*) and Frizzling (*F*) genes on the fertility and hatchability of two lines of locally developed commercial layer parent lines. The second phase was an experiment on the influence of the feather cover genotypes on the external and internal egg quality parameters while the third phase was a study conducted on the feather pattern (pterylosis) exhibited by birds with the *Na* and *F* genes compared to those with the wild type genes.

3.1 DESCRIPTION OF STUDY AREA AND PERIOD OF STUDY

The research was carried out at the Poultry Farms and Hatchery of Akate Farms and Trading Company Limited at Saaman, Kumasi, Ghana from February 6, 2012 to December 18, 2012. The area has a prevailing tropical climate with the mean ambient daily temperature ranges from 23° to 31°C (73° to 87°F).

3.2 THE EXPERIMENTAL BIRDS

The birds used for the research were obtained from the experimental birds kept by Akate Farms. Three different genetic groups were randomly selected from the stock maintained at the breeding unit of the farm. The genetic groups selected were Naked Neck, Frizzle Feathered and Normal Feathered birds.

Three hundred and sixty (360), twenty four (24) weeks old crossbred females made up of one hundred and twenty (120) heterozygous Naked Neck (*Nanaff*), one hundred and twenty (120) heterozygous Frizzles (*nanaFf*) and one hundred and twenty (120) Normal

Feathered birds (*nanaff*) were housed in eighteen (18) open-sided deep litter pens with twenty (20) females in each pen. The birds used were the offspring of crosses between local heterozygous naked neck (*Nana*) and heterozygous frizzle (*Ff*) males and hybrid commercial Lohmann females. The heterozygous Naked Neck (*Nana*) and heterozygous Frizzles (*Ff*) were crossed with Normal Feathered (*nanaff*) Lohmann Brown Classic layers in two separate mattings producing offspring that were heterozygous for the Naked Neck gene (*Nanaff*), heterozygous for the Frizzle gene (*nanaFf*) and those that had Normal Feathers (*nanaff*) in the first filial (F1) generation (Figure 1).

Figure 1: Illustration of F1 generation

♂ ♀ ♀ ♂

Nanaff X *nanaff* *nanaff* X *nanaFf*

Male gamete		*Naf*	*naf*
Female gamete	*naf*	*Nanaff*	*nanaff*
	naf	*Nanaff*	*nanaff*

Male gamete		*naF*	*naf*
Female gamete	*naf*	*nanaFf*	*nanaff*
	naf	*nanaFf*	*nanaff*

Nanaff♂ = Naked neck male, *nanaff*♀ = normal feather female, *nanaFf*♂ = frizzle male

The F1 heterozygous Naked Neck males were then mated to the F1 heterozygous Frizzle females in a reciprocal cross to produce *NanaFf*, *nanaFf*, *Nanaff* and *nanaff* in the F2 generation in both mattings (figure 2).

Figure 2: Illustration of F2 generation

♀ ♂ ♂ ♀

nanaFf X *Nanaff* *nanaFf* X *Nanaff*

	Male gamete *Naf*	Male gamete *naf*
Female gamete	*naF*	*NanaFf*
Female gamete	*naf*	*Nanaff*

	Male gamete *naf*	Male gamete *naf*
Female gamete	*Naf*	*NanaFf*
Female gamete	*naf*	*nanaFf*

Nanaff♂ = Naked neck male, *nanaff*♀ = normal feather female, *nanaFf*♂ = frizzle male

The Naked Neck (*Nanaff*), Frizzle (*nanaFf*), Normal Feathered (*nanaff*) and double heterozygous Frizzled-Naked Neck birds *(NanaFf*) of the second filial generation (F2) were selected and mated producing homozygous Naked Neck (*NaNaff*), heterozygous Naked Neck (*Nanaff*), homozygous Frizzles (*nanaFF*), heterozygous Frizzle (*nanaFf*), Normal Feathered (*nanaff*) and Frizzled Naked Neck birds (*NaNaFf, NanaFF, NanaFf and NaNaFF*) as the third filial (F3) generation.

Heterozygous Naked Neck *(Nanaff*), heterozygous Frizzle (*nanaFf*) and Normal Feathered (*nanaff*) birds of the F4 generation were selected for this research work.

Plate 1: Brown Naked Neck chickens

Plate 2: White Naked Neck Chicken

Plate 3: Brown Frizzle Chickens

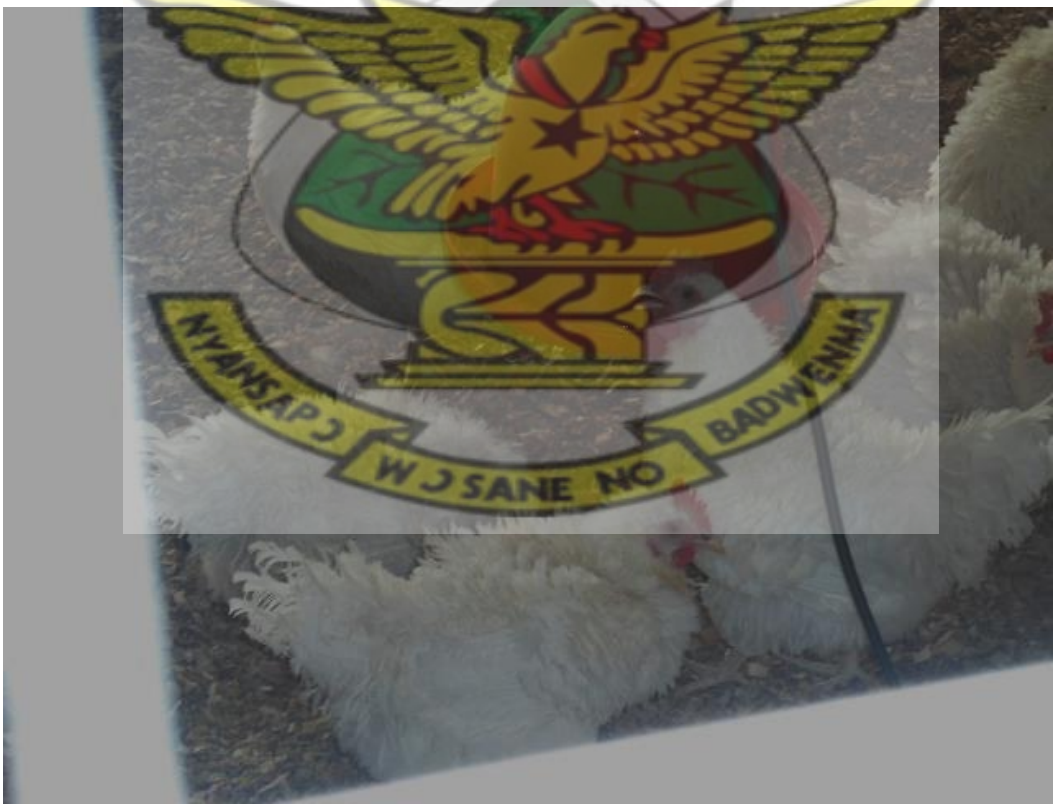

Plate 4: White Frizzle Chickens

Plate 5: Brown Normal Feathered Chickens

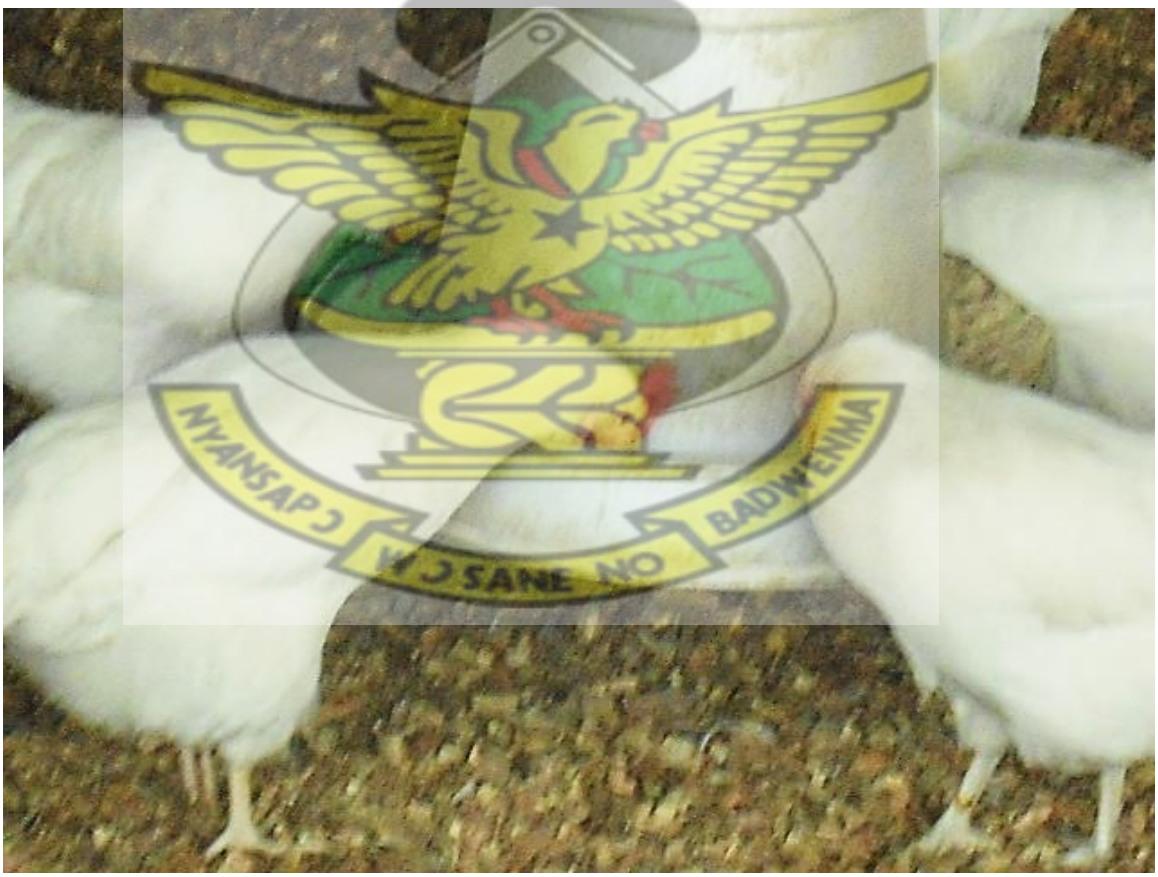

Plate 6: White Normal Feathered Chickens

3.3 HOUSING AND MANAGEMENT

The different genotypes were kept in eighteen (18) open-sided deep litter pens with twenty (20) females in each pen suitable for the quantitative measurements of egg production and feed intake.

3.3.1 DISEASES AND PARASITE CONTROL

Vaccination was carried out for Newcastle and gumboro. A Coccidiostat, amprolium was added to their drinking water occasionally to control coccidiosis. Treatment for worms and lice were occasionally done using Levasol and Ectomin respectively (Table 2). Procedures for vaccination were as recommended by the Veterinary Directorate of ministry of food and Agriculture and dosage were given according to the manufacturer's specification.

Table 2. Vaccination schedules and medication

Week	Vaccine	Method of administration
1	HB1	Drinking Water
2	Gumboro	Drinking Water
4	Lasota	Drinking Water

Source: Akate Farm and Hatchery Co. Ltd.

3.3.2 FEEDING

The birds were fed layer mash containing crude protein and metabolizable (table 3) energy from 24 weeks of age to the end of the experiment (46 weeks). The feed and water was supplied ad libitum.

Table 3: Feed composition of the layer mash fed the birds

Feed	Amount/Kg
Maize	520
Concentrate	50
Cotton	50
Wheat brand	140
Soya beans	145
Salt	95
Toxin blander	

Source: Akate Farm and Hatchery Co. Ltd.

3.4 EGG COLLECTION PROCEDURE

Eggs were collected for a period of 9 months for the determination of hatchability and fertility and also for the measurement of egg quality parameters.

Collection of fertile eggs began seven days after introducing the males. The eggs were collected two times daily. Only sound eggs, without cracks and discoloration, were selected for incubation. The eggs were properly labeled to indicate the batch number, genotype, and the date of lay before sending them to the hatchery each week.

3.4.1 EGG STORAGE AND PRESERVATION

After the collection of eggs, the eggs were screened for cracks, morphological deformities and dirt stains (soiled) and stored for one to seven days under hatchery storage temperature after which the eggs were conveyed for incubation at the Akate Farm's Hatchery at Bosori, Kumasi. Proper cleaning, disinfection and fumigation were carried out before setting of eggs.

3.5 INCUBATION, CANDLING AND HATCHING

The clearly labeled eggs were placed with the large end up in the setting trays. The eggs were set at the temperature of 38-39^{o}C and humidity of 60-65% for the first eighteen days. After which eggs with living embryos were then transferred to the hatching chamber of the incubator.

Candling was carried out on the 18th day of incubation for the identification of fertile eggs. The process was carried out in a dark room using a Candler. The fertile eggs were seen to be densely clouded and opaque with network of veins indicating development of embryo within the eggs while the infertile eggs were translucent under the light. Numbers of infertile eggs and embryonic mortality were recorded. After candling, the fertile eggs were transferred into the hatching tray, according to the genotypes and then into the hatching unit. After the chicks had hatched, they were left in the hatchery until 90% were dried.

On the 21st day, the numbers of hatched chicks (including the normal, weak and abnormal) and dead-in-shell embryos were recorded.

3.6. EGG DATA COLLECTION

The egg production, reproduction and survival parameters taken included:

1. Egg number: this is the total number of eggs laid by each genotype during the experimental period.
2. Percentage of eggs set: This is the percentage of eggs set, out of the total number of eggs collected.

   $$\text{Percentage egg set} = \frac{\text{Eggs set}}{\text{Eggs collected}} \times 100$$
3. Percentage fertility: This was taken as the percentage of eggs that were fertile out of the eggs set.

   $$\text{Percentage Fertility} = \frac{\text{Total number of fertile eggs}}{\text{Total number of set eggs}} \times 100$$
4. Percentage Hatchability: This was taken as the percentage of eggs that hatched out of all the fertile eggs set.

   $$\text{Percentage Hatchability} = \frac{\text{Total number of chicks hatched}}{\text{Total number of fertile eggs}} \times 100$$
5. Percentage dead- in- shell: This was taken as the percentage of dead- in- shell embryos out of all the fertile eggs set

   $$\text{Percentage dead- in- shell} = \frac{\text{Number of dead in shell}}{\text{Number of fertile eggs}} \times 100$$
6. Chick weights were taken right after the chicks were pulled out of the incubator using a 500 grams digital scale

Eggs were collected for egg quality analysis which was done in the Physics Lab of the Department of Physics at the Kwame Nkrumah University of Science and Technology. Data taken included:

A.

1. Egg weight – by using electronic balance with 0.5g precision
2. Egg width using a digital Vernier caliper
3. Egg length using a digital Vernier caliper
4. shell thickness – using micrometer screw gauge

B.

1. yolk color – using Roche yolk colour fan
2. Yolk height using a tripod Spheremeter
3. Yolk weight – using a digital scale
4. Yolk index = $\frac{\text{yolk height}}{\text{Average yolk width}} \times 100$

C

1. albumen weight- using a digital scale
2. Albumen height – using a sphere meter
3. Albumen width – using a ruler
4. Shape index = $\frac{\text{maximum width}}{\text{Maximum length}} \times 100$
5. Haugh unit = $100 \times \log(h - 1.7w^{0.37} + 7.6)$

   w = Weight of egg in gram, h = Observed height of the albumen in millimeters

3.7 PTERYLOSIS

Twenty seven (27) birds, nine (9) from each feather types naked (neck, frizzle and normal feathered) were slaughtered for the determination of the feather pterylosis of the dorsal, ventral, and lateral regions of the birds' body. The study was carried out at the Poultry Section of the Department of Animal Science at the Kwame Nkrumah University of Science and Technology. The pterylae of some tracts of the three regions were counted as to the number of lines and follicles of pteryla found in each tract of each region. The results were then analyzed.

3.8 Experimental Design: The experimental design was 2 X 3 factorial experiments in a Randomized Complete Block Design with (2 lines- white and brown birds and 3 feather cover genotypes *Nanaff, nanaFf* and *nana/ff*) with three replications (Table 4).

There were 360 experimental birds made up of 180 female line and 180 male line parents. This design was used for fertility, hatchability and all egg quality work. While a completely randomized design was used for the pterylosis work.

Table 4 showing feather cover genotype and replication

Line	**Feather cover genotypes**	**Replication**		
		1	**2**	**3**
White	*Nanaff*	20	20	20
	nanaFf	20	20	20
	Nanaff	20	20	20
Brown	*Nanaff*	20	20	20
	nanaFf	20	20	20
	Nanaff	20	20	20

Nanaff = Naked neck strain, n*anaFf* = Frizzle strain, *nanaff* = No feathered strain

3.8.1 STATISTICAL ANALYSIS

Data were analyzed using the PROC MIXED procedure of SAS at $P \leq 0.05$ (SAS Institute, 2012). Where significant differences were observed, the least squares means were separated by the PDIFF procedure of SAS (SAS Institute, 2012). All data were analyzed for the main effect of fertility, hatchability, egg quality and pterylosis in a randomized design. All data were analyzed for the main effect of egg weight, egg length, egg diameter, egg shell thickness, yolk colour, yolk diameter, albumen weight, albumen height, albumen diameter, shape index, albumen index, yolk index, Haugh unit, chick hatch weight, hatchability and fertility for the locally developed parent lines. All data were calculated to evaluate the relationship between egg weight, egg length, egg diameter, yolk colour, chick hatch weight, hatchability and fertility. Significance for all tests was at $p<0.05$ unless stated otherwise.

The linear model below was used for the data analysis.

$$Y_{ijk} = \mu + \alpha_i + \beta_j + \lambda_k + \alpha_i\beta_j + \varepsilon_{ijkl}$$

Where, Y_{ijk} = effect measured, μ = Overall mean, α_i = main effect of genetic strain, β_j = main effect of feather colour, λ_k = random effect due to either number of birds or number of times experiment was replicated or number of eggs selected for experiment and ε_{ijk} = residual error term. $\alpha_i\beta_j$ = interaction of genetic strain and feather colour,

Data for pterylosis were analyzed using the PROC MIXED procedure of SAS at $P \leq 0.05$ (SAS Institute, 2012). Where significant differences were observed, the least squares means were separated by the PDIFF procedure of SAS (SAS Institute, 2012). All data were analyzed for the main effect of number of line and follicles in completely randomized design.

The linear model below was used for the data analysis.

$$Y_{ik} = \mu + \alpha_i + \lambda_k + \varepsilon_{ikl}$$

Where, Y_{ik} = effect measured, μ = Overall mean, α_i = main effect of genetic strain, λ_k = random effect due to either number of birds or number of times experiment was replicated and ε_{ik} = residual error term.

CHAPTER FOUR

4.0 RESULTS

Fertility is the fertile status of groups of eggs laid over a period of time by single hens, by a small group of hens or by a commercial flock. Table 5 shows the fertility of eggs as affected by the various genotypes in this study

Table 5. Effect of feather cover genotype and feather colour on fertility of two locally developed layer parent lines

	Egg set (%)	Fertile eggs (%)
Feather cover genotype		
Naked neck (*Nanaff*)[1]	99.33	71.99[a]
Frizzle (*nanaFf*)[2]	99.13	70.29[a]
Normal (*nanaff*)[3]	98.86	63.17[b]
SEM[4]	0.2001	1.98
Feather colour (FC)		
Brown (*s*-)[5]	98.84[b]	64.93[b]
White (*S*-)[6]	99.38[a]	72.03[a]
SEM	0.1634	1.62
Feather*FC		
Naked neck* brown (*Nanaffs*-)	99.04	71.73[a]
Naked neck*white (*NanaffS*-)	99.62	72.25[a]
Frizzle*brown (*nanaFfs*-)	98.85	67.95[a]
Frizzle*white (*nanaFfS*-)	99.41	72.64[a]
Normal feather*brown (*nanaffs*-)	98.62	55.13[b]
Normal feather*white (*nanaffS*-)	99.10	71.20[a]
SEM	0.2830	2.74
P-value		
Feather cover genotype	0.2481	0.0031
Feather colour	0.0211	0.0012
Feather type*Feather colour	0.984	0.0157

Superscripts [a-c] indicate significant difference between means in column ($p<0.05$)
[1]Naked neck strain, [2]Frizzle strain, [3]Normal feathered strain, [4]Standard error of means, [5]Brown birds, [6]White birds (s- = brown, S- = white)

4.1 FERTILITY

4.1.1 Feather cover genotype: There was no significant ($p>0.05$) difference among the three feather cover genotypes for percent egg set. However, the naked neck (*Nanaff)* and

frizzled birds (*nanaFf)* recorded significantly ($p<0.05$) higher percentage values for fertile eggs compared to their normal feathered (*nanaff*) counterparts (Table 5)

4.1.2 Feather colour: The white feather birds (*S*-) recorded significantly ($p<0.05$) higher more values for percent egg set and percent fertile eggs compared to the brown birds (*s*-), (Table 5).

4.1.3 Interactions: The results show no significantly differences value for the interaction between feather colour and feather cover. Normal feathered brown birds showed significantly lower values ($p<0.05$) for percent fertile eggs compared to brown and white naked neck, brown and white frizzled birds and normal feathered white birds while there was no significant differences ($p>0.05$) between brown and white naked neck birds (Table 5).

Hatchability as affected by the different feather cover and feather colour genotype.

Table 6. Effect of feather cover genotype and feather colour on hatchability of two locally developed layer parent lines

	Number of fertile eggs set	Average # of chicks hatched	# of chicks culled	# of Dead-in-shell	Total hatchability (%)	Hatchability of fertile (%)	Chick weight (g)
Feather Cover Genotype							
Naked neck (*Nanaff*)[1]	109.06[b]	57.62[b]	2.067[b]	45.36	42.41	58.37	41.17
Frizzle (*nanaFf*)[2]	121.79[a]	72.21[a]	4.46[a]	45.40	43.04	60.55	39.60
Normal (*nanaff*)[3]	108.46[b]	62.10[b]	2.99[ab]	43.07	38.14	57.97	47.78
SEM[4]	3.98	3.60	0.67	2.98	2.06	2.21	5.14
Feather colour (FC)							
Brown (*s*-)[5]	109.45	52.94[b]	1.47[b]	54.11a	32.10[b]	48.68[b]	40.75
White (*S*-)[6]	116.75	75.02[a]	4.87[a]	35.10b	50.30[a]	69.24[a]	44.96
SEM	3.33	2.94	0.55	2.44	1.68	1.81	4.20
Feather*FC							
Naked neck* brown (*Nanaffs*-)	122.21[a]	58.05[b]	1.13[c]	60.10	35.32	49.79	43.44
Naked neck*white (*NanaffS*-)	95.91[c]	57.19[b]	3.00b[c]	30.62	49.51	66.94	38.91
Frizzle*brown (*nanaFfs*-)	112.62[b]	55.81[b]	1.46[c]	54.02	33.85	49.28	39.64
Frizzle*white (*nanaFfS*-)	130.95[a]	88.62[a]	7.47[a]	36.78	52.24	71.82	39.55
Normal feather*brown (*nanaffs*-)	93.53[c]	44.95[b]	1.83[bc]	48.23	27.13	46.99	39.16
Normal feather*white (*nanaffS*-)	123.39[a]	79.24[a]	4.15[b]	37.90	49.14	68.96	56.41
SEM	5.36	5.09	0.94	4.18	2.91	3.13	7.27
P-value							
Feather cover genotype	0.0178	0.0154	0.037	0.8139	0.1916	0.6756	0.4908
Feather color	0.0697	<.0001	<.0001	<.0001	<.0001	<.0001	0.4784
Feather type*Feather color	<.0001	0.0008	0.053	0.0716	0.4082	0.6404	0.2907

Superscripts [a-c] indicate significant difference between means in column, ($p \leq 0.05$) [1]Naked neck (*Nanaf*) strain, [2]Frizzle (*nanaFf*) strain, [3]Normal feather strain, [4]Standard error of means, [5]Brown birds, [6]White bird, (*s*- = brown, *S*- = white)

4.2 HATCHABILITY

4.2.1 Feather cover genotype: The frizzles (*nanaFf*) had a significantly higher number of fertile eggs, average number of chicks hatched and chicks culled compared to the naked neck (*Nanaff*) and normally feathered birds (*nanaff*) but there was no significant difference ($p>0.05$) among the birds for dead-in-shell, total hatchability, hatchability of fertile eggs and chick weight (Table 6).

4.2.2 Feather colour: The white birds performed significantly better ($p<0.05$) for average number of chicks hatched, total chicks hatched and percent chicks hatched of fertile eggs compared to the brown feather birds while the brown birds recorded a significantly ($p<0.05$) higher value for number of dead-in-shell compared to the white birds. There was no significant ($p>0.05$) difference between the two colours for number of fertile eggs and the weight of the chicks hatched for the two feather colours (Table 6).

4.2.3 Interactions: The *Nanaffs-*, *nanaFfS-* and *nanaffS-* had significantly higher values for number of fertile eggs set compared to their sibs. With respect to the average number of chicks hatched, frizzled white and normal feathered white birds performed significantly ($p<0.05$) better than all the others (Table 6).

4.3 EXTERNAL EGG QUALITY MEASUREMENTS

External egg quality as affected by the naked neck and frizzling genes two commercial layer parent lines.

Table 7. Effect of feather cover genotype and feather colour on external egg characteristics

	EW (g)[1]	EL (mm)[2]	ED (mm)[3]	ST (mm)[4]	SI[5]
Feather Cover Genotype					
Naked neck (*Nanaff*)[6]	61.68	57.47	43.06	0.52	74.96
Frizzle (*nanaFf*)[7]	61.35	57.35	42.97	0.52	74.93
Normal (*nanaff*)[8]	59.51	56.61	42.69	0.52	75.41
SEM[9]	0.7013	0.5287	0.3197	0.0010	0.3818
Feather colour (FC)					
Brown (s-)[10]	62.31^{a}	57.45	43.17	0.52	75.17
White (S-)[11]	59.39^{b}	56.84	42.64	0.52	75.03
SEM	0.5726	0.4552	0.2610	0.0008	0.3700
Feather*FC					
Naked neck* brown (*Nanaffs*-)	64.74^{a}	59.09^{a}	43.88	0.5196	74.27^{d}
Naked neck*white (*NanaffS*-)	58.62^{c}	55.84^{b}	42.24	0.5174	75.65^{ab}
Frizzle*brown (*nanaFfs*-)	62.10^{ab}	56.98^{b}	42.98	0.5172	75.46^{ab}
Frizzle*white (*nanaFfS*-)	60.59^{bc}	57.73^{ab}	42.96	0.5175	74.41^{cd}
Normal feather*brown (*nanaffs*-)	60.07^{bc}	56.27^{b}	42.64	0.5153	75.78^{a}
Normal feather*white (*nanaffS*-)	58.95^{c}	56.95^{b}	42.73	0.5194	75.04^{bc}
SEM	0.9918	0.7047	0.4521	0.0014	0.4150
P-value					
Feather cover genotype	0.1019	0.4017	0.6909	0.6522	0.1157
Feather colour	0.0036	0.2839	0.1803	0.5226	0.4928
Feather type*Feather colour	0.0488	0.0190	0.1444	0.1112	0.0007

Superscripts $^{a-d}$ indicate significant difference between means in column ($p<0.05$)
[1]Egg weight in grams, [2]Egg Length, [3]Egg diameter, [4]shell thickness, [5]Shape index=egg diameter/egg length*100, [6]Naked neck strain, [7]Frizzle strain, [8]Normal feathered strain, [9]Standard error of means, [10]Brown birds, [11]white birds, g = grams, mm = millimeter (*s*- =brown, *S*- = white)

4.3.1 Feather cover genotype: There was no significant ($p>0.05$) difference among the feather cover genotypes with respect to egg weight, egg length, egg diameter, shell thickness and shape index (Table 7).

4.3.2 Feather colour: Brown feathered birds displayed significantly ($p<0.05$) higher values for egg weight compared to the white feathered birds but there were no significant differences between the white and brown feathered birds for egg length, egg width, shell thickness and shape index (Table 7).

4.3.3 Interactions for egg weight: *Nanaffs-* (brown line naked neck birds) produced significantly ($p<0.05$) heavier eggs compared to *NanaffS-* (white Naked Neck), *nanaFfS-* (white frizzles) and both brown and white normal feathered birds but no significant ($p<0.05$) differences existed between *Nanaffs-* and *nanaFfs-*. Also, there was no significant difference among *nanaFfS-*, *nanaffs-*, *NanaffS-* and *nanaffS-* (Table 7).

4.3.4 Egg length: Brown naked neck birds (*Nanaffs-*) had significantly ($p<0.05$) longer egg lengths compared to all the other feather color combination except *nanaFfS-*. Also, there were no significant ($p<0.05$) differences among the other feather type and feather colour combinations (Table 7).

4.3.5 Egg diameter: There was no significantly ($p>0.05$) higher values for egg diameter for all interaction of feather cover and feather colour genotype (Table 6).

4.3.6 Egg shell thickness: The data indicated that there was no significantly ($p>0.05$) difference for shells thickness amount the feather cover and feather colour genotype (Table 7).

4.3.7 Shape index: There were significant ($p<0.05$) differences observed for shape index for *nanaffs-* compared to *Nanaffs-* and *nanaffS-* but there was no significant ($p<0.05$) difference among *NanaffS-*, *nanaFfs-* and *nanaffs-* (Table 7).

4.4 INTERNAL EGG QUALITY PARAMETERS OF THE YOLK

Internal egg characteristic of the yolk as affected by the various genotypes

Table 8. Effect of feather cover genotype and feather colour on egg yolk characteristics

	YW (g)[1]	YD (mm)[2]	YH (mm)[3]	YI[4]	YC[5]
Feather Cover Genotype					
Naked neck (*Nanaff*)[6]	16.6[a]	37.32[a]	10.30	27.60[b]	4.15
Frizzle (*nanaFf*)[7]	16.51[a]	36.98[b]	10.26	27.74[b]	4.01
Normal (*nanaff*)[8]	15.70[b]	36.45[c]	10.29	28.24[a]	3.86
SEM[9]	0.1498	0.1111	0.0153	0.0790	0.0987
Feather colour (FC)					
Brown (*s*-)[10]	16.15	36.78[b]	10.3	28.00[a]	3.99
White (*S*-)[11]	16.44	37.05[a]	10.3	27.72[b]	4.03
SEM	0.1223	0.0976	0.0125	0.0684	0.0806
Feather*FC					
Naked neck* brown (*Nanaffs*-)	16.78	37.30	10.32	27.67	4.16
Naked neck*white (*NanaffS*-)	16.59	37.34	10.28	27.54	4.15
Frizzle*brown (*nanaFfs*-)	16.33	36.85	10.27	27.86	3.91
Frizzle*white (*nanaFfS-)*	16.69	37.10	10.25	27.62	4.12
Normal feather*brown (*nanaffs-)*	15.36	36.19	10.31	28.48	3.90
Normal feather*white (*nanaffS*-)	16.05	36.71	10.27	27.99	3.82
SEM	0.2118	0.1443	0.0216	0.1044	0.1397
P-value					
Feather Cover Genotype	0.0013	0.0002	0.1299	0.0002	0.1555
Feather colour	0.1243	0.0299	0.1146	0.0045	0.7350
Feather type*Feather colour	0.1596	0.2321	0.8919	0.2192	0.5547

Superscripts [a-d] indicate significant difference between means in column, ($p<0.05$)
[1]Yolk weight in grams, [2]Yolk diameter in millimeter, [3]Yolk height in millimeter, [4]yolk index= yolk height/yolk diameter, [5]Yolk colour, [6]Naked neck strain, [7]Frizzle strain, [8]Normal feathered strain, [9]Standard error of means, [10]Brown birds, [11]White birds (*s*- = brown, *S*- = white)

4.4.1 Feather cover genotype: The naked neck and frizzled birds laid eggs that had significantly ($p<0.05$) higher yolk weight compared to their normal feathered sibs. The *Nanaff* also produced eggs with significantly ($p<0.05$) higher yolk diameter than their *nanaFf* and *nanaff* sibs while, the normal feathered (*nanaff*) showed a significantly ($p<0.05$) higher yolk index over the *Nanaff* and *nanaFf*. There was no significant difference in yolk weight and yolk colour score for all three feather types (Table 8).

4.4.2 Feather colour: There were no significant ($p>0.05$) differences in yolk weight, yolk height and yolk colour score but the white colour birds showed significantly ($p<.05$) higher average yolk diameter compared to the brown color birds while the brown birds had significantly ($p<0.05$) higher values for yolk index over the white birds (Table 8).

4.4.3 Interactions: There was no significantly ($p>0.05$) higher values for all the parameters taken for interactions of feather cover and feather colour genotype (Table 8).

4.5 INTERNAL EGG QUALITY MEASUREMENTS OF THE ALBUMEN

Internal egg characteristics of albumen qualities as affected by feather cover and feather colour genotype in this study

Table 9. Effect of feather cover genotype and feather colour on albumen characteristics

	Al weight (g)[1]	Al diameter (mm)	Al height (mm)	Al index2	HU[3]
Feather Cover Genotype					
Naked neck (*Nanaff*)[4]	34.82	95.23[a]	7.28[a]	7.62[a]	84.82[a]
Frizzle (*nanaFf*)[5]	35.32	91.71[b]	6.55[b]	7.14[b]	80.32[b]
Normal (*nanaff*)[6]	34.71	91.25[b]	6.52[b]	7.15[b]	80.66[b]
SEM[7]	0.3325	0.5000	0.0763	0.0994	0.5508
Feather colour (FC)					
Brown (*s*-)[8]	35.89[a]	94.09[a]	7.15[a]	7.58[a]	83.8[3a]
White (*S*-)[9]	34.00[b]	91.37[b]	6.42[b]	7.03[b]	80.03[b]
SEM	0.2715	0.4083	0.0623	0.0812	0.4497
Feather*FC					
Naked neck* brown (*Nanaffs*-)	37.03[a]	98.34[a]	8.21[a]	8.35[a]	89.87[a]
Naked neck*white (*NanaffS*-)	32.60[c]	92.11[b]	6.34[b]	6.89[b]	79.77[b]
Frizzle*brown (*nanaFfs*-)	35.50[b]	91.97[b]	6.58[b]	7.15[b]	80.23[b]
Frizzle*white (*nanaFfS*-)	35.13[b]	91.46[b]	6.53[b]	7.14[b]	80.40[b]
Normal feather*brown (nanaffs-)	35.14[b]	91.96[b]	6.65[b]	7.24[b]	81.39[b]
Normal feather*white (*nanaffS*-)	34.28[b]	90.53[b]	6.39[b]	7.05[b]	79.93[b]
SEM	0.4702	0.7071	0.1079	0.1406	0.7789
P-value					
Feather cover Genotype	0.4166	0.0002	0.0001	0.0079	0.0001
Feather colour	0.0004	0.0005	0.0001	0.0004	<.0001
Feather type*Feather colour	0.0019	0.0034	0.0001	0.0004	<.0001

Superscripts [a-d] indicate significant difference between means in column
[1]Al = albumen, [2]Al index= Al height/Al diameter*100, [3]HU = Haugh unit = 100*log(h – 1.7w$^{0.37}$ + 7.6), [4]Naked neck strain, [5]Frizzle strain, [6]Normal feathered strain, [7]Standard error of means, [8]brown birds, [9]white birds, g = grams, mm = millimeter, (*s*- = brown, *S*- = white)

4.5.1 Feather cover genotype: Average values for albumen diameter, albumen height, albumen index and Haugh unit were significantly higher in eggs from *Nanaff* (naked necks) compared to *nanaFf* (frizzled birds) and *nanaff* (normal feathered birds) while

there was no significant (p>0.05) difference in albumen weight for the three feather cover genotypes (Table 9).

4.5.2 Feather colour: The brown feathered birds showed significantly (p<0.05) higher albumen weight, albumen diameter, albumen height and HU compared to white feathered birds (Table 9).

4.5.3 Interactions: *Nanaffs-* values were significantly (p<0.05) higher for all albumen parameters compared to the other feather cover genotypes in this study (Table 9).

4.6 PTERYLOSIS OF THE DORSAL, VENTRAL AND LATERAL REGIONS

Table 10 shows the number of feather lines of the dorsal region as affected by the naked neck and frizzling genes.

Table 10. Effect of feather cover genotype on the number of lines in feather tracts of the dorsal region

Feather cover genotype	Dorsal caudal tract	Dorsal cervical tract	Dorsopelvic tract	Interscapular tract
Nanaff[1]	5.00[b]	0.00[b]	23.33	6.33[b]
nanaFf[2]	6.00[a]	17.33[a]	23.67	10.67[a]
nanaff[3]	6.33[a]	17.33[a]	23.00	11.33[a]
SEM4	0.19	0.27	0.27	0.47
P-value[5]	0.018	<.0001	0.25	0.001

Superscripts [a-b] indicate significant difference between means in column, (p<0.05)
[1]Naked neck, [2]Frizzle, [3]Normal feathered, [4]Sstandard error of mean, [5]Pprobability value

4.6.1 Dorsal Region: Average values for the dorsal caudal tract, dorsal cervical and interscapular tract showed significantly (p<0.05) lower numbers of lines in the naked neck compared to their frizzle and normal feathered sibs. There was no significant difference for the dorsopelvic tract among the three feather cover genotypes (Table 10) and (plates 7-9)

Plate 7: Dorsopelvic Tract of Normal Feathered Chicken

Plate 8: Dorsopelvic Tract of Frizzle Chicken

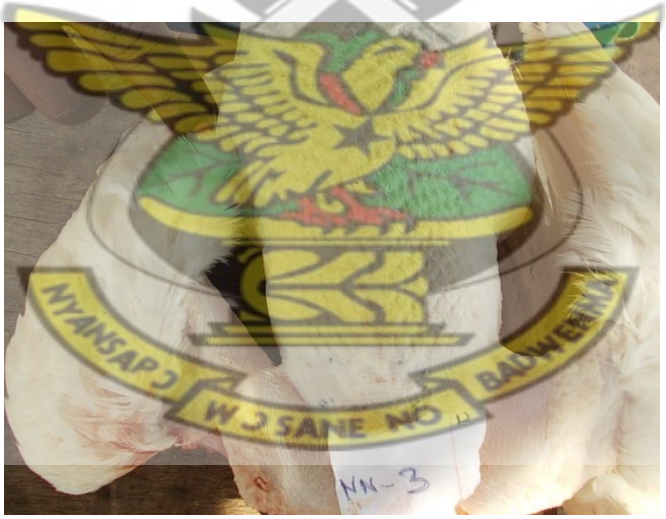

Plate 9: Dorsopelvic Tract of Naked Neck Chicken

Pterylosis of the ventral region showing the number of line in feather tracts as affected by feather cover and feather colour genotype.

Table 11. Effect of feather cover genotype on the number of lines in feather tracts of the ventral region

Feather cover genotype	Pectoral tract	Sternal tract	ventral cervical apterium	ventral cervical tract
Nanaff[1]	16.00[b]	2.00[c]	0.00[c]	5.33[b]
nanaFf[2]	19.00[a]	4.00[b]	6.33[b]	16.00[a]
nanaff[3]	17.00[b]	5.67[a]	7.33[a]	15.67[a]
SEM[4]	0.33	0.19	0.27	0.51
P-value[5]	0.01	0.0005	<.0001	<.0001

Superscripts [a-c] indicate significant difference between means in column, ($p<0.05$)
[1]Naked neck strain, [2]Frizzle strain, [3]Normal feathered strain, [4]Standard error of means, [5]Probability value

4.6.2 Ventral Region: The naked neck had a significantly ($p<0.05$) lower number of lines in the pectoral tract, sternal tract, ventral cervical apterium and ventral cervical tract compared to the frizzled and normal feathered birds while the frizzled birds showed a significantly ($p<0.05$) lower number of lines for sternal and ventral cervical tracts compared to that of the normal feathered (Table 11) and (plate 10).

Plate 10: Sternal Tract of Normal Feathered (*cc*), Frizzle (*Ff*) and Naked Neck (*Na*)

Pterylosis of the lateral region showing the number of line in feather tracts as affected by feather cover and feather colour genotype.

Table 12. Effect of feather cover genotype on the number of lines in the feather tracts of the lateral region

Feather cover genotype	femoral tract	Lateral body tract
Nanaff[1]	16.67[b]	1.00[b]
nanaFf[2]	22.33[a]	4.33[a]
nanaff[3]	19.67[ab]	4.00[a]
SEM[4]	0.82	0.19
P-value[5]	0.0193	0.0005

Superscripts a-b indicate significant difference between means in column, ($p<0.05$)
[1]Naked neck strain, [2]Frizzle strain, [3]Normal feathered strain, [4]Standard error of means, [5]Probability value

4.6.3 Lateral Region: The naked neck had a significantly lower ($p<0.05$) number of feather lines in the femoral tract compared to the frizzled birds but there was no difference ($p>0.05$) between frizzle and normal feathered, and naked neck and normal feathered birds. The naked neck had a significantly ($p<0.05$) lower number of feather lines in the lateral body tracts than the frizzle and normal feathered locally developed commercial layer parents (Table 12) and (plate 11)

Plate 11: Lateral Body Tract of Normal feathered (*cc*), Naked Neck (*Na*) and Frizzle (*Ff*)

4.7 FOLLICLES MEASURED OF THE DORSAL, VENTRAL AND LATERAL REGIONS

The pterylosis of the number of follicles found in the dorsal region as affected by the naked neck and frizzling genes are shown in (Table 13) below.

Table 13. Effect of feather cover genotype on the number of follicles of feather tracts of the dorsal region

Feather cover genotype	Dorsal caudal tract	Dorsal cervical tract	Dorsopelvic tract	Interscapular tract
Nanaff[1]	56.00[b]	0.00[c]	445.67	73.00[b]
nanaFf[2]	63.33[a]	218.67[b]	454.67	114.67[a]
nanaff[3]	67.6[a]	242.33[a]	469.00	115.33[a]
SEM[4]	1.75	3.90	18.69	3.26
P-value[5]	0.009	<.0001	0.689	0.001

Superscripts a-b indicate significant difference between means in column, ($p<0.05$)
[1]Naked neck strain, [2]Frizzle strain, [3]Normal feathered strain, [4]Standard error of means, [5]Probability value

4.7.1 Dorsal Region: Average values for dorsal caudal, dorsal cervical, and interscapular tracts were significantly lower for feather follicles in the naked neck as compared to the frizzle and normal feathered genotypes. But the frizzle possessed significantly ($p<0.05$) lower feather follicles in the dorsal cervical tract as compared to the normal feathered strain and no significant ($p>0.05$) difference was observed in the dorsopelvic tract for the three feather cover genotypes (Table 13).

The pterylosis of the number of follicles found in the ventral region as affected by the naked neck and frizzling genes are shown in (Table 14) below.

Table 14. Effect of feather cover genotype on the numbers of follicles of feather tracts found in the ventral region

Feather cover genotype	Pectoral tract	Sternal tract	Ventral cervical apterium	Ventral cervical tract
Nanaff[1]	87.00[c]	15.67b	-355[-17b]	0.00[c]
nanaFf[2]	117.67[b]	21.00a	10.33[a]	217.00[b]
nanaff[3]	144.00[a]	19.33a	13.33[a]	229.33[a]
SEM[4]	4.05	0.794	1.23	1.61
P-value[5]	0.0002	0.0083	0.001	<.0001

Superscripts [a-c] indicate significant difference between means in column, ($p<0.05$)
[1]Naked neck strain, [2]Frizzle strain, [3]Normal feathered strain, [4]Standard error of means, [5]Probability value

4.7.2 Ventral Region: The naked neck was observed to have a significantly ($p<0.05$) lower value for the number of follicles in the pectoral tract, sternal tract, ventral cervical apterium and ventral cervical tract compared to the frizzle and normal feathered birds. The frizzle on the other hand showed a significantly ($p<0.05$) lower number of follicles for the pectoral and ventral cervical tracts compared to the normal feathered strain (Table 14).

The pterylosis of the number of follicles found in the lateral region as affected by the naked neck and frizzling genes are shown in (Table 15).

Table 15. Effect feather cover genotype on the number of follicles of feather tracts of the lateral region

Feather cover genotype	femoral tract	Lateral body tract
Nanaff[1]	226.33	4.67[b]
nanaFf[2]	232.00	17.67[a]
nanaff[3]	241.33	19.33[a]
SEM	6.05	0.67
P-value	0.28	<.0001

Superscripts a-b indicate significant difference between means in column, ($p<0.05$)
[1]Naked neck strain, [2]Frizzle strain, [3]Normal feathered strain, [4]Standard error of means, [5]Probability value

4.7.3 Lateral Region: No significant ($p>0.05$) difference was recorded for follicles in the femoral tract for the three feather cover genotypes but the naked neck showed a significantly ($p<0.05$) lower number of feather follicles for the lateral body tract compared to the frizzle and normal feathered birds (Table 15).

CHAPTER 5

5.0 DISCUSSION

5.1 FERTILITY

Fertility affects the number of progeny that can be achieved from a given number of eggs and is determined by candling and microscopy. The significantly ($p<0.05$) lower mean fertility recorded by the *nanaff* (normal feathered) birds (Table 5) could be attributed to the effect of the high ambient temperature prevailing in the experimental area but need to be investigated. It is possible that due to heat stress, feed intake might have been reduced in the *nanaff* (normal feathered) birds compared to birds possessing the Naked neck (*Nanaff*) and frizzle (*nanaFf*) genotype. Chickens struggle at high temperature, because of their feather cover and this hinders internal heat dissipation leading to elevated body temperature and subsequently a decrease in feed intake and thus nutrient intake. Hence, eggs produced by the *nanaff* hens may not have contained enough of all the essential nutrients necessary for embryonic development to take place. The *nanaff* birds could not have deposited in their eggs the necessary elements for normal embryonic development and growth. The significantly ($p<0.05$) higher fertility levels recorded by the naked neck (*Nanaff*) in this study supports the report of Fayeye *et al.* (2005) who reported that the Fulani ecotype chickens have a percentage fertility of 76% with a significantly lower fertility (56%) recorded for the normal feathered chickens. The significantly ($p<0.05$) higher average fertility recorded by the frizzle (*nanaFf*) compared to the normal feathered *(nanaff*) birds in this study contrasts with the report of Peter *et al.* (2008) that mating between frizzle feathered and naked neck resulted in lower fertility.

Fertility and hatchability are interrelated traits that vary among breeds and individuals in a breed or variety (Sapp *et al.,* 2004). Fertility is a major parameter of reproductive performance and it is most sensitive to environmental and genetic influences (Stromberg, 1975). A number of other factors including length of storage (Tarongoy *et a*l., 1990), storage condition (Brah and Sandhu, 1989), age of flock (Rogue and Soares, 1994; Buhr, 1995), system of husbandry and rearing technology (Weis, 1991), mating system (Gebhardt-Henrich and Mark, 1991), incubation relative humidity and eggs turning angle (Permsak, 1996), have been shown to influence the fertility of poultry eggs.

The results show no significantly differences value for the interaction between feather colour and feather cover this could be due to the presence of the naked neck and frizzle genes. Normal feathered brown birds showed significantly lower values ($p<0.05$) for percent fertile eggs compared to brown and white naked neck, brown and white frizzled birds and normal feathered white birds while there was no significant differences ($p>0.05$) between brown and white naked neck birds.

5.2 HATCHABILITY

Hatchability is the percentage of fertile eggs that hatched or percentage of eggs that hatched from all the eggs incubated over a period of 21 days. There are many factors contributing to the failure of a fertile egg to hatch and these include lethal genes, insufficient nutrients in the egg, bad hatchery practices (Olympio and Badu 1985) and exposure to conditions that do not meet the needs of the developing embryo. Breed has little effect on hatchability of poultry eggs, although light breeds have been reported to

have higher fertility and hatchability (King'Ori *et al.*, 2010). Hatchability of eggs is also affected by several other factors which include fertility of the egg, egg quality and management conditions during incubation and handling of eggs (Peters, 2005).

The naked neck (*Nanaff*) birds in this study recorded a lower number of chicks hatched compared to the frizzle (*nanaFf*) and this supports the observation of Peters (2005) that mattings that involved naked neck (*Nanaff*) birds produced a higher percentage of infertile eggs and dead-in-shell embryos due to the Naked neck (*Na*) genes. Heritability estimates for fertility and hatchability in chickens range from 0.06-0.13 (Sapp *et al.*, 2004). This indicates that non-genetic factors have a higher influence on these traits. Peters *et al.* (2008) recorded a reduction of 6.1 % for naked neck *(Nanaff*) in embryonic survival when compared with normal feathered (*nanaff*) birds and explained that this embryonic mortality was normal during the last stage of incubation (18-21 days). The embryonic deaths attributed to the naked neck could explain the low hatchability associated with the naked neck (*Nanaff*) birds in this experiment.

The significantly ($p<0.05$) low percentage hatchability recorded by the naked neck (*Nanaff*) birds compared to the frizzle (*nanaFf*) birds may be attributed to other factors associated with eggs since fertility was significantly higher in the naked neck birds.

The *Nanaffs-*, *nanaFfS-* and *nanaffS-* had significantly higher values for number of fertile eggs set compared to their sibs. With respect to the average number of chicks hatched for feather colour and feather cover, frizzled white and normal feathered white birds

performed significantly ($p<0.05$) better than all the others this could be due to the presence of the frizzling genes.

5.3 EGG QUALITY PERFORMANCE

5.3.1 EXTERNAL EGG QUALITY

Egg weight and size are major traits of economic interest in commercial egg production. Egg weight and size are affected by feed intake, age of the bird and to some point the prevailing environmental conditions. The naked neck and frizzle birds produced eggs with significantly ($p<0.05$) heavier average egg weight than eggs laid by the normal feathered bids. This confirmed the observation made by Mahrous *et al*. (2008), Pech-Waffenschmidt (1992), Host (1988) and Haaren-Kiso *et al*. (1988) that the presence of the naked neck and frizzle genes significantly increased egg weight.

The significantly ($p<0.05$) lower egg weight recorded by the normal feathered birds may be attributed to environmental factors and high ambient temperatures in the study area. This finding supports the report of Cary *et al.* (1993) that average egg weight is largely affected by environmental factors, feed restriction and parental body weight. The egg weight reported by Galal *et al.* (2007) for *Dw-Nana* (62.12±0.50g) and (60.72 ±0.68g) are almost the same ranges reported in this study.

The absence of significant differences among the feather color genotypes for egg length, egg diameter, shell thickness and shape index contradicts the findings of Sergeyeva (1986) that local chickens under the intensive management system laid eggs with thicker egg shell, which is an important bio-economic trait during egg storage. Thick egg shells also encourage the best use of nutrients in the egg by the embryo by reducing entry of

microorganisms and preventing the egg from dehydration (Rogue and Soares, 1994). The average shell thickness of 0.52mm for the locally developed layer parent lines in this study means the birds produced eggs with thinner egg shell as compared to 0.58 mm, 0.67mm, and 0.77 for Fulani ecotype chickens in Nigeria, Mecha and Debre-Elias chickens of Ethiopia (Fayeye *et al.,* 2005; Mogesse, 2007) respectively. Fraga and Lam (1987) and Sharifi (2006) found better egg shell strength in heterozygous naked neck birds under high ambient temperature conditions compared to their normal feathered counterparts. According to Singh *et al.* (1996) the naked neck gene has positive influence on egg quality traits.

Nanaffs- (brown line naked neck birds) produced significantly ($p<0.05$) heavier eggs compared to *NanaffS-* (white Naked Neck), *nanaFfS-* (white frizzles) and both brown and white normal feathered birds but no significant ($p<0.05$) differences existed between *Nanaffs-* and *nanaFfs-*. While the Brown naked neck birds (*Nanaffs-*) had significantly ($p<0.05$) longer egg lengths compared to all the other feather color combination except *nanaFfS-*. There were significant ($p<0.05$) differences observed for shape index for *nanaffs-* compared to *Nanaffs-* and *nanaffS-* but there was no significant ($p<0.05$) difference among *NanaffS-*, *nanaFfs-* and *nanaffs-*.

5.3.2 INTERNAL EGG QUALITY PARAMETERS OF YOLK

The significantly ($p<0.05$) higher yolk weight observed in the naked neck and frizzle eggs could be due to the heavier egg weight in both naked neck and frizzle birds obtained from the study.

The frizzled birds have their feathers modified and are therefore able to regulate their body temperature under high ambient temperatures, though not to the same extent as the naked neck birds. This may account for the superiority of the frizzle birds over the normal feathered birds in yolk diameter.

The absence of significant differences in yolk colour among the three feather cover genotypes could be due to the feed that was fed to the layers during the period of the experiment.

The colour of the yolk is due to substances called 'carotenoids'. Yolk color is dependent on the amount of carotenoid pigments that a hen consumes. A high level of carotenoid pigments in the diet means that the yolk will have a deeper, more orange color, and a lower level carotenoid pigments means the yolk will have a paler, yellow color (Table 6). Natural sources of carotenoid pigments include yellow maize (corn) and alfalfa (lucerne). The superiority in yolk weight, yolk diameter and yolk height of the white and brown naked neck birds and white and brown frizzle birds over their counterpart could be due to the 20 to 40% reduction in plumage of the naked neck birds, since they reserves protein which would have been used for feather formation, for productive activities such as the development of the egg (Akhtar-Uz-Zaman, 2006).

5.3.3 INTERNAL EGG QUALITY OF THE ALBUMEN

Albumen quality, one of the most important egg quality standards, is determined by its height. Albumen height varies between 1.5mm for low quality eggs and 11.5mm for good

and fresh eggs (TSS, 1980). Albumen quality is influenced by both genetic and non-genetic factors according to Crawford (1990).

The significantly ($p<0.05$) higher average values for albumen diameter, albumen height, albumen index and Haugh unit score for naked neck birds (*Nanaff)* compared to the other feather cover genotypes could be as a result of the naked neck gene having positive effect on some genes that control the albumen quality of an egg. Another reason could be the high ambient temperature (25-34^{0}C) during the experimental period which could lead to stress in the layers and which would affect egg development and quality. Conversely, the presence of the naked neck gene improved heat dissipation in the birds thereby alleviating stress due to high ambient temperature and resulting in the improvement in egg quality.

Haugh unit is one of the best indicators of internal egg quality, the higher the Haugh unit the better the quality (Isikwenu *et al.* 1999). The superior Haugh unit in the naked neck in this study supports the findings of Missohou *et al.* (2003) who found that, the frizzle gene does not significantly influence egg quality.

The results in this study are similar to those of Mathur (2003), Somes (1988), Njenga (2005) and Haaren-Kiso (1991) who reported that under constant heat stress heterozygous naked neck birds performed better in egg quality traits than their normal feathered sibs.

The (Naked neck Brown) *Nanaffs*- values were significantly ($p<0.05$) higher for all albumen parameters compared to the other feather cover genotypes in this study for feather cover and feather colour genotypes.

5.4 PTERYLOSIS

5.4.1 EFFECT OF NAKED NECK AND FRIZZLING GENES ON THE NUMBER OF LINES IN THE DORSAL, VENTRAL AND LATERAL REGIONS

The significantly ($p<0.05$) lower number of lines in the dorsal caudal, dorsal cervical and interscapular tracts of the dorsal region, the ventral cervical apterium, pectoral, sternal and ventral cervical tracts of the ventral region and the femoral and lateral body tracts of the lateral region in the naked neck compared to the frizzle and normal feathered birds could be due to the presence of the *Na* gene that reduces the surface area covered by feathers by up to 30 to 40%. This is in conformity with the observation of Bordas *et al*. (1978) that the naked neck gene, (*Na*), is a genetic mutant with approximately 40% reduced feather covering in homozygous (*NaNa*) and approximately 30% reduced covering in heterozygous (*Nana*) birds.

5.4.2 EFFECT OF NAKED NECK AND FRIZZLING GENES ON THE NUMBER OF FOLLICLES IN THE DORSAL, VENTRAL AND LATERAL REGIONS

The average number of follicles in the naked neck was significantly ($p<0.05$) lower than in the normal feathered birds for the dorsal, ventral and lateral regions. This result shows that the *Na* gene reduce the number of feather follicles and thereby give the naked neck and frizzle the opportunity to perform better in the high temperature in the tropics than the normal feathered birds. Touchburn *et al*. (1980) observed that reduced feathering associated with the *Na* gene (40% in *NaNa* and 30% in *Nana*) results in increased flexibility in regulating their body temperature (BT) at high ambient temperature. The

main effect of the naked neck gene is the reduction of the whole feather percentage especially in neck and breast areas by about 30-40% as compared with normal chickens (Mérat, 1986, Horst and Rauen, 1986).

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

From the results obtained in this study, the following conclusion can be drawn.

1. The naked neck (*Nanaff*) and frizzle (*nanaFf*) birds recorded a higher fertility of eggs stored for a period of 1-7 days compared to the normal feathered (*nanaff*) birds.
2. Average Number of chicks hatched for frizzle (*nanaFf*) birds was higher when eggs were stored for 3-7 days.
3. The *Nanaff produced* heavier eggs compared to *nanaff* birds.
4. The presence of the *Na* and *F* genes improves fertility, hatchability and egg quality but the *Na* gene is more pronounced then the *F* genes
5. The *Na* gene has a positive effect on feather reduction

6.2 RECOMMENDATIONS

From the results obtained from this study the following recommendations are made:

1. That *Na* and *F* genes be incorporated either singly or in combination into commercial layer parent lines that are to be reared in hot humid areas.
2. That the experiment be repeated to include measurements on ambient temperature, feed intake and internal and external body temperatures.
3. As a result of the superior performance of the naked neck and frizzle birds, the genes should be incorporated into local breed development strategies.

4. Marker selection should be used to identify the day-old frizzle since it is difficult to identify the day-old chick by observation.
5. That the Ministry of Agriculture and the Universities work in partnership with scientists interested in improving the local chicken, since the poor majority in urban and rural areas are involved in keeping these birds

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APPENDICES

ANOVA for percent egg set

Type 3 Tests of Random Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
genotype	2	120	1.41	0.2481
fc	1	120	5.46	0.0211
genotype*fc	2	120	0.02	0.9840

ANOVA for percent infertile eggs

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
genotype	2	111	6.06	0.0032
fc	1	99.2	10.97	0.0013
genotype*fc	2	113	4.31	0.0158

ANOVA for percent fertile eggs

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
genotype	2	111	6.08	0.0031
fc	1	99.2	11.06	0.0012
genotype*fc	2	113	4.31	0.0157

ANOVA for number of fertile eggs set

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
genotype	2	94	4.20	0.0178
fc	1	84.1	3.38	0.0697
genotype*fc	2	95.3	16.01	<.0001

ANOVA for average number of chick hatched

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
genotype	2	120	4.32	0.0154
fc	1	120	28.24	<.0001
genotype*fc	2	120	7.63	0.0008

ANOVA for chick culled

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
genotype	2	118	3.40	0.0367
fc	1	113	20.74	<.0001
genotype*fc	2	119	3.02	0.0527

ANOVA for dead-in-shell

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
genotype	2	118	0.21	0.8139
fc	1	112	32.18	<.0001
genotype*fc	2	119	2.70	0.0716

ANOVA for hatchability of fertile eggs

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
genotype	2	120	0.39	0.6756
fc	1	120	64.76	<.0001
genotype*fc	2	120	0.45	0.6404

ANOVA for total hatchability

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
genotype	2	120	1.68	0.1916
fc	1	120	58.46	<.0001
genotype*fc	2	120	0.90	0.4082

ANOVA for chick hatched weight

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
genotype	2	120	0.72	0.4908
fc	1	117	0.51	0.4784
genotype*fc	2	119	1.25	0.2907

ANOVA for egg weight

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
genotype	2	12	2.78	0.1019
fc	1	12	12.99	0.0036
genotype*fc	2	12	3.93	0.0488

ANOVA for egg length

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
genotype	2	10	1.00	0.4017
fc	1	10	1.28	0.2839
genotype*fc	2	10	6.05	0.0190

ANOVA for shell thickness

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
genotype	2	12	0.44	0.6522
fc	1	12	0.43	0.5226
genotype*fc	2	12	2.65	0.1112

ANOVA for egg diameter

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
genotype	2	12	0.38	0.6909
fc	1	12	2.02	0.1803
genotype*fc	2	12	2.28	0.1444

ANOVA on yolk height

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
genotype	2	12	2.43	0.1299
fc	1	12	2.90	0.1146
genotype*fc	2	12	0.12	0.8919

ANOVA on yolk diameter

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
genotype	2	10	23.05	0.0002
fc	1	10	6.40	0.0299
genotype*fc	2	10	1.70	0.2321

ANOVA on yolk color

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
genotype	2	12	2.18	0.1555
fc	1	12	0.12	0.7350
genotype*fc	2	12	0.62	0.5547

ANOVA for yolk index

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
genotype	2	10	23.82	0.0002
fc	1	10	13.31	0.0045
genotype*fc	2	10	1.77	0.2192

ANOVA for shape index

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
genotype	2	10	2.70	0.1157
fc	1	10	0.51	0.4928
genotype*fc	2	10	16.54	0.0007

ANOVA on yolk weight

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
genotype	2	12	12.12	0.0013
fc	1	12	2.73	0.1243
genotype*fc	2	12	2.15	0.1596

ANOVA on albumen weight

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
genotype	2	12	0.94	0.4166
fc	1	12	24.22	0.0004
genotype*fc	2	12	11.12	0.0019

ANOVA on albumen height

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
genotype	2	12	31.31	<.0001
fc	1	12	68.30	<.0001
genotype*fc	2	12	42.41	<.0001

ANOVA on albumen diameter

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
genotype	2	12	18.93	0.0002
fc	1	12	22.25	0.0005
genotype*fc	2	12	9.47	0.0034

ANOVA for albumen index

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
genotype	2	12	7.46	0.0079
fc	1	12	23.28	0.0004
genotype*fc	2	12	15.87	0.0004

ANOVA for Haugh unit

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
genotype	2	12	20.72	0.0001
fc	1	12	35.72	<.0001
genotype*fc	2	12	25.07	<.0001

ANOVA on dorsal caudal tract (lines)

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Genotype	2	4	13.00	0.0178

ANOVA on dorsal cervical tract (lines)

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Genotype	2	6	1352.00	<.0001

ANOVA on dorsal pelvic tract (lines)

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Genotype	2	4	2.00	0.2500

ANOVA on interscapular tract (line)

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Genotype	2	6	33.17	0.0006

ANOVA on pectoral tract (lines)

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Genotype	2	4	21.00	0.0076

ANOVA of sternal tract (lines)

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Genotype	2	4	91.00	0.0005

ANOVA for ventral cervical apterium (lines)

Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Genotype	2	6	213.50	<.0001

ANOVA for ventral cervical tract line

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Genotype	2	4	564.25	<.0001

ANOVA on the femoral tract (lines)

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Genotype	2	4	12.40	0.0193

ANOVA on lateral body tract (lines)

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Genotype	2	4	91.00	0.0005

Dorsal Caudal Tract Follicles

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Genotype	2	6	11.31	0.0092

Dorsal Cervical Tract Follicles

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Genotype	2	6	1175.50	<.0001

Dorsal Dorsopelvic Tract Follicles

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Genotype	2	6	0.40	0.6891

Fermoral Tract Follicles

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Genotype	2	6	1.57	0.2836

Interscapular Tract Follicles

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Genotype	2	4	67.00	0.0008

Lateral Body Tract Follicles

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Genotype	2	6	145.08	<.0001

Pectoral Tract Follicles

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Genotype	2	6	49.71	0.0002

Sternal Tract Follicles

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Genotype	2	6	11.82	0.0083

Ventral Cervical apteriun Follicles

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Genotype	2	4	60.05	0.0010

Ventral Cervical Tract Follicles

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Genotype	2	6	6417.96	<.0001