CHAPTER ONE

1.0 INTRODUCTION

Ghana is a developing country with a population of approximately 22 million people and occupying a total land area of about 385,500 square kilometres. Agriculture is the mainstay of the country's economy, providing employment and serving as a source of livelihood to approximately 60% of the population (Ghana Statistical Service, 2000). While agriculture as a whole contributes about 38.5% of the nation's Gross Domestic Product (GDP), the livestock sub-sector contributes only about 7–9% to the Nation's GDP (GSS, 2000) as against 60% by the crop sub-sector. Livestock offers employment to about 50% of rural Ghana (MoFA/DFID, 2002). In Ghana, livestock including poultry, are kept by about 1.54 million households and is estimated that about 12 million people depend on livestock for their livelihood (Ashley and Annor-Frempong, 2004). According to Aning (2006), about 94.4% of livestock farmers keep poultry, with chicken farmers constituting about 75.5% of poultry keepers.

For the majority in the rural sector, livestock acts as a 'walking bank', and is sold for income to meet domestic needs of households (MoFA/DFID, 2002). It is an undeniable fact that the potentials of the livestock industry have not been fully harnessed. Despite Ghana's vast forage resources, its livestock resource base is modest with about 1.4 million cattle, 3.1 million sheep, 3.9 million goats, 0.3 million pigs and 28.7 million poultry as at the year 2004. About 54% of the population also lives in the rural areas

where most of the country's crop and livestock are produced, (MoFA, 2005). In almost all households, males and females as well as children rear chickens. The local birds do not only provide for the protein requirement of the family on occasions but also act as the 'poor man's bank' and animals for sacrifices, festivities and gifts (Naazie *et al*., 2002). These birds serve as the first source of income for other household needs. They also serve as a starting point for scaling over to small ruminant keeping and consequently to cattle keeping. Substantial amount of literature have shown that there is a relationship between livestock keeping and poverty reduction in rural communities (Ashley and Annor-Frempong, 2004). Rural family poultry, namely village chickens, are also capable of providing the population with cheap and readily harvestable meat and eggs (Aini, 1998; Guèye, 2000).

A study by Dankwa *et al.* (2000) on local chickens in Ghana, revealed that the productivity of the local chicken was comparatively low and irregular, with an average annual egg production of 52 eggs per bird, egg size between 29 and 46g and mature body weights of 1.0 and 1.3kg at 5 months for hens and cocks respectively. The females reach sexual maturity at 28-30 weeks of age with a clutch size of about 3-5. The keeping of these chickens is characterized by traditional and small scale systems of farming and operated predominantly by small-scale or peasant farmers. These farmers keep the indigenous birds despite their low productivity because these birds form an integral part of the lifestyle of the rural farmers. Although, the indigenous village chicken is the most prominent class of livestock in the country and constitutes about 60-80% of the total poultry population, (Aryee and Kutame, 1991), their productivity levels

are low because of poor nutrition and low genetic potential. There is little or scanty data to support the importance of the village chicken production systems in household and national economies (Kitalyi, 1998).

In an effort to address the problem of low productivity in local chickens, high-yielding exotic breeds have been introduced through the cockerel exchange programme by the government. This intervention is bedevilled with many challenges; prominent among them is the birds' adaptation to the hot and humid environment. According to Cowan and Michie (1988) the reduced feed intake and retarded growth are the consequences when the exotic birds are exposed to high environmental temperatures and humidity. These unfavourable environmental conditions do not permit the expression of the full genetic potential of the exotic breeds (Barua and Howlider, 1990).

According to Nwachukwu *et al*. (2006) the tropical environment is generally characterized by such stress factors like excessive heat, poor nutrition, poor housing and disease. They therefore propose the development of stocks that can tolerate stressful environment and give acceptable level of production. There has been indiscriminate crossbreeding of indigenous chickens with exotic ones without enough consideration of local environmental conditions for poultry production. Lack of plans on how to maintain a suitable level of upgrading or on how to maintain the pure breeds for future use in crossbreeding contribute to non-sustainability of introduced breeding strategies. High levels of upgrading have generally led to animals with less resistance to diseases and impaired ability to withstand environmental stress (ILRI, 2003). Lack of analysis of

the different socio-economic and cultural roles that local chickens play in each situation usually leads to wrong breeding objectives and neglect of the potentials of indigenous chickens. There is also lack of comprehensive approaches to design simple, yet effective breeding strategies in low-input environments (ILRI, 2003).

Currently there is a major global thrust on genetic preservation and biodiversity which is reflected in efforts on development of genome and data banks (Crawford, 1992). Again, the impact of global warming and climate change on chicken production cannot be overemphasized. Under hot and humid conditions - a major characteristic effect of global warming, the use of major genes like naked neck (*Na*) and frizzle (*F*), to improve productivity in chicken breeding programmes is advocated (Galal *et al*., 2007). This is because these conditions do not permit the birds to reach their full genetic potential for growth, body weight, meat yield and egg production because dissipation of their excessively produced internal heat is hindered by the feathers (Cahaner *et al*., 2008). The naked-neck and frizzle birds have been found to be thermal stress tolerant as compared to their normally feathered counterparts (Nwachukwu *et al*., 2006). Horst and Mathur (1992) observed that the feather restriction or naked-neck gene results in 20-30% less feather coverage overall, with the lower neck appearing almost naked. This considerably reduces the need for dietary nutrients to supply protein, which is a limiting factor in local chicken nutrition, for feather production. This means naked-neck chickens can tolerate low dietary protein levels more than normal chickens (Monnet *et al*., 1979). The frizzle gene has also been reported to reduce the insulating properties of the feather cover (reduce feather weight) and make it easier for the bird to radiate heat

from the body. Horst and Mathur (1992) have shown that, when reared under high temperatures, the naked-neck and frizzle feathered layers perform better in terms of egg production and growth rate compared to their normally feathered counterparts. Again, the naked-neck and the frizzle genes have been found to be associated with heat tolerance and therefore in high ambient temperature, birds with these genes are superior to their normally feathered counterparts for egg size, egg number and feed efficiency (Garces *et al*., 2001). The direct and indirect effect of these genes on the productive performance of chickens must be exploited so as to broaden their production base. Fayeye *et al*. (2006) also reported that birds with the naked-neck and frizzle genes have better adult body weights compared to their normally feathered counterparts.

The advantages of these genes in the heterozygous state are one-half that in the homozygous state, but producing layer stocks homozygous for these genes is not commercially feasible because of poor hatchability (Merat, 1986). Therefore to ensure further reduction in feather cover and mass and thereby improving heat dissipation through the reduced feather and the exposed skin, the two genes could be used in combination to evaluate their interactive effects. According to Mahrous *et al*. (2008) the naked-neck and frizzle genes in combination confer consistent superiority in body weight, feed conversion, egg production and disease resistance at moderate (25^0C) to high (32^0C) ambient temperatures. The two genes (Na and F) are marker genes identified by qualitative criteria (visual, biochemical and serological) that may show association with quantitative traits, either because of pleiotropy or linkage with other genes (Merat, 1990).

The general objective of this research was to evaluate the effects of naked-neck and frizzle genes and their combination on growth, carcass characteristics and egg production of crossbred chickens.

The specific objectives of the study were therefore:

1. To determine the frequency of naked-neck (Na) and frizzle (F) genes in the local chicken population in some selected villages in the Ashanti region of Ghana.
2. To evaluate the effect of *Na* and *F* genes and their combination on growth performance and carcass characteristics of crossbred cockerels.
3. To evaluate the effects of *Na* and *F* genes and their combination on production traits of crossbred pullet under the intensive system.
4. To compare the egg production performance of crossbred naked-neck and frizzled pullets and farmers' own local pullets under the semi-scavenging system.
5. To evaluate the effect of genotype-location interaction on egg production performance of crossbred naked-neck and frizzle pullet genotypes.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin of Poultry

The term poultry is usually used as a general name for a variety of domesticated birds such as chickens, ducks, guinea fowls, turkeys, geese, pigeons, swans etc. which are reared mainly for their meat and eggs. Collectively they are probably the most economic converters of locally available feed such as grains and grain by-products into high quality sources of animal protein in the form of table eggs and meat (Tweneboah, 2002). According to Crawford (1990), the interest in the origin and history of poultry species to the present has always been mostly academic. Little improvement has been made through the use of wild ancestors or primitive relatives of modern stocks, as pertains in crop breeding. In spite of this, the knowledge of origins and history of chickens will have a practical use, considering the rapid development in genetic engineering. According to modern ornithology, there are four species of the jungle fowl, but the red jungle fowl (*Gallus gallus*) is found to be a major contributor or an ancestor to the domestic fowl (Crawford, 1990).

Conventionally it is thought that all the other three wild species (*G. lafayettei*, *G. sonnerati* and *G. varius*) interbred with *Gallus gallus* and those domestic stocks owe some of their inheritance to all of these species. From these various species have arisen domestic hens of various types. Some, known as the 'fancy breeds', are of little direct

commercial value. The 'fancy breeds' such as the Cornish Red and the White Rock have been very important contributors to the strains that now produce our modern strains of broilers. It is very important that these breeds are maintained in the future as 'gene banks' because they may contain useful genes that could be exploited commercially (Smith, 1990). The genome of the domestic chicken has a haploid number of 39 chromosomes, eight pairs of macro chromosomes, one pair of sex chromosomes (*Z* and *W*) and 30 pairs of micro chromosomes. The size of the chicken genome is estimated to be 1.2 X 109 bp (Olofsson and Bernardi, 1983; Groenen *et al.*, 2000). Chickens, like other avian species, differ from mammals in that the female is the heterogametic sex (*ZW*) and the male is the homogametic sex (*ZZ*), the *Z* and *W* chromosomes displaying heteromorphism (Singh, 2000).

2.2 Family Poultry Management Systems in Africa

Family poultry, also referred to as village chicken production, plays a very important socio-economic role for farmers in developing countries. They provide regular household income and are used for gifts, sacrifices and starting capital for young people (Guanaratne *et al.*, 1993; Guèye, 1998; Sonaiya *et al.*, 1999). In developing countries, traditional poultry production development programmes were either lacking or limited in scope. As a result, village poultry production is not sufficiently understood in relation to existing farming systems (CNRST, 1995). Moreover, off take (sale or consumption) from the village chicken system at farm level is low. Furthermore, there is no significant improvement of family poultry production system in general and indigenous chicken production system in particular. According to Aini (1998) many studies have been done

to improve the performance of village chickens, either by cross-breeding or improved feeding but the impact of these studies in practice is hardly felt.

Many authors described the indigenous domestic fowl (*Gallus gallus*) reared in the African rural areas and gave them names like 'African chicken', 'bush chicken' or 'runner chicken' (Berte, 1987; Oluyemi, 1989; Sonaiya, 1990; Kounta, 1991; Guèye and Bessei, 1997). Village chickens seem to be well adapted to their environmental conditions such as hot or cold weather, rain and periodic feed shortages (Guèye, 1998).

Poultry-keeping systems in Africa have evolved over time. The earliest were the farmyard operations, in which small flocks of birds had almost complete freedom of movement. There has been most development work on systems for hens, but many systems are used for various poultry. As a matter of fact, there is no generally accepted definition of rural poultry production system, but various systems have been described by a number of researchers, including Aini (1990) and Cumming (1992). The systems described by these authors are characterized as consisting of small flocks, with no or minimal inputs, low outputs and periodic devastation of the flocks by diseases.

Under these systems, birds are owned by individual households and are maintained under a free range system, with little or no inputs for housing, feeding or healthcare. Typically the flocks are small in number with each flock containing birds from each age group, with an average of 7-10 growers of various age groups. Cumming (1992) also described village flocks in Asia as consisting of 10-20 birds of different age groups per

household. Sonaiya (1990) also stated that family poultry in Africa consisted of birds ranging from 5-10 on average. Tadelle and Ogle (1996) also defined the village poultry production system as being characterized by minimum inputs, with birds roaming freely in the backyard, and no investment beyond the cost of the foundation stock, a handful of grain each day and possibly simple perches at night. Bessei (1987) classified family poultry in Africa into four broad production systems, namely: free range extensive, backyard extensive, semi-intensive and intensive systems.

2.2.1 Free Range Extensive System

According to Bessei (1987), under this system, the birds are not confined and can roam freely in search of food over a wide area. Rudimentary shelters and perches may sometimes be provided, but these may or may not be used. The flock usually contains birds of different species and varying age groups.

2.2.2 Backyard Extensive System

In Africa, Asia and Latin America, about 80% of the farmers keep their birds under the free range extensive or the backyard extensive systems. Under the backyard extensive system, the birds are housed at night but allowed free range during the day (Bessei, 1987). The major intervention is in the area of feed and water supplementation, overnight housing and, to a much lesser degree, health care. Supplementation consists of giving household wastes or grains of cereals, generally in the morning or late in the afternoon according to the farmer's ability (Chrysostome *et al*., 1995). The supplementary feeds are usually given to the birds in the mornings and evenings when

they have returned from scavenging. Under this system, meat production cannot be divorced from egg or chick production, and as a result a highly broody, low body weight (low feed requirement) bird is best for survival under this condition (Kitalyi, 1998). Here, there is little reproductive control of hens, as they brood their own chicks for continuous regeneration of the flock.

2.2.3 Semi-Intensive System

According to Bessei (1987) the semi-intensive system is a combination of the extensive and the intensive systems where birds are confined to a certain area with access to shelter. It is commonly found in urban and peri-urban and sometimes in rural situations. In the "run" system, the birds are confined in an enclosed area outside during the day and housed at night. Feed and water are available in the house to avoid wastage by rain, wind and wild animals. The semi-intensive system is generally observed in Asian countries. In this system, the chickens are fed with formulated diets either bought commercially or produced from feed mills (Aini, 1990). Flock size varies between 50 and 500 birds on average (Sonaiya *et al*., 1999). Roberts (1999) suggested the use of specialized birds in this type of system rather than indigenous animals.

2.2.4 Intensive System

This system is used by medium to large scale commercial enterprises. It becomes a backyard intensive when used at the household level under small scale. The birds are completely confined either in houses or cages. Under the intensive system, capital outlay is high and birds are totally dependent on their owners for all their requirements.

Production cost in this system is also relatively higher than the extensive and the semi-intensive systems. The birds are either kept in the deep litter or the battery cage system under the commercial production system. The system requires a high initial capital injection and is mostly confined to large scale commercial egg laying operations (Bessei, 1987).

2.3 Traditional Poultry Husbandry in Africa

The manual of poultry production in the tropics (IEMVT, 1987) gives an exhaustive description on traditional poultry husbandry. It shows that in Africa, traditional poultry husbandry has the following characteristics:

- The birds range freely during the day, they are usually gathered at night into a basic shelter to avoid losses through predators;
- The feed is limited to what the birds can find by themselves (insects, seeds, kitchen wastes);
- Sometimes a supplement is given, but this supplement depends on the availability of the feedstuffs used in the household;
- Very poor productivity: the hens lay a low number of eggs per year, the growth rate of broilers is slow and the losses in the flocks are important;
- Eggs are rarely consumed. They are preferably hatched. Only the chickens are consumed and they are appreciated for their taste, their relatively dry meat being well adapted to the prolonged cooking practiced in Africa (IEMVT, 1987).

According to Ashley and Annor-Frempong (2004) the management system for smallholder poultry rearing in Ghana is usually treated from the standpoint of the level of intensification and three are identified in the country, namely: (i) intensive system, (ii) semi-intensive system and (iii) extensive/free range. The multiple-role keepers, particularly in the rural areas who raise poultry of all types use the free range/extensive management system. There is virtually no investment in housing and equipment. There is no supplementation of feeding with manufactured feed.

The authors continued that keeping poultry and some non-conventional livestock such as rabbits in the backyard of households is quite common in the peri-urban areas and even in urban areas in Ghana. In the backyard, the birds are kept under intensive system. Simple pens are usually provided for sheep and goats within or attached to the owner's house and forages and household wastes are used to feed the animals. Sometimes manufactured feed is used to feed the birds. Raising livestock at the backyard is usually a small scale enterprise with profit as the main motive.

Veluw (1987) in a study on traditional free-range system of the Mamprusi tribe in Northern Ghana, observed that local chickens on the free range management system received some form of supplementation, especially early in the morning and in the evening when the birds are about to roost. The hens lay throughout the year, but guinea fowls lay only in the rainy season. Village or local hens produce about 20 to 40 eggs a year and guinea fowls about 50. Most of the eggs are used for hatching. The author also found that chickens hatch guinea fowl eggs, as guinea fowls are not good mothers.

Hatching takes place throughout the year, although most of the hens incubate their eggs in the rainy season. Veluw (1987) stated that a reproduction cycle (laying, hatching, caring for chicks and resting) takes about 20 weeks. Mortality is high (75 percent) among the young chicks. Out of ten chicks that may be hatched, only about two reach adulthood, due mainly to disease, predators and road accidents. Newcastle Disease in particular kills many poultry in the dry season. Worms, as internal parasites, are a great problem, weakening the birds. Predators include snakes, birds of prey, cats and dogs. Mortality up to two months of age is 50 percent, with a further 25 percent thereafter up to sexual maturity.

2.4 Poultry Breeding Strategies for Local Chickens

Strategies to develop poultry suitable for smallholder poultry production in Africa must differ from those used in intensive production, and should focus on improving the indigenous breeds while also making use of pure exotic and crossbred chickens where appropriate (Kitalyi, 1998). Comparatively little research and development work has been carried out on village poultry, despite the fact that they are usually more numerous than the commercial chickens in most developing countries (Cumming, 1992). The few attempts that have been made to increase productivity include upgrading and crossbreeding with exotic ones, and then leaving the hybrid offspring to natural selection (Kitalyi, 1998).

Horst (1988) reported that local domestic chicken in developing countries still contribute much towards meat and egg supply, despite the distribution of high yielding

stocks from developed regions. The products from the local poultry stock are widely preferred because of their pigmentation, taste, leanness and their availability for special dishes. He added that there is a vast potential for improving and increasing local poultry through smallholder schemes, the success of which depends essentially on improvement of genetic and non-genetic components of the industry. Horst (1988) concluded that for any breeding strategy to be sustainable there is the need to first conserve and then preserve the local breeds possessing genetic variations specific to the particular environment.

Kitalyi (1998) also suggested two rules that should be incorporated into any breeding strategy for local poultry. First, the germplasm in traditional conditions should not be modified unless management and housing have been improved. Even then, selection should be restricted to local breeds. When technical conditions are optimum and ready markets for the products are available, then improved breeds, crosses and hybrid strains that have been selected for high performance can be introduced into the peri-urban systems.

According to Crawford (1990) the various alternative breeding strategies for local poultry improvement available in developing countries are: (1) development of native stock through pure breeding (2) gradual replacement of local males (3) use of local genomes and major genes and (4) development of a breed by cross breeding.

2.4.1 Development of Native Stock through Pure Breeding

Some indigenous breeds have been reported to be highly productive. An example is the native Deshi chicken in Bangladesh, which has been reported by Ahmed and Hashnath (1983) to possess tremendous surviving ability under stressful conditions, ability to withstand local diseases and to retain their scavenging habits. These birds have been found to produce 45 eggs in a laying cycle with an average egg weight of 33.5g. This strategy of developing the local stock is sustainable because the introduction of the exotic breeds or strains into small farming systems demands a high level of management and expensive feed (Mukherjee, 1990). In the most poorly developed nations, the above breeding strategy would be quite appropriate, which means efforts need to be directed to the introduction and development of selection within local breeds. The challenges posed by this strategy are that selection within breeds under extensive conditions will be extremely difficult due to lack of any genetic estimates of growth and reproduction parameters. Also, identification of birds in village conditions will not be easy. A study by Gondwe and Wollny (2003) showed a potential productivity of local birds in Malawi and the need to promote the local breed through breeding and management.

2.4.2 Gradual Replacement of Local Males

Under this method, genetically improved males of locally adapted exotic stocks should be released by breeding farms to smallholder systems for village poultry development. Omeje and Nwosu (1986) have found that less productive local breeds can be of commercial and breeding utility if crossed with improved breeds and strains. Their

results showed that the body size and feed conversion efficiency of F_1 crosses (local X Gold link) could be as high as the imported Gold-link chickens, and the back cross progeny (F_1 X Gold-link) showed even a higher growth performance and feed conversion efficiency without significant reduction in production traits. This strategy also suggests that a continuous upgrading scheme either through backcrossing or line breeding is possible to obtain a synthetic breed genetically close to the exotic breed.

2.4.3 Use of Local Genomes and Major Genes

The use of single or combined dominant genes for feather restriction (Naked-neck, *Na*) and feather structure (Frizzle, *F*), as well as sex-linked recessive gene for reduced body size (Dwarf, *dw*), has been found to influence biological efficiency in chickens in the tropics (Horst, 1989; Haaren-Kiso *et al.*, 1995). A study by Fayeye *et al.* (2006) revealed that birds that possessed thermoregulatory genes (*Na* and *F*) had a higher adult body weight than their normally feathered counterparts. According to Kitalyi (1998) in an FAO paper on breed improvement, there are seven known potentially useful major genes, namely: naked-neck (*Na*), dwarf (*dw*), slow feathering (*K*), Fayoumi (*Fa*), frizzle (*F*), silky (*H*), and fibro-melanosi (*Fm*). Once the phenotypic effects of these genes on physiological and anatomical traits are characterized, it would be easy to incorporate these genes into crossbreeding programmes by establishing paternal breeding lines with dominant and or sex-linked major genes. Aside the major genes identified, Kitalyi (1998) also found other morphological traits that allow better heat dissipation. These include large combs, large wattles and long legs. Gene coding for these traits, which are not major genes but the result of multiple genes and their interactions, could also be

considered for incorporation into the development of high performing local birds for the tropics.

2.4.4 Development of a Breed by Crossbreeding

Crossbreeding certainly is one elementary technique that can be used to improve productivity. It has its justification in the improvement of farm animal productivity under tropical conditions. The outcome of crossbreeding is the phenomenon of heterosis which is expressed in the performance of the hybrids. Because heterosis is almost exclusively the aggregate of all single locus dominance effects, and because these are usually positive or beneficial, heterosis can be expected to be usually in the favourable direction (Kitalyi, 1998). To utilize the good adaptive characteristics of the indigenous chicken and possibly exploit the phenomenon of heterosis, Oluyemi *et al.* (1979) proposed that crossbreeding programmes including upgrading local chicken with suitable exotic stocks would be more appreciable. A study by Njenga (2005) revealed that the crossbred offspring of Rhode Island Red and Fayoumi (Sonali) had the best level of egg production, body weight, highest cost-benefit ratio and the best egg quality with low mortality among four different breeds under a semi-scavenging system of production in Kenya. The genetic potential of the indigenous chicken could be improved by crossing them with selected but still robust exotic breeds (Guéye, 1998).

2.5 Breeding Systems for Village Chickens in Ghana

In Ghana, the Public Sector is seen to be the largest institutional force in relation to livestock, including poultry, and it tends to control animal genetic resource activity

(Annor-Frempong and Ashley, 2002). It is rather unfortunate that attempts by the country to maintain pure lines of indigenous breeds to avoid total loss of economically important genomes as part of its breeding policies have faced a lot of challenges. It looks as if poultry breeding and improvement strategies are relegated to the background. This is because with all the breeding stations in the country there is yet to be a breeding station for poultry especially chicken. There are three main types of chicken found in the country. They are indigenous breeds, crossbreeds and exotic ones. The exotic breeds are normally reared under commercial rearing conditions (Annor-Frempong and Ashley, 2002).

The family poultry employs the keeping of both exotic breeds which are normally crossbreeds and indigenous ones. Until recently, the village farmer was keeping purely indigenous chickens which are nondescript. Under this system, an exotic cock in a community or a household is seen to be crossing hens in the community or the household. The other system employed is when exotic cockerels are reared and sold on festive occasions (Annor-Frempong and Ashley, 2002). They continued that as a result of the high demand for village poultry, the birds are kept as multi-purpose breeds and as such meat production cannot be separated from egg or chick production. Therefore a highly broody, small body size bird is best for survival under these conditions. Surplus cockerels, whatever their body weight, are usually sold when they reach sexual maturity at 15 to 20 weeks. Under the village management system, according to Annor-Frempong and Ashley (2002), there is little control over reproduction because the hens brood their own chicks for continuous regeneration of the flock. The brooding and chick

rearing activity by the hen increases the length of the reproductive cycle. As a result of this, most hens produce chicks about four to five times per year, and only four times if the rearing period is extended to eight weeks.

A study by Naazie *et al.* (2007) showed that there existed wide genetic variations among the indigenous chicken in the country. They found that the indigenous birds are not only highly adapted to their environment, but they also form an integral part of the lifestyle of the rural people. The study revealed the existence of the following thermoregulatory genes among the indigenous birds; naked-neck, frizzle, silky, crest feathered, and dwarfism and other genes like polydactyly, ptilopody and rose comb etc

Again, the government of Ghana under the National Livestock Services Project (NLSP), under the Medium Term Agricultural Development Programm (MTADP), embarked on breed development programmes like the improvement of the local chicken breeds through cockerel exchange, vaccination of layers and cockerels for crossing local hens (Ministry of Food and Agriculture, 2005). There is also the provision of local poultry breeds to start backyard poultry keeping. There are other on-going local poultry improvement strategies in the country being spearheaded by NGOs like Ricerca and Cooperazone, Heifer International, Opportunities Industrialisation Centre (OIC), Kindness International, World Vision and German Technical Cooperation (GTZ). All these have identified the rural poultry development as an effective short-term means of improving livelihoods and improved rural protein intake. The interventions used by these organisations include the establishment of smallholder layer and exotic cockerel

production for eggs and meat. In some places, the exotic cockerels have been used for genetic improvement of village chickens.

2.6 Socio-Economic Importance of Village Chicken Rearing

Throughout the continent of Africa, the keeping of indigenous chickens by village folks has been practised for many generations. These birds, which are generally kept extensively, currently make up more than 80% of the continent's poultry flock (Guéye, 1998). This enterprise is available to all farming families, including the poorest (Bell, 1992). According to Crawford (1990) the village chicken comprise local unimproved, nondescript poultry breeds commonly found in developing countries. These breeds include mixed (unspecified) ones resulting from uncontrolled breeding (Kalube, 1990).

As a valued venture of every household, the rearing of village chicken plays an important role in the developing world, and the absence of a backyard chicken in a rural household is a sure sign of poverty (Nalugwa, 1996). Family poultry is therefore defined as small scale poultry keeping by households using family labour and, wherever possible, locally available feed resources (Kitalyi, 1998). These birds may range freely in the household compound and find much of their own food, getting supplementary amounts from the householder.

According to Sonaiya (1990) rural poultry represents a significant part of the rural economy. Sonaiya (1990) also defined rural poultry as a flock of less than 100 birds, unimproved or improved, raised in either extensive or intensive farming systems.

Labour is not salaried, but drawn from the family household. This is quite distinct from medium to large scale commercial poultry farming. Kitalyi (1998) showed that the existence of poultry in rural households does not imply necessarily that the farmers are willing and in a position to expand poultry production. The author found that poor management practices by rural poultry keepers are a setback to the attainment of full genetic potential of local birds. The first step in village chicken development is therefore the encouragement of the keepers to change their attitudes towards poultry keeping and the traditional system.

It has become extremely difficult to determine the most important purpose of raising birds in the rural areas because it is impossible to compare the spiritual benefit of sacrifice with the financial benefit of a sale. Rural poultry keeping is rarely the sole means of livelihood for the family but is one of a number of integrated and complementary farming activities contributing to the overall well-being of the household (Kitalyi, 1998). Prominent among the benefits derived from this enterprise is the provision of food in the form of meat and eggs. Apart from increased quantitative production of animal protein in rural households, chicken meat and eggs provide the needed protein of a higher biological value than that of red meat (Kitalyi, 1998). The meat and eggs from chickens are reported to complement staple diets of rural Africa due to the higher nutrient concentration. The village chicken is reported to provide readily harvestable animal protein to rural households, and as a result, in some parts of Africa, is raised to meet the obligation of hospitability to honoured guests (Kitalyi, 1998). Kuit *et al*. (1986) in their study conducted in Mali found that the main function of village

chickens from the farmers' perspective is the provision of meat and eggs for home consumption. According to Alam (1997) and Branckaert and Guéye (1999), in low income, food-deficient countries, meat and eggs from family poultry are estimated to contribute 20 to 30% of the total animal protein supply.

Another important benefit derived from local poultry is income. Income generation is seen to be an important goal of family poultry keeping. The eggs produced can provide regular, though small, income while the sale of live birds provides a more flexible source of cash as required. According to Rauen *et al.* (1990) in the Dominican Republic, family poultry contributes 13% of the income from animal production. Ouandaogo (1990) reported that in Burkina Faso, about 25 million rural poultry produce 15,000 tonnes of meat, out of which 5000 tonnes are exported to Cote d´Ivoire, at a value of 19.5 million US dollars. In Kenya, it has been reported that the poultry population is about 29.8 million chickens consisting of 21.8 million local chickens, 4.4 million broilers and 2.9 million layers (Mbugua, 1990). According to Njue (2002) the local chicken is the main source of income for 90% of the rural households, which comprise 80% of the population. He therefore suggested that there is the need to harness and utilize the local chicken for poverty alleviation because these birds are among the many local resources of poor people living in rural areas.

Poultry products have social and spiritual benefits and play an important role in rural economies. In many customs of indigenous people, poultry is used for ceremonies, sacrifices, gifts and as savings in the village. Chickens are given or received to show or

to accept good relationship or to say thanks for a favour or help (Sonaiya, 2000). Besides, poultry can serve as a unit of exchange in societies where, there is no circulation of money (Guéye, 1998). For example, in Gambia five adult hens can be bartered for one sheep and 25 hens for one herd of cattle. Under normal conditions, birds are sold when the household is in need of money. The income from the sale of chickens is additional revenue to earnings from cash crops from the field (Sonaiya, 2000).

Tadelle (1996) revealed that the main objective of keeping poultry is for the production of eggs for hatching (51.8%), sale (22.6%), and home consumption (20.2%) and the production of birds for sale (26.6%), sacrifice for healing ceremonies (25%), replacement (20.3%) and home consumption (19.5%). In some cases, farmers give live birds (8.6%) and eggs (5.4%) as gifts and invite special guests to partake of the popular dish "doro watt" which contains both chicken meat and egg and is considered to be one of the most exclusive dishes in Ethiopia. According to Sonaiya *et al*. (1999), in Nigeria the sale of birds and eggs take place in the villages market. Prices fluctuate during the year being low during the hungry season when the granaries are empty, and the crops are still growing and everybody needs ready cash. At such times, traders come to buy and to resell in big cities. Sometimes middle men are involved. Poultry products contribute about 15% of the annual financial income of the household (Sonaiya *et al.*, 1999). Similarly, Tadelle (1996) indicated that farmers sell live birds and eggs, particularly during holidays and festivals; they also sell at the onset of local disease

outbreak to prevent expected financial loss. In such circumstances prices fall dramatically due to the high supply of bird's relative to demand.

Other important benefits that can be derived from rural poultry are as a source of sacrificial offerings in traditional worship and as insurance against crop failure or lean harvest (Kitalyi, 1998). According to Gondwe *et al*. (2005) rural poultry can serve as a means of payment of fines to settle disputes. Veluw (1987) and Sonaiya (1990) have also reported that rural poultry play a significant role through their contribution to the cultural and social lives of rural people. This is because rural poultry integrate very well and in a sustainable way into other farming activities, because they require little in a way of labour and initial investment compared to other farm activities (Tadelle and Ogle, 1996).

2.7 Constraints to Village Chicken Rearing

Family poultry keeping is well integrated into most village farming systems with local breeds representing 40-70% of the national meat and egg supply in most tropical countries. Due to their scavenging adaptability, production ability and low cost, the local breeds are kept by rural smallholders, landless farmers and industrial labourers. In spite of these inherent positive potentials, there are challenges that militate against the full expression of their potentials (Kitalyi, 1998). The constraints identified are as follows:

2.7.1 Disease and Health Constraints

According to Lony and Mopaté (1998) the health problems related to infectious diseases and parasites constitute a major bottleneck in the development of the family poultry industry in Chad. Guéye (1998) concluded that in Nigeria high mortality, especially in growers, constitutes the greatest constraints to the development of the village poultry. Bessin *et al.* (1998) studied the causes of mortality in young guinea fowls in Burkina Faso and showed that mortality rates were as high as 80% in unimproved and traditional farms, with the highest mortality rate observed in August during the rainy season. Aini (1998) also observed that infectious diseases remain the biggest hindrance to the growth of village chicken production in villages in South-East Asian countries. One of the major constraints of village fowl production in Africa is undoubtedly the prevalence of various diseases (Guèye, 1998).

The problem of diseases in village chickens is compounded by the interactions of different entities that are of significant importance to disease epidemiology. At the rural level, contacts between flocks off different households, the exchange of birds as gifts, sales and purchases are the main sources of infection transmission (Kitalyi, 1998). He added that the critical management objective for scavenger free-range systems is to reduce the high mortality in both growing and adult age groups, but especially the 60 to 70 percent mortality in the growers. Due to the scavenging nature of village chicken, there is the likelihood of infection between other domestic fowls and wild birds. Some common diseases that have been reported to contribute to loss of flock size are Newcastle, Fowl Pox, Coccidiosis and Bacillary White Diarrhoea (Kitalyi, 1998).

According to Chrysostome *et al.* (1995), the local breeds have a reputation for hardiness and for resistance to diseases. However, the review of Guèye (1998) and the study of Mourad *et al*. (1997) revealed high chick mortality in rural flocks, ranging from 46% to 80% (Table 2.1.). Newcastle Disease (NCD) is the main cause of this mortality (Guèye, 1998; Chrysostome *et al*., 1995; Sonaiya *et al.*, 1999). The wild birds are a reservoir of NCD-virus (Guèye, 1998). Other diseases that affect village chickens to a lesser extent (3% to 14%) are fowl pox, pullorum diarrhoea, fowl cholera and coccidiosis (Atteh, 1989; Bonfoh, 1997; Mourad *et al*., 1997). In the study of Mourad *et al*. (1997) the most important cause of mortality for adult chickens was Newcastle Disease. For chicks and pullets, the most important one was the pullorum diarrhoea (Table 2.2). In addition to the diseases mentioned there is a high degree of internal and external parasitism.

Also, aerial and terrestrial predators contribute to mortality (Chrysostome *et al*., 1995; Sonaiya *et al*., 1999). Appropriate measures against chicken diseases such as NCD have been suggested by several authors (Card, 1961; IEMVT, 1987; Alders *et al.*, 1994; Nguyen *et al.*, 1996). In West Africa, June and December are the most strategic months to vaccinate chickens. These months were chosen to ensure that immunity is established before the outbreaks are most likely to occur (Alders *et al*., 1994). Losses caused by NCD are highest in the cold dry season in West Africa (Sonaiya *et al*., 1999). According to Guèye (1998) in Senegal, outbreaks of Newcastle Disease occur generally during the dry season, from January to June. Mourad *et al.* (1997) showed in their study in Guinea (Table 2.2), that NCD outbreaks were observed at the beginning of the raining seasons (May and June) and during the cold dry season (December, January and

February). Alders *et al.* (1994) stated that the introduction of an effective vaccination against NCD should be the first step in assisting village poultry production.

Table 2.1: Chick Mortality in Rural Production Systems in Some African Countries

Country		**% Mortality**			**Average**
Nigeria	50	46	50	55	50.25
Senegal	60	56	55	55	56.5
Ghana	70	80	40	60	62.5
Ethiopia	65	61	60	60	61.5
Cote d'Ivoire	55	50	55	55	53.75

Source: (Guèye, 1998; Chrysostome *et al*., 1995; Mourad *et al*., 1997; Sonaiya *et al*., 1999)

Table 2.2: Causes of Mortality (%) In Village Chickens

Causes of Mortality	**Adult chickens**	**Chicks/Pullets**
Newcastle Disease	54.70	25.31
Pullorum diarrhoea	26.91	35.34
Fowl pox	10.99	18.17
Bad management and others	7.40	21.18

Source: Mourad *et al*. (1997).

2.7.2 Nutritional Constraints

The feed resource base for village chicken production is scavenging and consists of household waste, anything edible found in the immediate environment and small

amounts of grain supplements provided by the women and children (Kitalyi, 1998). A study by Tadelle and Ogle (1996) revealed that protein supply may be critical, particularly during drier months, whereas energy may be critical during the rainy season. This agrees with the findings of Cumming (1992) that the feed resource base of the village is very variable, depending on the season and rainfall. Tadelle and Ogle (1996) concluded that supplementation of the diet of local birds with food sources containing energy, protein and calcium brought a considerable increase in egg production.

According to Sonaiya (1998) feed supply is one of the main constraints to rural chicken production. This was confirmed by a work he carried out on the nutritional status of local laying hens from chemical analysis of their crop contents. The work showed that the crop contents of the local layer consisted of 52.3% dry matter, 9.1% crude protein, 0.9% calcium, 0.7% phosphorus and 11.9kJ/kgME. These values were below the requirement for egg production, indicating the need for supplementation. His findings also showed that feed resources are the major inputs in the village poultry production systems, but unlike commercial poultry, it is very difficult to estimate the total feed cost of the village chicken production system because there are no direct methods of estimating the scavenged feed which constitutes most of the feed inputs. Sonaiya *et al.* (2002) recommended that for improved production, village chicken should be given supplementary ration compounded from locally available agro-industrial by-products twice a day with cool drinking water. They added that feed resource base for scavenging is limited and varies with seasonal circumstances such as rainfall,

cultivation, harvest and crop processing. If the supply of the scavenging feed resource is exceeded by the nutritional requirements of the animals, then the 'biomass' of the village flock is reduced accordingly.

2.7.3 Environmental Constraints

Village chicken production depends on environmental conditions. A high mortality of village chickens is observed due to unfavourable environmental conditions in relation to housing, diseases and predators. Several authors (Guèye, 1998; Sonaiya *et al*., 1999; Kitalyi, 1998) have reported on housing conditions for village chickens. Their work showed that the village chicken may perch on high places, on verandas or shelter in human houses or kitchens. There are several traditional housing units available for the village chicken. These traditional poultry housing structures are small and have poor hygienic conditions. Often there is high infestation with external parasites (Kitalyi, 1998). In Mali fowl houses were mostly small and constructed from sun-dried clay (Kuit *et al*., 1986). An improved housing system for village chickens was developed in Burkina Faso (Saunders, 1984). The house is a round compartment of three metres in diameter with two or more windows. In Zimbabwe, a run is attached to the poultry house and the term fowl-run in local poultry is commonly used (Kitalyi, 1998).

2.7.4 Socio-Cultural Constraints

For any meaningful improvement on the performance of the village chicken, there is the need to appraise the socio-cultural factors existing in the village. This is because these factors contribute to the wide variety of response of village poultry keepers even under

identical economic conditions. In some communities, there is a ban on duck keeping because they are presumed to be dirty and destructive to drinking water supplies (Kitalyi, 1998).

Another socio-cultural constraint to poultry development, according to Kitalyi (1998), is the value placed on poultry for use at ceremonies and festivals or even as a source of food or as a regular source of income. The high value placed on crop production at the expense of livestock production is also a major constraint to poultry production. This affects the willingness to invest much time, money and efforts into the livestock sector. Theft which results in loss of flock is also a great constraint because farmers who have lost all their birds through theft may be unwilling to start all over again. Kitalyi (1998) concluded that the social norm that determines the ownership of livestock can militate against the development of rural poultry. Unlike crop farming which is mainly a man's business, keeping livestock and poultry is perceived to be a supplementary source of employment and therefore relegated to women and children hence the low investment in that sector.

2.7.5 Technical Constraints

Kitalyi (1998) stated that the most common family poultry flock size of between 5 and 20 birds seems to be the limit that can be kept by a family without special inputs in terms of feeding, housing and labour. These small flocks scavenge sufficient feed in the surroundings of the homestead to survive and to reproduce. Any significant increase in flock size often leads to malnutrition if no feed supplement is provided. She continued

that larger flock sizes must forage at greater distances, which may involve damage to neighbours' vegetable gardens. Any move to fence in or enclose the poultry then involves the need to provide a balanced ration. Larger flock sizes can easily arise once mortality is reduced through vaccination and improved hygiene. Flock size can rapidly increase to the point where the feed requirement exceeds the available Scavengable Feed Resource Base (SFRB) in the area around the where the birds scavenge. The author concluded that, at this stage, either supplementary feeding or a semi-intensive system of management is required. If balanced feed, day-old hybrid chick and vaccine input supplies (and markets) are available and well organized, then intensive poultry management systems may be a viable option (Kitalyi, 1998).

2.7.6 Inadequate Investment in Village Chicken Production

Family poultry is usually the responsibility of women and children. In the rural areas of sub-Saharan Africa, more than 70% of the chicken owners are women (Guèye, 1998). Because village chickens are maintained with very low levels of inputs (land, labour and capital), they can be kept by those in the poorest social strata of rural populations (Guèye, 1998). Many authors (Guanaratne *et al*., 1993; Panda and Mohapatra, 1993; Guèye, 1998; Sonaiya *et al*., 1999) have indicated that family poultry in general and village chickens in particular represent a significant part of the village and national economies. These birds, according to them, play a significant role in the cultural life of rural people as gifts and as sacrifices. Improvement in village chicken production will require some form of investments which will be hard to find in the poorest poultry owners.

2.7.7 Marketing Constraints

According to Kitalyi (1998) the sale of village chicken and its products (meat and eggs) is not well organized. The birds are sold live to meet family needs and most of the sales occur at home. The age groups which are first to be sold are the young males, followed by the cocks while most of the females are kept for breeding purposes. Sale and consumption of birds and eggs, according to Kitalyi (1998), peak during the festive periods such as Christmas and Easter. The eggs produced by the hen are hardly sold or consumed as they are mainly used for hatching. The marketing and product utilization aspect of village chicken must be taken seriously.

A study by Rushton (1996) showed that egg and chicken consumption levels in rural communities are low, with average household consumption levels of one chicken and eight eggs per month in Ethiopia. The levels reported in the Gambia from the same study were found to be lower than that in Ethiopia. He therefore recommended the need, especially in Africa, for vigorous promotion of the consumption of chicken meat, eggs and chicken-derived products among rural communities. Various chicken product preparation methods, either from traditional or introduced dishes, or use of eggs in producing snack foods should be included in training sessions, particularly where women's groups are involved.

2.7.8 Breeding Constraints

The most common method used in the productive performance of the village chicken is crossing them with exotic ones, and then leaving the hybrid offspring to natural

selection (Kitalyi, 1998). Another method adopted is the use of hybrid chickens under free-range rural conditions. This strategy sometimes leads to increased egg and meat production, but only when there is a corresponding improvement in nutrition and veterinary hygiene. One problem encountered with the use of this strategy is that the use of exotic, high egg producing layers results in the elimination of broodiness in hens, due to the negative genetic correlation between high egg production and broodiness (Kitalyi, 1998). Any effort to improve on the gene pool of the village chicken must take into consideration the problem of local chicken breeding which is uncontrolled and indiscriminate. Under this, the male and the female chickens run together resulting in the hen producing chicks all year round. Although many strategies deemed appropriate for village chicken production systems have been implemented, most have not succeeded due to a lack of management input to support the improved potential (Kitalyi, 1998).

Factors that have contributed to the failure of most rural poultry genetic improvement programmes in a number of African countries, according to Kaiser (1990), are operational and financial problems of state-owned farms or stations maintaining the parent stocks, inability to maintain higher management level of improved stock in the villages, lack of adequate extension support and poor or inadequate institutional and organizational support (Kaiser, 1990). The preference for meat from commercial poultry is low. Many traditional consumers complain of commercial poultry meat having less flavour and the texture being too soft, although higher price were paid for village-produced poultry meat and eggs. Thus for any meaningful and sustainable

breeding strategy, there is the need to maintain and improve local birds to meet this demand, (Kitalyi, 1998) and also the strategy should focus on the genetic potentials of the indigenous breeds (Yalcin *et al*., 1997).

The poor management systems and environment the birds are exposed to are also militating factors for the full expression of the genetic potential of the crossbred birds (Barua and Howlider, 1990). Another constraint to local poultry breeding is the easy flow of genetic material as a result of extension of markets and economic globalization. This has resulted in the loss of local breeds through indiscriminate crossbreeding and dilution of gene pool of local genetic material (Tisdell, 2003). There is also a problem of adaptability of exotic breeds under the climate of Bangladesh, as reported by Cowan and Michie (1988). The exotic birds are more susceptible to heat and diseases compared to the local ones. When the exotic birds are exposed to high temperature and high humidity, they experience reduced feed intake and retarded growth rate which consequently lead to death (Kitalyi, 1998).

2.8 Productive Performance and Potential of Village Chickens

The productivity of village chicken production systems in general and the free range system in particular is known to be low (Guanaratne *et al*., 1993; Guèye, 1998). According to Aini (1990), poor reproductive performances, diseases and high feed costs are the main constraints. Under village conditions, the annual egg production per hen ranges from 20 to 100 eggs with an average egg weight ranging from about 34 to 52g (Sonaiya *et al*., 1999; Aini, 1998; Guèye, 2000). In South-East Asia, village chickens

reach a market weight of 1.0 - 1.5 kg at the age of 4 to 5 months (Aini, 1998). In Africa, the adult male and female weights range from 1.2-3.2 kg and from 0.7 - 2.1 kg, respectively (Guèye, 2000). Mortality is high and can reach up to 53% until four weeks of age (Guèye, 2000). In a study on village chicken characteristics in Guinea, Mourad *et al.* (1997) indicated that on average, the age at first laying was 180 days, egg weight was 30.7 g and hatching rate was 83%. Kitalyi (1998) also found out that the local chicken breeds in Ethiopia reached sexual maturity between 166 to 230 days, with hatchability and fertility values ranging from 39 to 44 and 53 to 60 percent.

Guèye (1998) indicated some advantages of village chicken production such as good egg and meat flavour, hard egg shells, high dressing percentages and especially low cost with little special care required for production. Village chicken meat is well appreciated in the developing countries and has a premium price: two to threefold in Indonesia and a 10 to 20% increase in Sri Lanka over the price of product from an intensive farm (Roberts, 1999). High dressing percentages (carcass weight divided by live weight) were observed for village chickens. Chrysostome *et al.* (1995) reported that the local breeds have a reputation for hardiness and resistance to diseases. Because village fowls are maintained with very low levels of input (land, labour and capital), they can be kept by those in the poorest social strata of rural population (Guèye, 1998).

According to Kitalyi (1998) the genetic development of the local breeds and strains in developing countries first requires proper documentation of their productive and reproductive performance. The village chickens in developing countries are generally

small in size, mature late (up to 36 weeks of age) and have low egg production (25-45 annually). They also have small clutch size (2-10 eggs), have long pauses between laying of clutches and a predominant inclination to broodiness; they have high fertility and hatchability of eggs, their eggs have high breaking strength, high yolk percentage and low cholesterol content (Mukherjee, 1990). The eggs of local chickens also have very thick shells (Fayeye *et al*., 2005).

According to Guèye (1998) village chickens are not particular breeds but are the result of erratic crosses between local and imported stocks. He continued that their growth and egg production are low and their limit of performance is rapidly reached when feeding and management are improved. Barua *et al*. (1998) found that the performance of the village chicken is far below that of the standard exotic stock. Missohou *et al.* (1998) observed from a study on village chickens in Senegal that the average live weight of the bird is 1.02± 0.337kg with an average tarsus length of 9.21cm. The egg number per hen was found to be 12.4, with an average egg weight of 31.7± 3.9 g.

Sonaiya *et al.* (1999) described three different production systems for family poultry, namely free range, backyard and small scale intensive with productivity of 20-60, 30-100 and 80-150 eggs per hen per year respectively. Body weights of 1.2kg and 800g were obtained at 32 weeks for normal size and dwarf breeds of local chickens under free range systems, respectively. They added that although the local chickens are slow growing and poor layers producing small sized eggs, they are however ideal mothers, good sitters and hatch their own eggs, excellent foragers, hardy and possess some

degree of natural immunity against common diseases. They concluded that these traits are of great importance as the farmers cannot afford to buy expensive concentrates and incubators, which at the moment are considered necessary for raising exotic birds.

In a study carried out on some farms in Senegal by Sall (1990), flock sizes of birds were found to range from under five birds to more than 15 birds, with an average flock size of ten birds. Seven percent of the flocks were below five birds, 38 percent comprised five to ten birds, 41 percent comprised 10 to 15 birds, and 14 percent comprised more than 15 birds. The proportion of chicks and growers in the flock was about 60 percent while adults represented 40 percent. Sall (1990) stated that mortality in the first month of age was 40 percent. Four to five clutches of eggs were laid per year, with 8 to 15 eggs per clutch. Egg weights ranged between 38 and 43g with an average of 40g. The author continued that hatchability of eggs was about 80 percent. The production cycle was eight to ten weeks (10 to 15 days for egg laying, 21 days for incubation, and only 34 days for rearing). The chicks remained close to the hens for up to two weeks, during which time there was a relatively low mortality rate of 14 percent. He added that on leaving the immediate protection of the hens, mortality increased sharply to 40 percent between three and four weeks, and up to 66 percent by three months of age. Similarly, the average daily live-weight gain of birds under this extensive system decreased from 10 g at eight weeks to 6 g at 12 weeks.

Kitalyi (1998) found that indigenous chickens tend to be robust and are well adapted to harsh environmental conditions such as hot or cold weather, rain and periodic feed

shortages. These birds have many advantages such as good egg and meat flavour, hard egg shells, high dressing percentages, and especially low cost with little special care required for production. Improvement in body size and growth of indigenous chickens is important from economic considerations bordering on the need to increase egg size and to improve the post-lay value of the chickens (Ibe, 1995). With well-designed selection programmes, this can easily be achieved in the indigenous chickens because of the appreciable additive genetic variance observed in these breeds (Olori, 1994). Another study by Njenga (2005) showed that the local chicken phenotypes of Kenya produced at an average rate of 23 to 36 percent with egg weight ranging from 38.1 to 45.8g.

2.9. Major Heat Tolerant Genes and Their Effects on Productivity

According to Gowe and Fairfull (1995) one of the most obvious constraints to poultry production in the tropics is the climate. They stated that high temperature, especially when coupled with high humidity will cause severe stress on birds leading to reduced performance. There is therefore the need to develop strains that can tolerate the heat stress. They stated further that since most of the international poultry breeders are located in temperate regions, there is the problem of adaptability to heat stress when these breeds are introduced to the tropical regions. As a result of this, imported birds are unable to express their full genetic potentials resulting in huge economic losses. Due to the problem of adaptability on the part of improved commercial stocks and low productivity of the indigenous stocks, there is the need to complement the

thermoregulatory genes of indigenous chickens with the high egg production genes of improved commercial breeds through crossbreeding (Nwosu, 1992).

There are several genes found in the indigenous chicken that are important for thermoregulation. According to Ndegwa *et al*. (1998) there are high populations of indigenous birds carrying genes for dwarfism, frizzling, naked-neck, silkiness, crest feathering and slow feathering. The incorporation of these genes could be significant in the development of appropriate breeds and strains for smallholder poultry production in the tropics (Kitalyi, 1998). Other morphological traits that allow better dissipation of heat include large combs, large wattles and long legs.

2.9.1 Naked-Neck Gene

The naked-neck gene (*Na*) was first studied by Davenport in 1914, but the gene symbol was assigned by Hertwig in 1933 (Somes, 1990). Several names have been given to this gene due to its uniqueness, example; Turkens, Transylvania Naked-necks, Bare-necks, Hackleless and Rubber necks. It is a single autosomal dominant gene. The gene is an incompletely dominant one with the heterozygotes (*Na/na*$^{+}$) showing an isolated tuft of feathers on the ventral side of the neck above the crop, while the homozygote dominant (*Na/Na*) birds either lack this tuft or it is reduced to just a few pinfeathers or small feathers. The resulting bare skin becomes reddish, particularly in males as they approach sexual maturity (Somes, 1990).

The author continued that the feather tracts of these birds are either absent or reduced in area resulting in a reduced feather cover. There is a 30% increase in the lateral pelvic apteria width of *Na/Na* chicks compared to *Na/na*$^{+}$ chicks. The reduction in feather cover is less in the heterozygote than the homozygote (27 and 22% for *Na/na*$^{+}$ females and males respectively and 41 and 33% for the *Na/Na* females and males respectively). The dorsal and ventral cervical tracts of these birds are also absent. The dorso-pelvic, dorsal caudal and pectoral tracts are all markedly reduced in area. The feather follicles are also absent from the head and neck except around the comb, the anterior spinal tract and two small patches on each side above the crop. The naked-neck gene which controls the naked-neck trait is located near the middle of chromosome 3. It is a single autosomal incomplete dominant allele symbolized 'Na'. The Homozygous dominant (Na/Na) or heterozygous (Na/na^{+}) birds exhibit the naked-neck characteristic, though the heterozygote exhibit less reduction (20%) in feathering.

Horst (1988) advocated the introduction of the naked-neck gene into the local birds in the tropics for higher productive adaptability. Due to the naked-neck birds' alertness and fighting characteristics, they appear to be able to protect themselves and their chicks from being preyed on. They have been found to do well under heat stress and high humidity. According to Merat (1986) the naked-neck trait is present in several regions of the world, especially in the tropics where the climate is hot and humid. Due to their fewer feathers, they require less protein resulting in a reduced incidence of feather pecking and cannibalism. The reduced feather cover helps the bird to receive

more solar radiation, which may facilitate greater vitamin D synthesis and in turn, contribute to better egg shell quality.

The naked-neck is a major 'marker' gene identified by qualitative criteria (visual, biochemical or serological) that may show association with quantitative traits, either because of pleiotropy, defined by Johnson and Rendel (1968) as in the case when a gene influences two or more traits, or because of linkage with other genes (Crawford, 1990). Major heat-tolerant genes like naked-neck are of economic interest in modern breeding systems as they act as sex marker genes and disease resistant factors (e.g. avian leucosis). Recently research findings have proved that naked-neck genes can affect productive adaptability to tropical climates and management conditions (Islam and Nishibori, 2009). These major genes are also associated with improved feed intake, productivity and survivability under heat stress conditions. The autosomal incomplete dominant naked-neck (*Na*) gene is not only responsible for defeathering the neck region, but also restricts the feathering areas around the body by 20-30% in the heterozygous (*Na/na*) and up to 40% in the homozygous (*Na/Na*) genotype, because of incomplete dominance of the *Na* gene. In homozygous situations, naked-neck chickens have a completely bare neck whereas in the heterozygous condition they have a bare neck with a tuft of feathers (Horst, 1988).

According to Islam and Nishibori (2009) the '*Na*' gene and its effect on heat dissipation positively affects appetite. This happens for two opposing reasons: in cool climates, because of higher energy demands, and in hot climates because of an increase in body

temperatures. Under such conditions, feed intake increases, resulting in improved body weight, egg sizes and liveability. A specific effect of this gene is related to improved vitality and reduced liver fatness. Islam and Nishibori (2009) again observed that due to the dominant nature of the '*Na*' gene, physiological improvements are strongly related to the severity of the environmental stress situation. The gene is clearly expressed under unfavourable conditions such as higher ambient temperatures and humidity, smaller diurnal or seasonal fluctuations and under poor management conditions. Susceptibility of the '*Na*' gene to heat tolerance was found to be less than observed in other commercial broilers (N'dri *et al*., 2007). Normally feathered (*na/na*) birds are more susceptible to heat stress than naked-neck birds, because the latter have significantly greater dermal swelling capability compared to their '*nana*' counterparts in high ambient temperatures (El-Safty *et al.*, 2006). With respect to the naked-neck gene, the *Na* birds have received greater attention for poultry production, because of their association with the reduction in feather coverage, improved heat tolerance and better adaptability at high ambient temperatures (Merat, 1986).

2.9.1.1 Effect of the gene on growth, feed efficiency and meat yield

The relevance of the naked-neck gene in the tropics lies in its association with thermoregulation. The reduction in feather coverage of about 30-40% in these birds facilitates better heat dissipation resulting in a better relative heat tolerance under hot climates. In a study carried out by Merat (1990) on birds reared under high temperatures, about 30^0C or higher, the homozygous (*Na/Na*) or the heterozygous (Na/na) naked-neck birds showed a better average weight gain than their normally

feathered counterparts. There was also an improvement in the carcass yield for the heterozygous genotypes. There was however an increase in embryonic mortality observed in the *Na/Na* and *Na/na* birds. Yalcin *et al*. (1997) and Patra *et al*. (2002) also observed that under high temperatures, birds carrying the naked-neck gene had higher breast weight, superior growth rate, and better feed conversion ratio and carcass traits. Eberhart and Washburn (1993) reported that naked-neck birds were significantly larger than normal feathered birds when subjected to chronic heat stress although the two genotypes segregated from the same parents.

Merat (1986) studied naked-neck and normally feathered broilers reared at three different temperatures (20^0 C, 25^0 C and 30^0 C) and observed that at 20^0 C or lower, the differences between the normally feathered and the naked-neck birds in terms of body weights and weight gain almost the same. At 24-25^0 C, growth and feed efficiency between the naked-neck and the normally feathered genotypes were negligible. Near 30^0 C or higher, the naked-neck birds were heavier and had better feed efficiency than the normally feathered birds. On carcass yield, the study revealed that the reduction of plumage by 30 percent for the heterozygote and 40 percent for the homozygote resulted in gains of 1.5-2.0 percent and 2.5-3.0 percent in slaughter yield of the two genotypes respectively. There was also an increase in meat yield of dressed carcasses by as much as 5.5 percent and 4.0 percent for males and females respectively. This was evidenced in the higher proportion of muscle in naked-neck birds in the pectoral region. There was also a lower percentage of intramuscular and subcutaneous fat in the naked-neck birds as compared to the normally feathered birds (Merat, 1986).

Fayeye *et al*. (2006) observed that among the indigenous birds surveyed in some selected villages in Nigeria, those expressing the naked-neck trait were found to be superior in adult body weight. Horst (1988) worked on Dahlem Red stocks showing the naked-neck gene and reported that those genotypes expressing the gene were superior in egg production and body weight as compared to genotypes that were not expressing the gene. Alvarez *et al.* (2002) found that the heterozygous naked-neck (*Na/na*) genotype had a better cellular and humoral response than their normally feathered (*na/na*) and homozygous naked-neck (*Na/Na*) genotypes. Also, El-Safty *et al*. (2006) observed that the *Na/na* hens had a significantly greater dermal swelling (cell mediated) compared to the normally feathered ones. Additionally, the normal plumage hens had a higher mortality and culling rate than heterozygous naked-neck hens. Another research work by Mahrous *et al*. (2008) on the impact of naked-neck and frizzle genes on growth performance and immunocompetence in chickens showed that the presence of the *Na* gene in the single state significantly improved feed conversion ratio.

Under high ambient temperature, Galal and Fathi (2001) concluded that the naked-neck gene was associated with higher feed consumption compared to its homozygous recessive allele. The same authors found that the *Na* allele had a better effect on feed conversion ratio, where the *Na/na* genotypes had significantly lower feed conversion ratio as compared to the *na/na* ones. Alvarez *et al*. (2002) found that the feed conversion ratio was 2.42 in *na/na*, 1.84 in *Na/na* and 1.92 for *Na/Na* hens under moderate ambient temperature. Under the high ambient temperature (34^0C), Jianxia

(2002) reported that male broilers with frizzle and naked-neck genes increased feed intake by 6.0% on average when compared to the normally feathered broilers.

2.9.1.2 Effect of the Gene on Egg Production and Egg Quality Traits

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. Their study revealed that egg numbers at moderate temperature are not significantly affected by the naked-neck gene. At high temperature, the naked-neck hens had a better laying rate. At 20^0C, adult body weight was lower in naked-neck hens, especially the homozygotes, than in hens with complete plumage cover, but the trend reversed when the temperature increased above 30^0C. It has been reported that 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 compared with the na/na genotype. 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. They 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, (Ladjal *et al*., 1995), less body weight loss under heat stress, 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 cloacal 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.

According to Islam and Nishibori (2009) naked-neck chicken has a good heat dissipation mechanism, is well adapted to 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 ambient temperature but superior to their normally feathered counterparts at 30°C or more ambient 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). Feathering intensity and feather structure can increase heat loss, and so indirectly increases 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).

2.9.2 Frizzle Gene

This 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 the frizzling is located on chromosome 6. The gene is occasionally 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 less 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.

Frizzled birds have increased basal metabolism, leading to increased production of thyroid and adrenal gland hormones (Benedict *et al.,* 1932 and Boas and Landauer, 1933). They again found an increased feed intake, oxygen consumption, heart rate, and volume of circulating blood. As a result of this, frizzled birds are expected to have enlargement of the heart, spleen, gizzard and alimentary canal.

2.9.2.1 Effects of the Frizzle Gene on Egg Production and Egg Qualities

There is not enough information on the effects of the frizzle gene on productivity as compared to 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). They 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 the 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^{0}C) and (32^{0}C) revealed that the birds carrying the *F* gene laid 24 more eggs over a 364 day laying period in the hot (32^{0}C) environment. On the other hand, the *F* gene birds laid only 3 eggs less on average in the cooler (18^{0}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 immunocompetence 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^{0}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 relative 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.

2.9.3 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 implemented in breeding programmes 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 one or 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. For a favourable egg laying performance under hot and humid conditions, that is, above 30^0C, Horst (1989) and Haaren-Kiso *et al.* (1988) proposed the use of the double heterozygous condition of naked-neck and frizzling. 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 of 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 Harren-Kiso *et al.* (1995); thus, combining the two 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 birds heterozygous 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 34^0C, the double heterozygous birds (*Na/anF/f*) exhibited the highest feed consumption, body weight and egg production among the four genotypes.

According to a work by Mahrous *et al*. (2008), it was observed that the naked-neck frizzle (*Na/naF/f*) genotypes attained sexual maturity earlier than that of normally feathered females by about 4.3, while the age at sexual maturity was not significantly affected by the frizzle gene. The presence of naked-neck frizzle genes in combination significantly increased egg mass, egg number and egg weight compared to the fully-feathered genotype. 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 a combination with *F* gene significantly increased egg shell weight, egg shell percentage and egg shell thickness compared to normally feathered counterparts. The breaking strength of naked-neck frizzle genotype eggs was significantly higher than that of na/naf/f ones. Haematocrit level, plasma calcium and phosphorus of *Na/naf/f*, *na/naF/f* and *Na/naF/f* genotypes were significantly higher than that of na/naf/f birds. They 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 and birds heterozygous only for one of these genes (*Na/naf/f* and *na/naF/f*).

2.9.4 Genotype-Environment Interaction

Mathur (2003) defined a genotype-environment interaction as the change in the relative performance of two or more genotypes measured in two or more environments. This interaction illustrates the need for having the appropriate breed or strain for a particular environment in order to obtain optimum performance and also the need to compare and select potential animals to be parents under the same conditions in which their progeny will be produced. Genotype in this respect is defined as breed, strain, line or individuals such as sires whose progeny have been raised in more than one environment (Mathur, 2003). The environment, on the other hand, can be nutrition, climate, housing, management, location etc.

It has also been found that genotype-environment interactions may not be caused only by specifically differentiated genotypes, but also by single major gene effects (Mathur,

2003). Some major heat tolerant genes found in the tropics have shown important genotype-environment interactions. The same author continued that the naked-neck gene (*Na*) which is responsible for the general reduction of plumage over the body surface and total loss of plumage in the neck region has shown very favourable results under heat stress conditions. According to Mathur (2003) the heterozygous naked-neck condition has shown a significantly higher egg number, egg weight, egg mass and adult body weight under heat stress conditions. The frizzling gene (*F*) has also been found to elicit some favourable effects on productivity due to its ability to confer on the bird better heat dissipation during heat stress conditions.

The choice of suitable genotypes and selection for their further improvement depend on the nature and magnitude of the interactions. According to Mathur (2003), one of the challenges posed by genotype-environment interactions is that of selection. The problem is whether the breeder should select under more favourable environmental conditions that allow maximum expression of the genotype or whether the selection should be carried out in the environment where the genotype is actually destined to live.

2.10. Modern Trends in Poultry Breeding and Genetics

Effectively, poultry breeding started when the chicken was domesticated thousands of years ago (Albers *et al.*, 2008). The authors continued that through human intervention many different breeds evolved over the centuries, but breeders began to use scientifically based selection methods less than a century ago. The commercialisation of poultry has led to the exploitation of knowledge of single genes such as those for plumage colour and for sex linked traits that can be used for sexing of day old chicks.

Again, according to Albers *et al*. (2008) industrial breeding commenced with the hybridisation of the selected pure breeding lines sampled from some base populations and continued with more and more intense further selection of pure lines. One of the milestones in genetic selection is the development and application of the theory of quantitative genetics. Today's poultry breeding strategies apply full utilisation of pedigree of all birds and the exploitation of Best Linear Unbiased Programme (BLUP) breeding value estimations to obtain the best possible identification of superior breeding candidates. This will make it possible to identify the parents of the next generation as early as possible (to reduce the generation interval) and genetic selection would have to be devoted with the right emphasis to the right traits as determined by the market (Albers *et al*., 2008).

Several studies have indicated that use of genomic information is expected to contribute to traits that are difficult or impossible to measure on the individual, including sex-limited traits, which can only be measured late in the animal's life, or are of low heritability (Dekkers and Hospital, 2002). These findings are general and apply to Marker Assisted Selection (MAS), selection for known genes or Genome Wide Selection (GWS), and are based on the general principle that genomic information is an information source that does not rely on the availability of phenotypic observations. For some traits, traditional selection using phenotypic information does an excellent job and adding genomic information is not expected to make an important contribution. Examples of such traits are naked-neck and frizzle. This is because these traits can be measured in both sexes and can also be measured early in the bird's life. The naked-

neck trait can even be measured at day-old, hence making traditional selection very effective to select birds for naked-neck and frizzle conditions without resorting to MAS or GWS.

Dekkers and Hospital (2002) observed that traits like resistance to disease (eg. Ascites) is much more difficult to improve using traditional selection. Selection for ascites resistance can be done by challenging relatives of selection candidates under cold conditions or at high altitude, and recording the fraction that survive. Alternatively, indicator traits like the ratio of right ventricular over total ventricular weight can be used. However, this also requires that the individual is sacrificed and therefore traits need to be recorded on relatives of the selection candidates rather than on the selection candidate itself. Selection for disease resistance is thus complicated and expensive warranting the application of MAS.

According to Pakdel *et al.* (2005) an important advantage of having genomic information is that the information is available on all the selection candidates, which makes it possible to differentiate full sib individuals and thus facilitate selection within families. Moreover, when using MAS to measure disease resistance no birds need to be euthanized. Similar arguments apply for the expected contribution of genomic information in selecting, for example, for carcass traits or egg production. With the availability of genome-wide Single Nucleotide Polymorphism (SNP) assays and with the use of genomic selection, new opportunities have become available to selectively improve these types of traits.

According to Groenen *et al*. (1998) the first development that has had an impact on poultry breeding was the discovery of genetic markers. The markers that form the most widely used category were small anonymous repeat sequences of DNA (microsatellites) that are scattered across the entire genome and can be used as landmarks to construct a map of the chicken genome. According to the authors, the application of genetic markers was the establishment of linkages between some genes on the chromosomes and the genetic variability of traits of interest. Aggrey and Okimoto (2003) also observed that genetic variation within families, within species and between populations is assessed by genetic markers. Thus genetic markers are the basic tool for geneticists. Genetic markers may be operationally defined as a phenotypically recognizable genetic trait that can be used to identify a genetic locus, a linkage group, or a recombination event.

A review by Hocking (2005) on all Quantitative Trait Loci (QTL) mapping experiments in chicken shows that up to the end of 2004 well over 100 statistically significant QTL were discovered and these covered all major production traits. QTL are chromosome segments that affect a trait, but not necessarily a single locus (Falconer and Mackay, 1996).

According to Albers *et al*. (2008) many practical breeders choose not to explore QTL findings because major genes with large effects either do not exist or have been fixed due to many years of selection. The authors continued that due to the prohibitive cost involved in marker assays, it makes it an unattractive proposition to the breeding

companies. This is because practical selection for QTL would involve the genotyping of many animals for many markers, as the linkage phase between QTL and marker has to be established in every family. The future of poultry breeding looks bright because in the coming years there is likely to be a growing number of major genes being directly selected for poultry breeding programmes.

According to Mozdziak and Petitte (2004) with the coming into being of efficient and effective technology for genetic modification of chickens, the directed gene manipulation would be workable. With the emergence of specialised areas in genetics like genomics, proteomics, metabolomics, molecular genetics etc. the development of the first genetically modified chicken breed is eminent. According to Fulton (2008) one area of practical application of molecular genetics is in the area of selection for sex-limited traits. The ultimate aim of selection is to increase the frequency of those gene variants that cause desirable effects on the traits under selection. For egg production traits like age at first lay, total egg production as well as egg quality traits which are measured only in females, even though both males and females have the gene variants for better egg production, direct measurement is only done in the females. To overcome this and directly select based on individual performance irrespective of sex, the breeder must employ the use of molecular genetics (marker assisted selection). This is because in this method the selection is based on the DNA and since the DNA that directs the trait expression is present in the chick at hatch the breeder can select the individual early (at hatch) thereby reducing the generation interval and hence increase the genetic gain.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Introduction

The research was in two phases: a survey work and an experimental work. In the first phase a survey was conducted in some selected villages in the Ashanti region of Ghana to determine the incidence and frequency of occurrence of heat-tolerant (naked-neck and frizzle) genes. The second phase of the work was a performance evaluation study on some crossbred naked-neck and frizzle genotypes (*Na/naF/f*, *Na/naf/f*, *na/naF/f* and *na/naf/f*).

3.2 The Survey Work

3.2.1 Description of the Study Area

The survey was carried out in some selected villages located in six (6) randomly selected districts in the Ashanti Region of Ghana. The Ashanti Region is centrally located in the middle belt of Ghana. It lies between longitudes 0.15W and 2.25W, and latitudes 5.50N and 7.46N. The region shares boundaries with four of the ten political regions, Brong-Ahafo in the north, Eastern Region in the east, Central Region in the south and Western Region in the south west.

The region occupies a total land area of 24,389 square kilometres representing 10.2 per cent of the total land area of Ghana. It is the third largest region after Northern (70,384 sq. km.) and Brong-Ahafo (39,557 sq. km.) regions. The region has a population density

of 148.1 persons per square kilometre, the third after Greater Accra and Central Regions. More than half of the region lies within the wet, semi-equatorial forest zone, (MoFA, 2005).

Due to human activities and bushfires, the forest vegetation of parts of the region, particularly the north-eastern part, has been reduced to savanna. The region has an average annual rainfall of 1270mm and two rainy seasons. The major rainy season starts in March, with a major peak in May. There is a slight dip in July and another peak in August, tapering off in November. December to February is dry, hot, and dusty. The average daily temperature is about 27^0C. Much of the region is situated between 150 and 300m above sea level. The economically active population in the region is engaged in agriculture, excluding fishing, with 44.5% of them employed in that sector, (MoFA, 2005).

The region contributes quite significantly to poultry population in the country. The region could boast of about 101,776 cockerels, 115,803 broilers, 1,206,291 layers, 361,537 local birds and about 404,665 unspecified number of poultry species as at 2004 (MoFA, 2005). In terms of estimated number of eggs produced, the region was ranked first with an estimated amount of 1,032.2 million eggs per annum as against 323.2 million from the Greater Accra Region (MoFA, 2005).

3.2.2 Sampling and Sample Size for the survey

Six districts in the region were randomly selected. They were: (1) Atwima-Mponua (2) Kwabre (3) Bosomtwe-Atwima-Kwahoma (4) Sekyere East (5) Ejisu-Juaben and (6) Amansie East. After the selection of the districts, a multi-stage approach was adopted by taking a reconnaissance study at some villages in the selected districts. This enabled the researcher to identify farmers who kept naked-neck and frizzle birds. Households with these birds were purposely selected. A total of thirty (30) villages were purposely selected for the study, with five (5) villages in each districts. The farmers were briefed on what was going to be done. The farmers were made to understand that they were going to be direct beneficiaries of the research. Due to the participatory nature of the work, the farmers collaborated.

3.2.3 Data Collection Technique used in the survey

Data were collected by counting the number of birds showing the naked-neck and frizzle traits. The counting of the birds (both those which showed the traits and those which did not) was done early in the mornings or late in the evenings, when the birds had just come out of their nests or about to go to roost. The birds were individually observed for feather morphology or distribution (naked-neck condition) and feather structure (frizzle conditions). The frequencies of the genes were obtained by means of counting the number of birds expressing the genes as against those that did not and the number expressed as a percentage of the total number of birds.

Since the genes for the naked-neck and frizzle traits show incomplete dominance, that is, the homozygote can be distinguished from the heterozygote making it easy to differentiate between the two. However, during the enumeration, the researcher did not come across the homozygous dominant naked-neck or frizzle birds. There were only heterozygous naked-neck or frizzle birds that were enumerated. Chicks were not included in the enumeration because it was very difficult differentiating frizzle condition in chicks. In all a total of 604 birds were counted throughout the whole survey period (March-May, 2006).

3.2.4 Data Analyses for the survey work

The frequencies of the dominant genes (**Na** and **F**) and their recessive counterparts (**na** and **f**) were calculated using the Hardy-Weinberg equilibrium approach (Falconer, 1989) as follows:

$$q = \sqrt{\mathrm{m}}/\mathrm{t}$$

where:

q = frequency of the recessive genes (na and f)

m = observed number of birds with recessive trait under consideration

t = total number of birds examined

The frequency of the dominant alleles (Na and F) were calculated from

$p + q = 1$ where; $p = 1 - q$

Where:

p = the frequency of the dominant allele

The observed frequencies from the enumeration were tested against the expected Mendelian values of **0.75** and **0.25** for dominant and recessive alleles respectively using the chi-square test.

Calculated chi-square value (χ^2) was obtained as follows:

$$\chi^2 = \sum \frac{(observed - expected)^2}{expected}$$

Parental phenotypes	Frizzle	X	Lohman	Naked-Neck	X	Lohman
Parental genotypes	*na/naF/f*	X	*na/naf/f*	*Na/naf/f*	X	*na/naf/f*
	↓			↓		
Offspring genotypes	*na/naF/f*			*Na/naf/f*		
Offspring phenotypes	Frizzle			Naked-neck		F_1- Offspring

Fig.3.1: The first mating involving the local naked-neck and frizzle males and Lohman brown females showing the phenotypes and genotypes.

Parental phenotypes	Naked- neck	X	Frizzle		Frizzle	X	Naked-neck
	↓					↓	
Parental genotypes	*Na/naf/f*	X	*na/naF/f*		*na/naF/f*	X	*Na/naf/f*
	↓					↓	
Gametes	*Na* *na*		*F*	*f*	*Na*	*na*	*F* *f*
Offspring genotypes	*Na/naf/f*		*Na/naF/f*		*na/naF/f*		*na/naf/f*
Offspring phenotypes	Naked-neck		Naked-neck frizzle		Frizzle	Normal	F_2

Fig.3.2: The second mating (main and reciprocal) involving crossbred naked-neck and frizzle males and females showing the gametes, the phenotypes and the genotypes.

X

Local Heterozygous Frizzle cock Commercial Lohman Brown females

Fig. 3.3: The Mating Between the Local Heterozygous Frizzle Cocks and Lohman Brown Hens

Local Heterozygous Naked-neck cock

X

Commercial Lohman Brown females

Fig.3.4: The Mating Between the Local Heterozygous Naked-Neck Cocks and Lohman Brown Hens

Crossbred Frizzle Hens
(50% indigenous frizzle, 50% Lohman Brown)

X

Crossbred Naked-Neck Cocks
(50% indigenous naked-neck, 50% Lohman Brown)

Fig.3.5: The F_1 Crossing Involving Crossbred Naked-Neck Cocks and Frizzle Hens

X

Crossbred frizzle cocks

Crossbred naked-neck hens

Fig. 3.6: The F_1 Crossing Involving Crossbred Frizzle Cocks and Naked-Neck Hens

Fig. 3.7: Crossbred naked-neck frizzled hens

Fig. 3.8: Crossbred frizzled hens

Fig. 3.9: Crossbred Normally Feathered hens

Fig. 3.10: Crossbred naked-neck hens

3.3 The Experimental Work

The second part of the work was a performance evaluation study on some crossbred naked-neck and frizzle genotypes. The base population used to generate the crossbred genotypes consisted of mature local naked-neck and frizzle males purchased from some villages in the Ashanti Region of Ghana; and Lohmann Brown hens obtained from the Breeder Farm of Akate Farms and Trading Company in the Ashanti Region (see Fig. 3.3 and 3.4). The Lohmann brown hens have been intensively selected for egg production while the naked-neck and frizzle chickens were from unselected, random mating chickens. When the birds were brought, they were de-wormed using piperazine. They were also administered with the booster doses of Newcastle vaccine (Lasota).

The first crossing involved the local naked-neck and frizzle cocks (Fig. 3.3 and 3.4) which were heterozygous for the naked-neck and frizzle genes and Lohmann brown hens, homozygous recessive for the two alleles (see Fig. 3.1). A second mating was done in order to get birds which were double heterozygous for the naked-neck and frizzle genes (see Fig. 3.2). This is because these genotypes were not obtained after the first mating.

The mating system used to generate the F_2 birds involved main and reciprocal crossing (see Fig. 3.5 and 3.6). The second mating involved 128, 30-week old crossbred pullets (64 each of naked-neck and frizzle birds) and 16, 30-week old crossbred cocks (8 each of naked-neck and frizzle birds). All the crossbred F_1 birds used as parents for the second crossing were heterozygous for the two alleles (see Fig. 3.2). The mating system

employed was natural whereby the cocks treaded the hens. Eggs from the two genetic groups were collected daily, identified (pedigreed) and set in the incubator after ten (10) days.

Eggs for hatching were collected ten days after the males had been put on the females. This was to ensure high percentage of fertile eggs. Egg collection was done twice daily, 9am and 3pm. The eggs were stored in a cool, dry place to ensure that their fertility was not compromised. At the end of the second mating, there were four main genotypic groups (see Fig. 3.7, 3.8, 3.9 and 3.10) depending on whether the offspring possessed the naked-neck and the frizzle genes in the double segregation state, that is, naked-neck frizzle (Fig. 3.7) or single segregation states that is, frizzle (Fig. 3.8) and naked-neck (Fig. 3.10) or did not show the genes at all that is, normally feathered (Fig. 3.9).

3.4 Incubation of Eggs

The eggs were selected for artificial incubation according to size (pee wee and jumbo-sized ones discarded); cracked, blood-stained or dirty eggs were also discarded. They were fumigated with a mixture of 20ml Formalin (40%) and 10 gm Potassium permanganate, in an airtight wooden box. They were then incubated in a 10,000-capacity combined Setter/Hatcher incubator, which turned automatically at 90^0 every hour. The eggs were incubated at a temperature of 37.8^o C and 75% relative humidity for 18 days. The eggs were candled at day 9 and moved to the hatcher compartment at day 18. The incubator was set at 36.7^o C and 80% relative humidity for the last three

days. Day-old chicks were brooded at the poultry section of the Department of Animal Science, Kwame Nkrumah University of Science and Technology (KNUST).

3.5 Brooding Period (Rearing of the Crossbred F_2 Chicks)

There were four (4) different genotypes generated with respect to genes for feather structure and distribution. This was based on whether the bird was **Na/na** (naked-neck), **F/f** (frizzle), **Na/naF/f** (naked-neck frizzle) or **na/naf/f** (normally feathered). After hatching, the chicks were individually weighed, wing tagged and taken to the brooder house and fed with chick mash *ad lib.* The room temperature during the first week was kept at 35^0C and gradually reduced as birds developed feathers. Both the corrugated metal type and the open-sided concrete block type of brooder houses were used. To conserve heat for the latter type of housing, black polythene sheets were used to cover the side ventilation windows. The source of heat used was the 60 watts electric bulbs. Plastic chick drinkers and wooden trays were used to provide water and feed for the chicks during the brooding period. In all, there were three brooder houses, each partitioned into four for the four genotypic groups.

During the first week of rearing at the brooder house, the birds were individually weighed using a top-loading digital balance. This was because the frizzle and the normally feathered could not be differentiated since at that age their feathers had not fully developed. In that case, Marker Assisted Selection (MAS) would have been possible to select the genotypes at hatch. After the first week, they were grouped into four groups (**Na/naF/f; Na/naf/f; na/naF/f; na/naf/f**) depending on their genotype and

weighed. Genotypes were identified according to the morphological expression of the major genes for naked-neck (Na), frizzle (F) and naked-neck frizzle (NaF). Birds without any expression of the major genes were classified as normally feathered (na/naf/f).

The mean weights per group were recorded. The chicks were vaccinated against Newcastle disease during the second and fourth weeks of rearing while Gumboro vaccine was administered in the third and fifth weeks. Coccidiostat (Amprolium) was also administered through the drinking water bi-weekly.

3.6 Performance Studies on the Crossbred Birds

The growth, carcass yield and egg laying performance of the four genotypes (*double heterozygote, single heterozygote comprising naked-neck and frizzles and normally feathered*) identified at the end of the second crossing was evaluated. Data collection and analysis were done both on-station and on-farm. Under the on-station experiment, data were obtained during the brooding (day-old to eight weeks), growing (nine to fourteen weeks) and laying (eighteen to sixty weeks) stages of the various genotypes. The brooding stage experiment was from April to June, 2007. The growing stage experiment on the other hand was from June to July, 2007. Finally, the laying stage experiment spanned from August, 2007 to May 2008. With respect to the on-farm experiment, data on growth and egg laying performance on the crossbred naked-neck and frizzle genotypes and farmers own pullets were taken. The on-farm study was done at selected villages within the six randomly selected districts in the Ashanti Region.

With the brooding stage experiment, body weights, growth rate, weight gain, feed intake and feed conversion ratio were recorded from day-old to eight weeks of age.

3.6.1 Data Analysis for the Brooding Stage Data

The data obtained during the brooder stage were subjected to one-way analysis of variance with genotype effect using GenStat (Discovery Edition). When significant differences among means were found, means were separated using least significant difference (lsd) test. The linear model below was used for the brooder stage data analysis.

$Yij = \mu + gi + \varepsilon ij$

Where *Yij = performance of the jth chick of the ith genetic group*

μ = overall general mean common to all observations

gi = fixed effect due to ith genotype (i = 1, 2, 3, 4)

εij = random error effects peculiar to each observation

3.7 The grower stage experiment

3.7.1 Sample Size and Experimental Design

In this study, one hundred and twenty (120), nine-week old cockerels, 30 from each of the four genotypic groups (F_2 offspring) were assigned in a completely randomized design (CRD) experiment with genotypes as treatments. There were three replicates with ten (10) cockerels in each replicate group. The cockerels were kept at the Poultry Section of the Department of Animal Science, Kwame Nkrumah University of Science and Technology, Kumasi.

3.7.2 Management Practices Carried Out During Rearing

The birds were kept in an open-sided house constructed with sandcrete blocks. There were twelve pens (10 cockerels in each pen) with each pen measuring 270cm by 165cm. The feed and water were supplied in 2.5kg capacity hanging feeders and 10L capacity plastic fountain drinkers respectively. The plastic drinkers were cleaned daily throughout the experimental period. The floor of the pens was made of concrete and covered with 15 cm deep wood shaving which was changed every month.

The cockerels were fed commercial grower mash *ad lib* (see Table 3.1). The amount of feed remaining in the morning was monitored in order to increase or decrease the quantity for the next day. Vitamin and mineral premix was also supplemented in the water occasionally.

Table 3.1: Nutrient composition of the grower and layer mash fed to the birds.

Nutrient contents	Grower mash	Layer mash
Metabolizable energy/kcal/kg	**2650**	**2700**
Crude protein/%	**15**	**17.43**
Crude fat/%	**4**	**3.65**
Lysine /%	**0.75**	**0.83**
Methionine/%	**0.35**	**0.3**
Calcium/%	**1.0**	**1.0**
Cystine/%	**0.3**	**0.3**
Phosphorus/%	**0.45**	**0.45**

Source: Agricare Feeds Limited

3.7.3 Data Collection and Parameter Estimation

3.7.3.1 Body Weight Determination

Body weights (g) were taken weekly and the average body weight per genotype recorded. Weight gain was determined as the difference between final body weight and the initial body weight. Growth rate was therefore calculated as the weight gain divided by age (42 days).

3.7.3.2 Feed Intake and Feed Efficiency

Known amounts of feed (kg) were supplied to each group in each pen at the beginning of each week and the left-over at the end of the week was subtracted from the amount supplied at the beginning, to obtain the weekly feed intake. From the feed intake values

obtained, and the relevant weight gains, the feed efficiency was estimated to be the ratio of kg feed intake to kg weight gain.

3.7.3.3. Carcass Yield Determination

At the end of the 14 weeks, three cockerels from each of the four groups were randomly selected for slaughter and their carcass yield characteristics calculated. Before slaughter the cockerels were deprived of feed but not water for 10 hours to ensure easy evisceration procedure and also to know their actual live weights. The following carcass yield parameters were taken: live weight, carcass (dressed) weight and percentage, blood weight (this is the difference between bird's live weight before slaughter and after it has been completely bled) and feather weight. Carcass weight was calculated as the weight of the carcass after the feathers, lower legs, heart, crop, pancreas, lungs, head, digestive and urogenital tracts had been removed. Carcass (dressing) percentage was calculated as the ratio of the carcass weight to the live weight.

3.7.3.4 Data analysis for grower phase data

The data obtained were subjected to one-way analysis of variance with genotype effect using GenStat (Discovery Edition). When significant differences among means were found, means were separated using least significant difference (lsd) test. The linear model below was used for the data analysis.

$Yij = \mu + gi + \varepsilon ij$

Where *Yij = performance of the jth cockerel of the ith genetic group*

μ = overall general mean common to all observations

gi = fixed effect due to ith genotype (i = 1, 2, 3, 4)

εij = random error effects peculiar to each observation

3.8 Layer Stage Experiment

3.8.1 Experimental Design for Crossbred Pullets Reared On-station

The objective of this work was to evaluate the egg production and egg quality (internal and external) characteristics of the four crossbred F_2 genotypes (*double heterozygote, Na/naF/f; single heterozygote, na/naF/f* and *Na/naf/f* and *normally feathered birds, na/naf/f*). One hundred and twenty (120), 18-week old pullets, 30 each of the four genotypic groups were randomly assigned in a Completely Randomized Design experiment for a period of up to 60 weeks with genotypes as treatments. There were three replicates with ten (10) pullets in each replicate group.

3.8.2 Management of the On-Station Crossbred Pullets

The birds were kept in a partitioned open-sided deep-litter house constructed with sandcrete blocks with 10 pullets in each compartment. There were twelve pens with each pen measuring 270cm by 165cm. They were housed in partitioned deep litter pens with stock density of 0.15m²/bird. The feed and water were supplied in 2.5kg capacity hanging feeders and 10L capacity plastic fountain drinkers respectively. The birds were fed with commercial layer mash purchased from Agricare Feeds Limited, (Table 3.1). The plastic drinkers were cleaned daily throughout the experimental period. The house was constructed in such a way that there was adequate ventilation. There were two nests (measuring 30cm x 30cm x 35cm) in each pen. Egg collection was done twice a day, at 9:00am and 3:00pm.

Daily egg collection was recorded for each of the groups. Average weekly room temperature was recorded with the use of a thermometer. There were 12 hours of natural light which was supplemented with artificial lighting throughout the experimental period. This was achieved by providing 60 watts electric bulbs. This enabled the pullets to eat during the night thereby enhancing egg production. Fowl pox and 3rd Newcastle vaccinations were carried out at 12 and 16 weeks of age respectively. A Coccidiostat, Amprolium was added to their drinking water occasionally to control coccidiosis. Treatment for worms and lice were occasionally done using Levasol (water medication) and Ectomin (dipping). Miramed was given to them as a prophylactic treatment for Chronic Respiratory Disease (CRD). Vitamin supplements (mixture) like Vitalytes was given to the birds after debeaking, transfering and weighing.

3.8.3 Data Collection and Parameter Estimation

3.8.3.1 Egg Production

Data on daily egg production were kept throughout the laying period on pen basis. This was summed up every week and expressed as weekly hen-day egg production. Hen-day egg production was therefore calculated as the percentage of the number of eggs laid to the number of hen days according to (National Animal Production Research Institute, 2002). The formula used was as shown below:

$$Hen-day\ egg\ production\ (\%) = \frac{Number\ of eggs\ laid}{Number\ of\ hen-days}\ X\ 100$$

$$Number\ of\ hen-days = no.of\ laying\ days\ X\ number\ of\ birds\ alive$$

In terms of egg production, the parameters taken were number of eggs (hen-day), rate of lay (hen-day). Rate of lay was calculated as the number of eggs produced divided by the total laying period in days (from start of lay to end of experiment), multiplied by 100.

3.8.3.2 Age at Sexual Maturity

This was estimated to be the age the pullets laid their first egg. After the pullets in each pen (replicate group) had laid their first egg, the average age at first lay was calculated for each of the genotypic groups.

3.8.3.3 Body Weight Measurement

Body weight measurements were taken at regular intervals with the first bodyweight measured at the age of first lay and every ten weeks thereafter (i.e. body weight at 30 weeks, 40 weeks, 50 weeks and 60 weeks of age). In total there were five body weight measurements throughout the experimental period.

3.8.3.4 Egg Quality Estimation

Samples of fresh eggs were collected for quality test. The eggs were taken to the Department of Physics of the KNUST, for the quality test to be done. First test was done when the birds were 35 weeks old and every ten weeks thereafter. The number of eggs for the quality test depended on the number of eggs that were collected during the day of the test. Between 10 and 15 eggs from each genotypic group were used each time egg quality test was done. Egg eggshell thickness, albumen height, yolk height, Haugh unit and yolk colour score were considered as determinants for egg quality. Fresh eggs

were collected separately for the different groups and weighed using a top-loading digital balance. Albumen height was measured using a tripod micrometre. The eggs were broken on a metal plate and the height of the albumen was measured as the distance between the metal plate and the electrode placed on top of the thick egg white of the broken egg. In order to correct for difference in egg weight, the albumen height was converted into Haugh unit (HU). The Haugh unit was therefore estimated based on the formula by Haugh (1937):

$$HU = \log 10\,(-1.7\ x\ e^{0.37}\ x\ \ln(egg\ weight, g)\ + 7.6 + albumen\ height, mm)\ x100$$

The same tripod micrometre, which was used for albumen height, measured the yolk height; which was estimated as the distance between the metal plate and the electrode placed on top of the yolk of the broken egg. Shell thickness was measured by using a micrometer screw gauge. The shell was cleaned, washed and air dried at room temperature until constant weight was obtained and then thickness was measured along the equator lines. Yolk colour was determined using a Roche yolk colour fan. This was done by breaking the egg on a metal plate and the colour of the yolk compared with that of the Roche yolk colour fan.

3.8.3.5 Egg Weight, Feed Intake and Feed Conversion

Mean egg weight was obtained by weighing eggs from each replicate of each genotypic group. The eggs collected were taken to the Nutritional Laboratory of the Department of Animal Science of the Kwame Nkrumah University of Science and Technology where

they were weighed using an electronic top-loading balance. First egg weights were taken when the birds were 25 weeks old and every five weeks (30wks, 35wks, 40wks, 45wks, 50wks, 55wks and 60wks) thereafter. Daily feed intake was calculated as the total feed consumed (kg) divided by the total laying period (total number of days the layers were kept). The result was then divided by the total number of birds alive to get feed intake per bird. From the number of eggs obtained, the feed conversion was calculated as the amount of feed consumed (kg) in order to produce a dozen of eggs. The number of dead birds was recorded separately for each group and mortality estimated as the number of dead birds divided the number alive expressed as a percentage.

3.8.3.6 Behavioural Studies

The birds were regularly observed for some behavioural characteristics. They were observed for dust bathing, nesting behaviour (whether the birds laid in the nest or outside the nest), picking of food, and response of the various phenotypes to periods of high temperature especially in the afternoons. They were also observed for abnormal behavioural characteristics like, cannibalism and egg eating.

3.8.4. Data Analysis for On-station Crossbred pullets

The data obtained on growth and egg laying performances were subjected to one-way analysis of variance with genotype effect using GenStat (Discovery Edition). When significant differences among means were found, means were separated using least significant difference (lsd) test. The linear model below was used for the data analysis.

$Yij = \mu + gi + \varepsilon ij$

Where *Yij = performance of the jth pullet of the ith genetic group*

μ = overall general mean common to all observations

gi = fixed effect due to ith genotype (i = 1, 2, 3, 4)

εij = random error effects peculiar to each observation

3.9 Heterotic Effects for Growth and Egg Production Parameters

The heterotic effects for 26, 36, 46 and 56-week body weights; 30, 40, 50 and 60-week egg weights; age at first lay, rate of lay and egg production for the period were calculated on mid-parent according to Fairfull (1990) as follows:

$$\% \, Heterosis = \mathrm{F1} - (0.5\mathrm{P1} + 0.5\mathrm{P2})/(0.5P1 + \ 0.5P2)X \ 100$$

Where :

F**1** = mean performance of F_2 offspring

P**1** = mean performance of parents 1(crossbred naked-neck)

P**2 =** mean performance of parents 2 (crossbred frizzle)

3.10 On-Farm Experiment for the Crossbred and Local Pullets

The objective of this work was to compare the egg production and egg quality (internal and external) characteristics of the crossbred double and single heterozygous pullet genotypes (Fig. 3.7, 3.8 and 3.10) and farmers' normally feathered local pullets under the semi-scavenging system. In this on-farm trial, 240, nine-week old crossbred naked-neck and frizzle pullets were distributed to some purposely selected farmers in the Ashanti Region of Ghana to be reared alongside their own normally feathered local pullets which were of the same age as the crossbred pullets. In all, there were 10 farmers who were each given 24 pullets (8 double heterozygotes and 8 each of the single heterozygotes), (see Table 3.1). In total there were 4 different groups of pullets: (i) crossbred double heterozygous, (ii) crossbred naked-neck only (iii) crossbred frizzles only and (iv) normally feathered local pullets. The selected farmers had between 10 and 15 local pullets in addition to the crossbred pullets given to them.

Table 3.2: Distribution of the Crossbred Double and Single Heterozygous Pullets to the Farmers for the On-farm trial

Districts	***No of farmers***	***No of birds***	**Total**
1	2	8/8/8	48
2	2	8/8/8	48
3	2	8/8/8	48
4	2	8/8/8	48
5	2	8/8/8	48
Total	**10**		**240**

District 1- Atwima-Mponua, 2- Amansie East; 3- Sekyere East; 4- Bosomtwi-Atwima-Kwahoma; 5- Kwabre

3.10.1 Feeding of the on-Farm Experimental Pullets

After distribution, the pullets were confined for one week and gradually released so they could get acclimatized to the village conditions. They were allowed to roam in the homestead. Because the food they got during scavenging would most probably not meet their nutrient requirements, their diets were supplemented. The farmers were provided with a 50% layer concentrate to be added to their feed ingredients (maize and wheat bran) so they could formulate their own ration. They were taken through the feed formulation for the first week and were allowed to do it on their own thereafter. The supplementation used for the semi-scavenging birds followed the recommendation by Njenga (2005), on feed supplementation for semi-intensively kept birds. The author recommended 30gm/bird/day feed supplementation for semi-intensively kept birds. The feed was fed in the mornings before the birds were released and late afternoons just after the birds had returned from scavenging and were about to roost. The supplementary feed was provided such that half was given in the mornings and the other half in the late afternoons. In all there was an average of 10.7kg supplementary feed per bird throughout the experimental period (51wks).

The farmers were provided with scales so they could maintain constant levels of the supplements throughout the experimental period. Clean drinking water was provided daily. The watering bowl was cleaned thrice a week. All the farmers provided one form of shelter or the other ranging from wooden structures to uncompleted buildings that had been roofed for protection. Laying boxes were placed inside the shelters so the pullets could lay without being disturbed.

3.10.2 Data Collection for On-Farm Experimental Pullets

3.10.2.1 Age at Sexual Maturity

This was estimated to be the age the birds laid their first egg. After all the pullets in each farm and from each category had laid their first egg, the average age at first lay was estimated for each of the four groups.

3.10.2.2 Egg Production

The farmers did the egg collection themselves after the birds had laid their first egg. The eggs were collected from start of lay to the end of the experimental period (October, 2007-May, 2008). Eggs from each group were marked for easy identification and recording. In terms of egg production, the parameters taken were number of eggs (hen-day), rate of lay (hen-day). Hen-day egg production was estimated as the total number of eggs produced by the birds divided by the number of birds alive at the time of egg collection. Rate of lay was also calculated as the number of eggs produced divided by the total laying period in days (from start of lay to end of experiment). Signs of broodiness were observed and the birds that were found to be showing signs of broodiness were disallowed from sitting on the eggs. This was achieved by removing the eggs from the nests as soon as they birds laid.

3.10.2.3 Body Weight Measurement

The experimental birds were wing tagged for ease of identification and their body weight taken individually. Body weight measurements were taken at regular intervals with the first bodyweight measured at the age of first lay and every ten weeks thereafter

(body weight at 30, 40, 50 and 60 wks respectively); i.e. there were five body weight measurements throughout the whole experimental period. The birds were weighed by using 5kg-capacity top-loading balance. The first reading was done by the researcher for the farmers to learn how to read the scale and then afterwards they did it on their own.

3.10.2.4 Egg Quality

Samples of fresh eggs from each of the three groups were collected for quality test. The eggs were taken to the Department of Physics of the Kwame Nkrumah University of Science and Technology (KNUST), for the quality test to be done. The first test was performed fifteen days after the birds had laid their first eggs and every ten weeks thereafter. The number of eggs for the quality test depended on the number of eggs that were collected from the different farms during the day of the test. Eggshell thickness, albumen height, yolk height and yolk colour were considered as determinants for egg quality. The procedure used was the same as the one for the egg quality tests for the on-station experiment.

3.10.2.5 Egg Weight Determination

Fresh eggs were collected separately for the three different groups under study and weighed using an electronic digital balance. Mean egg weight was obtained by weighing samples of eggs from each of the groups. The eggs collected were taken to the Nutrition Laboratory of the Department of Animal Science of KNUST where they were weighed using an electronic top-loading balance. The first weighing of eggs was done

when the birds were 30 weeks old and the second when they were 35 weeks of age and every five wks (40, 45, 50, 55 and 60 wks) thereafter. This was done for each of the genotypes under study.

3.11 Behavioural Studies

The birds were regularly observed for some behavioural characteristics during scavenging. They were observed for dust bathing, nesting behaviour (i.e. whether the birds laid in the nest or outside the nest), scratching, response of the birds to periods of high temperature especially during afternoons.

3.12 Data Analyses for the On-farm pullets

The data from the on-farm experiment were subjected to two-way Analysis of Variance (ANOVA) with genotype and location effects using Genstat (Discovery Edition). Where significant differences among means were found, the means were separated using the Least Significant Difference (lsd) tests at 5% level of confidence.

$Yij = \mu + gi + dj + (gd)ij + \varepsilon ij$

Where *Yij = performance of the jth pullet of the ith genetic group of jth districts*

μ = overall general mean common to all observations

gi = fixed effect due to ith genotype (i = 1, 2, 3, 4)

dj = fixed effects due to jth districts (j=1, 2, 3, 4, 5)

(gd)ij= fixed effects of interaction between ith genotype and jth districts

εij = random error effects peculiar to each observation

CHAPTER FOUR

4.0 RESULTS

The result chapter has been divided into five (5) parts, namely: (i) survey results, (ii) brooding stage results, (iii) grower stage results (iv) on-station layer stage results and (v) results on on-farm experimental pullets.

4.1 Survey Results

Table 4.1 shows the data from the survey that was carried out to determine the frequency of naked-neck (*Na*) and frizzle (*F*) genes existing in the indigenous chickens in some selected villages in the Ashanti Region.

Table 4.1: Proportion and Frequencies of the naked-neck and frizzle genes in the local chicken populations in some selected villages in Ashanti Region.

Traits	*Gene symbol*	*No of birds*	*Prop %*	*Gene freq observed*	*Gene freg. expected*
Frizzle	F	38	6.29	0.03*	0.75
Normal	F	566	93.71	0.97*	0.25
Naked-neck	Na	59	9.77	0.05*	0.75
Normal	Na	545	90.23	0.95*	0.25

*Significant differences ($P<0.05$) from the expected Mendelian ratio.

The observed gene frequencies in the local chicken populations in the selected villages were 0.03 and 0.05 for frizzle and naked-neck respectively (Table 4.1).

The proportions or percentages of birds showing the frizzle and naked-neck condition state were 6.29% and 9.77% respectively. On the other hand, percentages of birds homozygous recessive for the two genes (*f* and *na*) were 93.71% and 90.23% respectively.

4.2 Brooding Stage Results

Table 4.2 shows the mean body weights of the crossbred chick genotypes during the eight weeks of brooding.

Table 4.2: Mean body weights (g) of crossbred chicks at different ages.

Age (wks)	**Genotypes**				
	Na/naF/f	*Na/naf/f*	*F /f na/na*	*na/naf/f*	±SEM
Day old	38.91	38.94	39.01	38.07	0.1242
1	71.80 [a]	70.78[b]	70.48[b]	70.66[b]	0.287
2	127.10[a]	125.86[b]	125.78[b]	125.96[b]	0.2559
3	170.58	169.53	165.87	168.67	1.863
4	236.80[b]	239.73[a]	236.54[b]	232.24[c]	1.422
5	357.33[b]	359.29 [a]	356.82[b]	351.24[c]	1.098
6	542.66[b]	544.62[a]	542.15[b]	536.57[c]	1.098
7	695.46	692.02	695.23	690.27	2.116
8	863.10[a]	859.98[b]	861.79[b]	855.68[b]	2.020

[abc]*Means in a row with different letters are significantly different at the 5% level.* Note: SEM-standard error of means.

Day-old body weight was not significantly (P>0.05) affected by the chick's genotype, however, the double heterozygous chicks were significantly (P<0.05) heavier during the first two weeks after hatching (Table 4.2). As the chicks advanced in age, the double heterozygotes maintained with their superior body weight, except in weeks three and seven when the body weights of the four genotypes did not differ significantly. The chicks which were single heterozygous for the naked-neck genes also showed their superiority over the normally feathered as the chicks aged.

The mean initial and final body weights, weight gains, growth rates, feed intake (g) and feed conversion ratio of the four genotypes during the first eight weeks have been presented in Table 4.3.

Table 4.3: Mean Body Weights (g), Weight Gain (g), Growth Rate, Feed Intake (g) and Feed Conversion Ratio (FCR) of the Chick Genotypes

Parameters	**Genotypes**				
	Na/naF/f	*Na/naf/f*	*F /f na/na*	*na/naf/f*	±SEM
Initial Body Weight	38.91	38.94	39.01	38.07	0.1242
Final Body Weight	863.10[a]	859.98[b]	861.79[ab]	855.68[c]	2.020
Weight Gain	824.19[a]	821.04[b]	822.78[ab]	817.61[c]	0.761
Growth Rate	15.72[a]	14.66[b]	14.69[b]	14.06[b]	0.014
Feed Intake	1242.9	1241.7	1242.1	1241.5	0.699
FCR	1.51	1.50	1.49	1.52	0.053

[abc]*Means in a row with different letters are significantly different at the 5% level.*

SEM-standard error of means.

The results showed that the chicks expressing the genes in the double heterozygous state (*Na/naF/f*) gained significantly (P<0.05) more weight than the Na/na and na/naf/f genotypes during the first eight weeks of rearing, however there was no significant difference in weight gain between the single heterozygous but they were better than the normally feathered chicks during the same period.

The results on growth rates showed a similar trend, with the double heterozygotes (*Na/naF/f*) growing at a significantly higher rate than the other genotypes during the first eight weeks of rearing. From Table 4.3 it could be seen that feed intake and feed conversion ratio were similar for all genotypes.

4.3 The Grower Stage Results

Growth parameters measured were body weights, growth rates, weight gains, feed intake and feed conversion. Also determined were dressing percentage, carcass weight, live weight, % feather, % thigh, % wing, % blood.

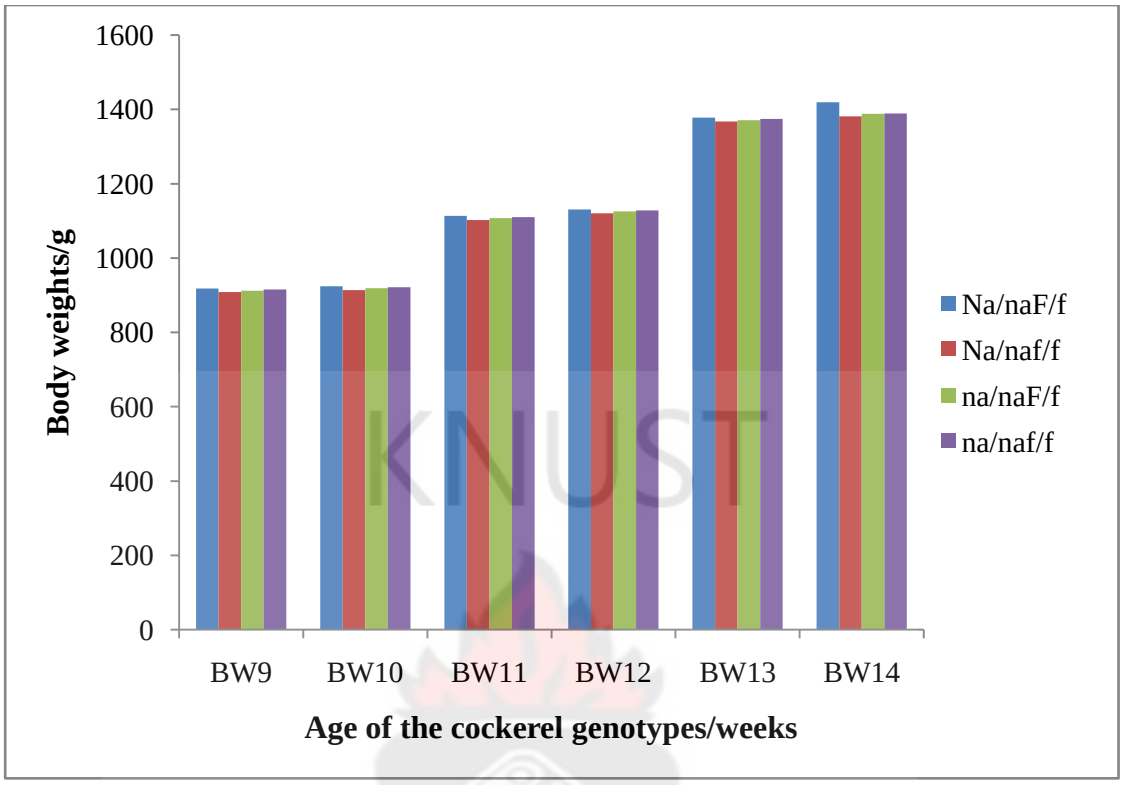

Fig. 4.1: Mean body weights (g) of the four cockerel genotypes from 9-14 weeks.

Figure 4.1 shows that the cockerels possessing the genes in the double heterozygous state were heavier than their counterparts that had the genes in the single state and those that did not show the genes at all.

Table 4.4 shows the mean initial and final body weights, weight gains, feed intake and feed conversion of the crossbred genotypes from week 9 to 14.

Table 4.4: Mean Initial Body Weights (g), Final Body Weights (kg), Weight Gain (g), Average Daily Gain (g), Feed Intake (kg), Mortality (%) and Feed Conversion Ratio of the Crossbred Cockerel Genotypes.

Parameters	**Cockerel Genotypes**				
	Na/naF/f	*Na/naf/f*	*F /f na/na*	*na/naf/f*	±SEM
Initial Body Weight	920.7	921.9	912.6	915.3	14.29
Final Body Weight	1415.0	1395.3	1386.9	1385.8	13.47
Weight Gain	474.62	473.61	473.60	473.72	0.984
Average Daily Gain	11.93	11.26	11.09	11.04	0.025
Feed Intake	1554.1	1534.3	1550.1	1564.2	10.22
FCR	3.17	3.23	3.22	3.24	0.010
Mortality	7.56	8.22	7.77	8.89	0.03

There were no significant differences (P>0.05) among the cockerel genotypes in terms of initial body weights, final body weights and mortality. Again, there were no significant differences in feed intake and feed conversion ratio among the various genotypes.

Table 4.5 shows the carcass characteristics of the four genotypes. There were no significant differences (P>0.05) among the genotypes in terms of percent wing (Table 4.5).

Table 4.5: Mean Carcass Parameters of the Crossbred Cockerel Genotypes

Parameters	**Cockerel Genotypes**				
	Na/naF/f	*Na/naf/f*	*F /f na/na*	*na/naf/f*	±SEM
% blood	19.4[b]	11.3[a]	14.5[a]	12.7[a]	0.603
% breast	18.3[a]	14.1[b]	13.7[b]	14.9[b]	0.826
% leg	6.2[a]	3.3[b]	3.9[b]	3.5[b]	0.410
% wing	10.7	10.1	10.3	9.8	0.283
% thigh	28.8[a]	26.3[b]	26.5[b]	25.0[b]	0.248
% feather	10.3[b]	14.7[a]	14.6[b]	14.2[a]	0.401
Dressed wt,	1055.2[a]	982.8[b]	985.1[b]	979.7[b]	5.95
Dressing %	74.8[a]	70.5[b]	71.1[b]	71.5[b]	0.38
Live weight	1449.6[a]	1401.5[b]	1409.1[b]	1398.0[b]	7.08

[ab]*Means in a row with different letters are significantly different at the 5% level.*

However, the normally feathered and the single heterozygous genotypes had significantly (P<0.05) higher percent blood and feather values than their double heterozygous counterparts. With respect to carcass yield characteristics, the double heterozygotes were significantly better in terms of percent leg yield, breast yield, thigh yield, dressed weight, dressing percentage, and live weight prior to slaughter as compared to their counterparts.

4.4 Results of the On-Station Experimental Crossbred Pullets

This section is devoted to the results on the egg production and egg quality (internal and external) characteristics of the four crossbred pullet genotypes (***double heterozygous, single heterozygous comprising naked-neck and frizzle and then normally feathered***) reared on-station. Growth and egg production parameters calculated were body weights, weight gains, egg production (number and size), rate of lay, age at first lay, feed intake and feed conversion. In terms of egg quality, parameters estimated were Haugh unit, albumen height, yolk height, yolk colour and egg shell thickness.

The egg production characteristics of the four crossbred genotypes are presented in Table 4.6. There were significant differences ($P<0.05$) among the genotypes in terms of egg production, with the double heterozygotes producing significantly more eggs than the single heterozygotes and the latter also producing more eggs than the normally feathered birds. In terms of body weight at age at first lay and at the end of the experiment (60 weeks of age) and weight gain per bird per week, the double heterozygous genotypes were significantly ($P<0.05$) heavier and gained more weight than the other genotypes. However, between the single heterozygous and the normally feathered genotypes, there were no significant differences ($P>0.05$) for body weights at first lay and at 60 weeks of age and weight gain.

The table below (Table 4.6) shows the egg production characteristics of the crossbred pullet genotypes.

Table 4.6: Mean Egg Production (no.), Rate of Lay (%), Body Weights (g), Age at First Lay (days), Feed Intake (g), Feed Conversion Ratio and Mortality (%) of the Four Crossbred Pullet Genotypes Reared On-station.

Parameters	**Pullet Genotypes**				
	Na/naF/f	*Na/naf/f*	*F /f na/na*	*na/naf/f*	±SEM
Total eggs produced	132.1[a]	121.6[b]	121.5[b]	115.5[c]	1.75
Wt at age at first lay	978.0[a]	965.0[b]	962.1[b]	958.3[b]	3.63
Weight at 60wks	2,455.3[a]	2,305.3[b]	2,308.5[b]	2,301.3[b]	2.517
Average daily gain	6.6[a]	5.39[b]	5.41[b]	5.34[b]	0.021
Rate of lay	50.8[a]	46.5[b]	45.3[b]	44.5[b]	0.616
Feed Intake	100.9	100.5	100.3	99.5	0.837
Feed Conversion	2.04[b]	2.33[a]	2.30[a]	2.32[a]	0.035
Mortality	8.6.0[b]	11.5[a]	11.7[a]	12.0[a]	0.412
Age at First Lay	156.1[b]	158.1[b]	155.0[b]	164.0[a]	1.144

[abc]*Means in a row with different letters are significantly different at the 5% level.*

The results showed the double heterozygotes producing eggs at a significantly higher rate than the single heterozygous and the normally feathered genotypes (see Table 4.6). There were significantly ($P<0.05$) more deaths recorded for both the single heterozygous (11.5% and 11.7%) and the normally feathered (12%) genotypes than for birds which had the genes in the double segregation state (8.6%). With respect to age at

first lay, the double and the single heterozygous genotypes laid their first egg significantly earlier than the normally feathered genotypes. In terms of feed intake, it was realized that genotype did not significantly influence the feed consumed. Again, the double heterozygous had significantly better feed conversion into egg production than the other genotypes, but between the single heterozygote and the normally feathered, there was no difference in feed conversion.

Table 4.7 shows the egg quality characteristics of the genotypes. There were no significant differences (P>0.05) among the genotypes with respect to the various internal and external egg characteristics measured (see Table 4.7).

Table 4.7: Mean Egg Quality (Internal and External) Parameters of the Four Crossbred Pullet Genotypes Reared On-Station

Parameters	**Pullet Genotypes**				
	Na/naF/f	*Na/naf/f*	*F /f na/na*	*na/naf/f*	±SEM
Shell Thickness, mm	0.38	0.36	0.36	0.34	0.056
Yolk Diametre, mm	38.97	37.68	36.57	36.86	1.433
Yolk Height, mm	17.22	16.84	17.25	16.41	0.585
Haugh Unit, %	77.42	80.33	79.65	80.18	2.291
Albumen Height, mm	8.22	8.24	8.12	8.19	0.097
Yolk colour score	4.25	4.70	4.65	4.65	0.566

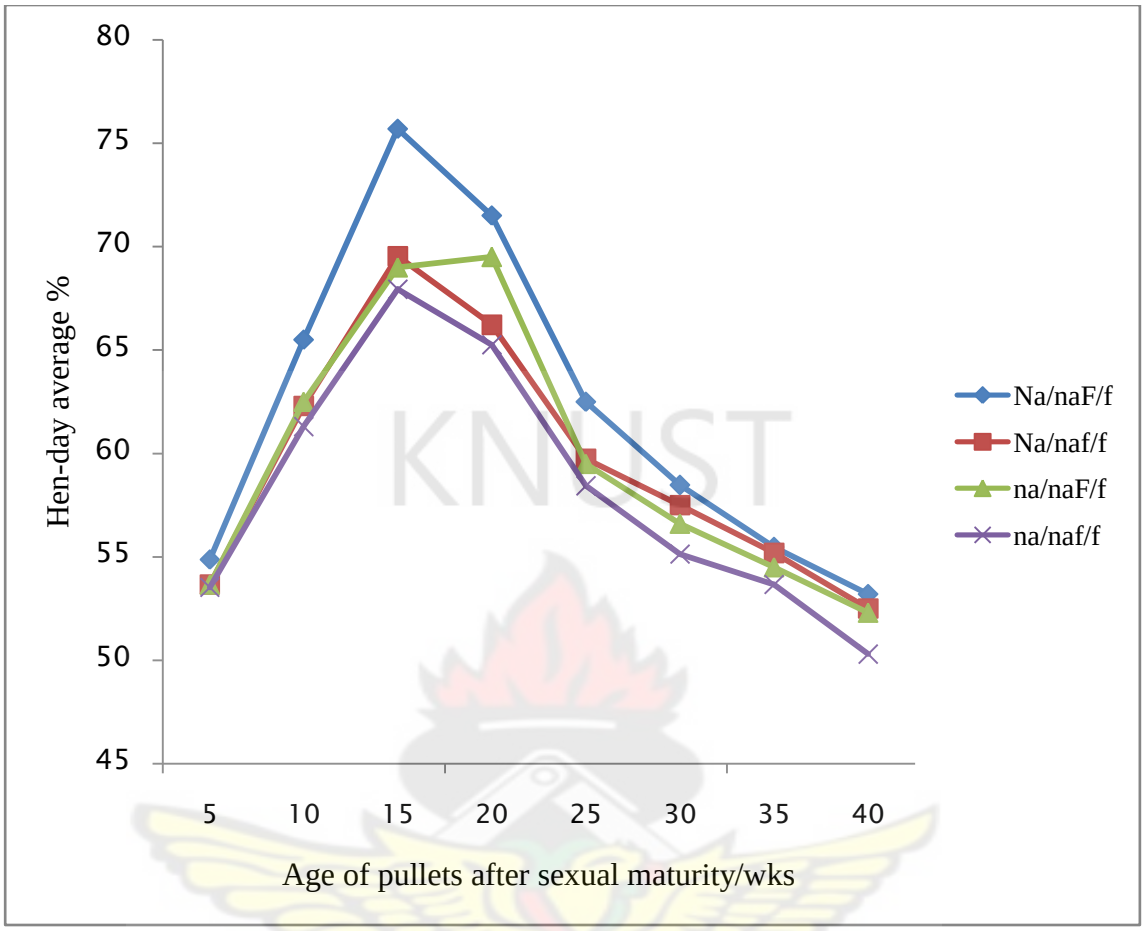

Fig. 4.2: Hen-Day Egg Production of the Four Crossbred Genotypes after Age at Sexual Maturity.

Figure 4.2 shows the hen-day egg production of the four genotypic groups of crossbred pullets. The graph shows a peak hen-day egg production at 15 weeks for all the genotypic groups, with the *Na/naF/f* genotypes producing the highest (75.7%) number of eggs (percent hen-day), followed by the single heterozygotes (69.5%) and the na/naf/f genotypes producing the lowest (67.9%).

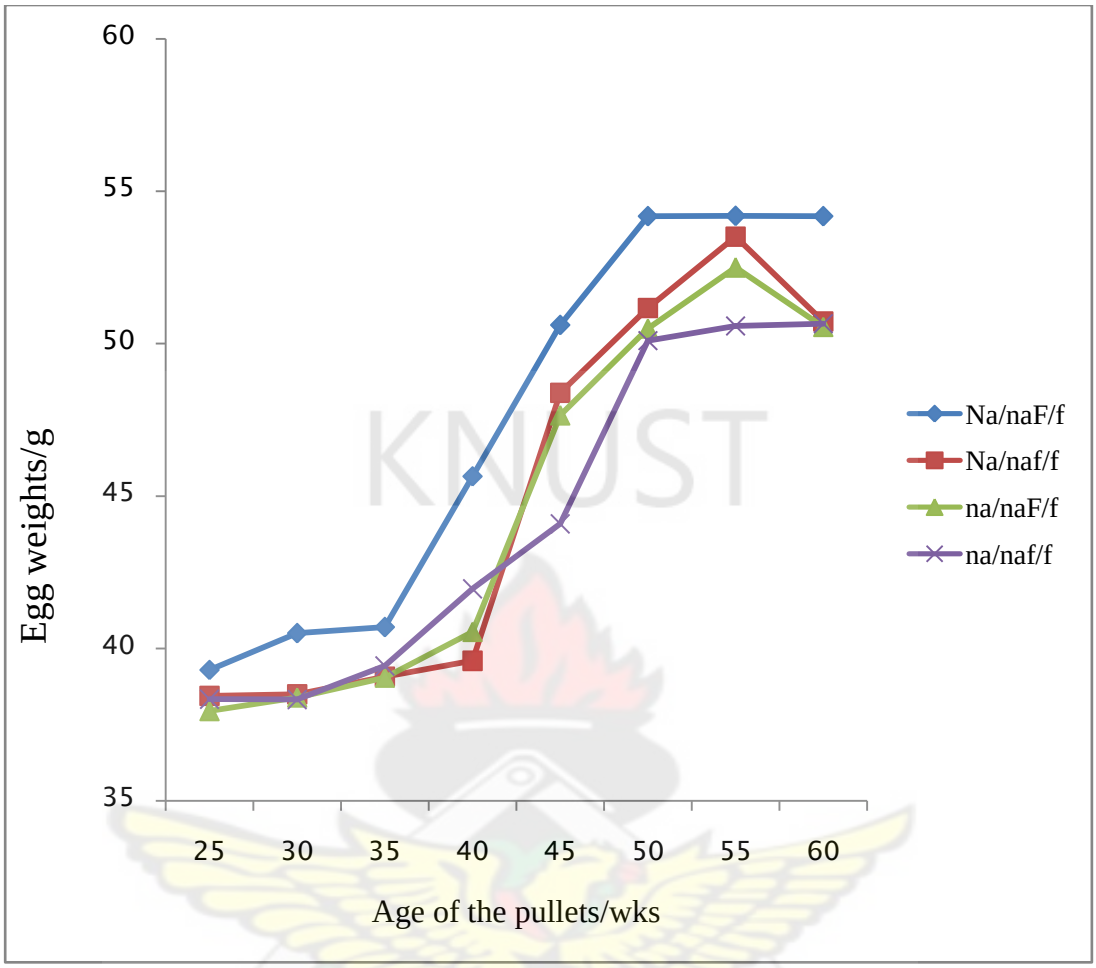

Fig. 4.3: Egg Weights of the Four Crossbred pullet Genotypes

Figure 4.3 shows the egg weights of the four genotypic groups of crossbred pullets over a 35 week period. Egg weight peaked at 55 weeks in all genotypes. There was a sharp increase in egg weight from the 35th to the 50th weeks of age for the double heterozygotes. The egg weights for the single heterozygous birds and their normally feathered counterparts were almost the same, but after 35 weeks of age, the trend changed with the normally feathered genotypes out-performing their single heterozygous counterparts in terms of egg weights.

4.5 Results on Egg Production Performance of the Crossbred Naked-Neck and Frizzle Genotypes and the normal Local Pullets Reared On-farm

This section is devoted to the results on the egg production and egg quality (internal and external) characteristics of the crossbred pullet genotypes (double and single heterozygote) and normally feathered local pullets reared on-farm. Growth and egg production parameters determined were body weights, weight gains, egg production (number and size), mortality, rate of lay and age at first lay. In terms of egg quality, parameters estimated were Haugh unit, albumen height, yolk height, yolk colour and egg shell thickness. Results on mortality, total number of eggs laid for the whole laying period, age at first lay and percent rate of lay, are shown in Table 4.8.

Table 4.8: Mean Egg Production (no.), Mortality (%), Age at First Lay (days) and Rate of Lay (%) of the Crossbred naked-neck and frizzle genotypes and normally feathered Local genotypes reared on-farm.

	Genotypes				
	Crossbred			***Local***	
Parameters	***Na/naF/f***	***Na/naf/f***	***F /f na/na***	***na/naf/f***	±SEM
Mortality, %	20.8[a]	17.8[a]	18.5[a]	10.8[b]	3.69
Egg production/ no	104.3[a]	104.0[a]	105.4[a]	78.0[b]	1.276
Age at First Lay/days	181.0[b]	181.3[b]	179.5[b]	217.8[a]	2.70
Rate of lay, %	43.67[a]	42.00[a]	43.25[a]	37.93[b]	0.489

[ab]*Means in a row with different letters are significantly different at the 5% level.*

Results obtained showed that the local pullets recorded significantly ($P<0.05$) lower deaths than the crossbred pullets, but between the crossbred pullets (double and single heterozygotes), there were no significant differences. The crossbred layers laid significantly ($P<0.05$) more eggs than the local layers (78 eggs) throughout the entire laying period, but among the three crossbred layers, there were no significant ($P>0.05$) differences. There was a significant difference ($P<0.05$) between the crossbred layers and the local layers with respect to age at first lay, with the latter laying their first egg about 5 weeks after the former had laid their first eggs.

Table 4.9 presents a comparison of body weight at age at first lay, weight gain and egg weights of the four groups of pullets at specific intervals. Egg weights were significantly ($P<0.05$) influenced by the type of pullets, with the crossbred naked-neck and frizzle pullet genotypes laying significantly ($P<0.05$) bigger eggs than the normally feathered local pullets throughout the entire laying period. However, among the crossbred pullets, there was no significant difference ($P>0.05$).

The table below (Table 4.9) shows the body weight, egg weights and weight gain of the developed crossbreeds and the normally feathered local pullets.

Table 4.9: Mean Egg Weights (g), Body Weight at Lay and at 60 Weeks (g) and Weight Gain (g) of the Crossbred Naked-neck and Frizzle Genotypes and the Normally Feathered Local Pullets Reared On-farm.

	Genotypes				
	Crossbred		***Local***		
Parameters	***Na/naF/f***	***Na/naf/f***	***F /f na/na***	***na/naf/f***	**±SEM**
Weight at age at first lay	955.3[a]	954.3[a]	955.4[a]	922.0[b]	8.08
Body Weight at 60wks	1803.0[a]	1792.0[a]	1799.4[a]	1634.0[b]	25.3
Weight Gain	847.7[a]	837.7[a]	840.7[a]	712.0[b]	23.88
Egg Weight at 26wks	40.75[a]	40.65[a]	40.55[a]	36.88[b]	0.669
Egg Weight at 36wks	43.17[a]	42.17[a]	42.65[a]	39.75[b]	0.629
Egg Weight at 46wks	46.22[a]	45.20[a]	45.55[a]	42.78[b]	0.452
Egg Weight at 56wks	50.60[a]	49.54[a]	50.25[a]	45.69[b]	0.909
Egg Weight at 60wks	53.74[a]	53.21[a]	53.25[a]	48.99[b]	0.792

[ab]*Means in a row with different letters are significantly different at the 5% level.*

The normally feathered local birds laid eggs that had significantly ($P<0.05$) thicker shells than eggs laid by the crossbred naked-neck and frizzle pullet genotypes (Table 4.10), but there was no significant difference in egg shell thickness among the crossbred pullets. The type of genotype did not significantly ($P>0.05$) affect yolk diameter, yolk height, Haugh unit, albumen height and yolk colour.

Table 4.10: Mean internal and external egg parameters of the naked-neck and frizzle genotypes and the normally feathered local pullets reared on-farm.

		Crossbred		*Local*	
Parameters	***Na/naF/f***	***Na/naf/f***	***F /f na/na***	***na/naf/f***	**±SEM**
Shell Thickness, mm	0.33[b]	0.33[b]	0.32[b]	0.35[a]	0.0039
Yolk Diametre, mm	36.93	37.07	37.55	37.60	0.369
Yolk Height, mm	18.03	17.67	17.79	17.84	0.514
Haugh Unit, %	78.37	78.79	79.15	80.71	1.414
Albumen Height, mm	8.23	8.27	8.25	8.07	0.1541
Yolk colour Score	7.35	7.12	7.23	7.17	0.1717

[ab]*Means in a row with different letters are significantly different at the 5% level.*

4.6 Location Effects

This section is devoted to results obtained from the three crossbred double and single heterozygous pullets reared at different locations to determine the effects of location on the performance of the crossbred layers. There were five locations where the crossbred layers were reared. Data was collected on egg production and quality (internal and external) characteristics of the three crossbred pullets (*Na/naF/f, Na/naf/f* and *na/naF/f*) and farmers' own normally feathered pullets at various locations. Growth and egg production parameters recorded were body weights, weight gains, egg production (number and size), mortality, rate of lay and age at first lay. In terms of egg quality, parameters calculated were Haugh unit and egg shell thickness.

Table 4.11: Mean Mortality (%), Egg Production (no.) and Shell Thickness of the Crossbred Naked-neck and Frizzle Pullet Genotypes Reared On-farm.

Genotypes	**Locations**					
	A-M	**A-E**	**S-E**	**B-A-K**	**K**	**± SEM**
			Mortality (%)			
Na/naF/f	16.7[b]	25.0[a]	29.2[a]	16.7[b]	16.7[b]	8.05
Na/naf/f	4.2[c]	20.8[b]	29.2[a]	8.3[c]	16.7[b]	1.05
nana/F/f	29.3[a]	20.4[b]	4.3[c]	8.6[c]	17.7[b]	1.04
			Total eggs produced (no.)			
Na/naF/f	118.4	108.5	118.2	117.6	108.8	2.853
Na/naf/f	107.0	104.9	108.7	102.6	96.7	2.66
nana/F/f	106.0	105.9	108.1	104.6	99.7	2.65
			Shell thickness (mm)			
Na/naF/f	0.31[b]	0.34[a]	0.32[b]	0.32[b]	0.32[b]	0.00859
Na/naf/f	o.35[a]	0.36[a]	0.33[b]	0.32[b]	0.33[b]	0.0090
nana/F/f	0.35[a]	0.32[b]	0.36[b]	0.32[b]	0.33[b]	0.00867

[ab]*Means in a row with different letters are significantly different at the 5% level.*

A-M: (Atwima-Mponua), A-E: (Amansie East), S-E: (Sekyere East), B-A-K: (Bosomtwi-Atwima-Kwahoma), K: (Kwabre).

Data on effect of location on mortality, total number of eggs laid throughout the laying period, age at first egg and the percent rate of lay of the three crossbred naked-neck and frizzle genotypes are shown in Table 4.11. Location had significant effect ($P<0.05$) on mortality, with birds reared in Amansie East and Sekyere East districts recording significantly ($P<0.05$) more deaths than those kept in other districts. There were no

significant (P>0.05) location effects on the number of eggs laid during the entire laying period. The districts where the birds were kept significantly (P<0.05) affected the shell thickness of the eggs the birds laid.

Table 4.12: Mean Age at first lay, Rate of lay and Haugh unit of the Crossbred Naked-neck and Frizzle Pullet Genotypes Reared On-farm.

Genotypes	**Locations**					
	A-M	**A-E**	**S-E**	**B-A-K**	**K**	**± SEM**
			Age at first lay (days)			
Na/naF/f	178	186	176	182	183	6.10
Na/naf/f	178	186	176	183	178	6.07
nana/F/f	179	182	182	183	178	6.08
			Rate of lay (%)			
Na/naF/f	41.7	39.3	41.3	42.0	39.0	0.869
Na/naf/f	37.7	38.0	38.0	36.7	34.7	0.823
nana/F/f	36.7	37.0	37.0	37.7	35.7	0.820
			Haugh Unit (%)			
Na/naF/f	75.28	82.68	75.60	76.80	81.40	3.22
Na/naf/f	75.28	82.68	75.60	78.93	81.48	3.28
nana/F/f	75.29	82.65	75.65	78.90	81.18	3.24

A-M: (Atwima-Mponua), A-E: (Amansie East), S-E: (Sekyere East), B-A-K: (Bosomtwi-Atwima-Kwahoma), K: (Kwabre).

The districts where the crossbred pullet genotypes were reared did not significantly (P>0.05) affect the birds' age at first lay, rate of lay and the haugh unit of the eggs laid by the birds. The birds laid their first egg between the ages of 176 to 186 days.

The egg production performances of the crossbred parents and their F_2 offspring have been presented in Table 4.13.

Table 4.13: Egg weight (g), body weight (g) and egg production records of the crossbred naked-neck and frizzle parents and their F_2 offspring.

	Parents		**Offspring**		
Traits	***Na/na***	***F/f***	***Na X F***	***F X Na***	**±SEM**
Egg weight at 30 wks	45.65^{b}	42.63^{c}	44.16^{bc}	49.97^{a}	0.984
Egg weight at 40 wks	49.4^{b}	46.90^{bc}	46.60^{c}	52.50^{a}	1.148
Egg weight at 50 wks	52.31^{b}	50.90^{bc}	50.71^{c}	54.37^{a}	0.675
Egg weight at 60 wks	54.53^{b}	54.18^{b}	52.20^{c}	56.70^{a}	0.332
Body weight at 26 wks	1121.3^{ab}	1117.0^{b}	1111.7^{b}	1130.7^{a}	4.40
Body weight at 36 wks	1411.7^{b}	1395.0^{c}	1386.3^{c}	1519.3^{a}	5.45
Body weight at 46 wks	1613.3^{b}	1614.7^{b}	1611.7^{b}	1711.0^{a}	4.73
Body weight at 56 wks	1831.7^{b}	1810.7^{b}	1816.7^{b}	1917.3^{a}	11.46
Rate of lay (%)	46.28^{b}	45.56^{b}	42.01^{c}	50.25^{a}	0.906
Total eggs laid (no.)	127.0^{a}	118.0^{b}	115.7^{c}	129.3^{a}	1.067
Age at first lay (days)	160.9^{a}	152.93^{b}	151.83^{b}	150.87^{b}	2.620

^{abc}*Means in a row with different letters are significantly different at the 5% level.*

The offspring from the reciprocal (F X Na) cross were significantly ($P<0.05$) heavier at 26wks to 56wks than their sibs from the main (Na X F) cross. The offspring from the reciprocal cross maintained their superiority in all the traits measured (Table 4.13).

Again, the offspring of the reciprocal cross laid their first egg significantly earlier than their sibs from the main cross. Heterosis estimates for egg weight, body weight and egg laying performance computed as a percent increase of the crossbreeds or reciprocal crosses above their parents are presented in Table 4.14. Results within crosses revealed that F X Na had positive and high heterotic percentage at all ages for all traits measured.

Table 4.14: Heterosis of egg weights, body weights and egg production characteristics for main and reciprocal cross.

Traits	***Na X F***	***F X Na***
Egg weight at 30 wks	0.05	13.21
Egg weight at 40 wks	-3.22	9.03
Egg weight at 50 wks	-1.73	5.36
Egg weight at 60 wks	-3.96	4.31
Body weight at 26 wks	-0.67	1.03
Body weight at 36 wks	-1.21	8.26
Body weight at 46 wks	-0.14	6.01
Body weight at 56 wks	-0.25	5.28
Rate of lay (%)	-8.51	9.43
Total eggs laid (no.)	-4.77	6.42
Age at first lay (days)	-3.2	2.51

Results on genotype-environment interaction have been presented in Table 4.15. The results revealed a genotype-environment interaction for rate of lay with Na/naf/f and na/naF/f genotypes laying at different rates in different environments.

Table 4.15: Genotype-environment interaction of rate of lay, age at first lay and total eggs laid for the naked-neck and frizzle genotypes.

Traits	Genotypes	Ranking	
		On-station	On-farm
Rate of lay	Na/naF/f	1	1
	Nanaf/f	2	1
	na/naF/f	2	1
Age at first lay	Na/naF/f	1	1
	Nanaf/f	1	1
	na/naF/f	1	1
Total eggs lad	Na/naF/f	1	1
	Nanaf/f	2	1
	na/naF/f	2	1
Mortality	Na/naF/f	1	1
	Nanaf/f	2	1
	na/naF/f	2	1

There was no genotype-environment interaction for age at first lay. The double heterozygotes could not maintain their superiority when they were kept under the on-

farm environment. The single heterozygotes did better than the double heterozygote under the on-farm environments in terms of mortality.

4.7 Behavioual Studies and Observation

4.7.1 Broodiness

The local layers were found to be showing signs of broodiness. Farmers in Atwima-Mponua, Amansie East and Kwabre Districts reported that their local birds were trying to sit on the eggs laid. It was only in Amansie East District that some of the farmers reported that the crossbred layers were showing signs of broodiness.

4.7.2 Scavenging, Scratching and Picking Behaviours

All the genotypes were found scavenging, scratching and picking feeds. But during scavenging the local layers were found to be walking comparatively longer distances in search of feed and they were also found to be very aggressive in their search for feed. Initially, the crossbred hens were docile but as time went on they began to learn from the local layers in the aggressiveness with which they searched for their feed.

CHAPTER FIVE

5.0 DISCUSSION

This chapter is divided into five main thematic areas, namely: the survey, the brooding stage, the growing stage (cockerel development), the laying stage which is subdivided into the two main studies (on-station and on-farm). The discussions on the results will be treated under these thematic areas.

5.1 Survey Results

The observed frequencies of the dominant genes were 0.03 and 0.05 for frizzle and naked-neck respectively. The frequencies obtained were very low for dominant genes. However, these are higher than values obtained by Fayeye *et al.* (2006) who also reported very low frequencies for naked-neck and frizzle genes in adult Fulani-ecotype chickens in Nigeria. They observed that the frequencies for gene carriers for feather morphology (*Na*) and structure (*F*) were 0.005 and 0.003 respectively. Work by Missohou *et al.* (1998) on morphological and biometrical characteristics of the Senegal native chickens showed similar gene frequencies of 0.005 and 0.01 for the frizzle and the naked-neck genes respectively.

The lower than expected gene frequencies for the dominant genes might be attributed to the naked-neck and frizzled birds being used for other purposes which normally feathered birds would not be used for. This will make the genes scarce. Interaction with

the local farmers revealed that the naked-neck and frizzled birds (adult males) were normally used during ritual ceremonies. This observation was also made by Sonaiya (2003) that the naked-neck and frizzle birds might become extinct if efforts were not made to preserve and conserve them. This study also confirms the findings of Moreki and Masupi (1997) who concluded that the frizzle gene appeared to be in serious danger of extinction in Botswana while the naked-neck genes also appeared to be endangered. However, farmers who kept naked-neck and frizzled birds reported of heavier adult body weight compared to the normally feathered birds. For these reasons these farmers continued rear these birds.

There were also reported cases of lower adult mortality for the naked-neck birds as a result of their alertness and fighting characteristics making them better able to run away from predators. The problem with the naked-neck and frizzled birds was high chick mortality especially during the rainy season when the weather is cold. This was because there was no artificial brooder house to cater for the chicks hence, they died through cold. These findings are very alarming considering the potential benefits of the naked-neck and frizzle genotypes as far as family poultry is concerned.

5.2 The Brooding Period

5.2.1 Body Weights

The chicks carrying the naked-neck and frizzle genes in the double heterozygous state were significantly heavier than the other genotypes, confirming the observation by Horst and Mathur (1992) that there is positive additive interaction between naked-neck and fizzle genes on growth and body weights. The crossbred day-old chicks in this work were also heavier than day-old chicks of some developed local breeds like Fayoumi (29.9g) obtained by (Katule and Mgheni, 1990).

5.2.2 Weight Gain, Growth Rate and Feed Efficiency

The double heterozygotes maintained their superiority in terms of weight gain and growth rate during the first eight weeks. This might be due to better heat dissipation when the two genes are combined as a result of the reduced feather mass and coverage. The higher growth rate means the bird can attain a higher body weight in a shorter time as compared to those with lower growth rate. Therefore, to achieve the highest body weight within the shortest possible time, the double heterozygotes would be recommended, for they are likely to reach market weight earlier than their counterparts.

The growth rate values obtained for the crossbred lines in this study were comparatively better than those obtained for Gassy (3.30g/bird/day) and Mecha (4.20g/bird/day) indigenous chickens reared under the intensive system in Ethiopia (Mogesse, 2007). With respect to feed consumption during the first eight weeks of rearing, there was no significant difference among the four genotypes. This disagrees with the findings of

Jianxia (2002) that four-week male broiler genotypes (*Na/naF/f*) reared under a high ambient temperature of 34^0C consumed 6% more feed on the average than their normally feathered sibs or their single heterozygous sibs.

With respect to feed conversion, the results disagree with work by Mahrous *et al*. (2008) that the heterozygous naked-neck and frizzled (*Na/naF/f*) birds had a better feed conversion ratio (2.38) than those possessing the genes in the single heterozygous state (2.42 and 2.51 for *Na/naf/f* and *na/naF/f* respectively) and their normally feathered genotypes (2.53) from the fourth to the eighth week of growth. The assertion that the heat-tolerant genes (naked-neck and frizzle) confer on the bird better ability to convert feed into body tissue was not prominent in this work.

5.3 Cockerel Development

Cockerel (the egg type male chicks) production is becoming an indispensable component of family poultry development with the rapidly increasing trends of commercial layer farming. Consumers prefer cockerels to broilers because they consider the former to be tastier than the broiler meat (Huque *et al*., 2004). Commercial layer-strains normally produce fifty percent male chicks which remain in the hatchery where disposal are conducted in different ways. According to Huque *et al*. (2004) the utilization of these male chicks through small holder family poultry farming helps to control environmental pollution, increase nutrition, income and employment in the rural community. Cockerel production and management is easier than broiler production particularly in the rural areas where modern facilities including electric supply are not

available. Consumers' choice, lower chick price, lower mortality and morbidity, lower management cost, lower initial investment, better market demand, low abdominal fat, less disease susceptibility, more organoleptic preference, family labor utilization and easy management are the strategic advantages for cockerel rearing in family poultry farming (Huque *et al*., 2004).

Since cockerel rearing is gaining momentum efforts must be made to reduce their rearing period so as to shorten the time they take to reach market weight. The crossbred cockerels in this study were kept for a period of up to fourteen weeks. The crossbred cockerels recorded heavier body weights at fourteen weeks of age (1419, 1381.3, 1377.9 and 1378.8g) than fourteen-week old Fayoumi (959g) and Sonali (1001g) breeds that were reared under similar management system in Bangladesh (Azharul *et al*., 2005). The 12-week body weights of the crossbred cockerels in this study were also better than results obtained from 12-week-old Indonesian crossbred chicken genotypes (1036g, 1087g, 975g and 843g for *Kampung, Black Kedu, White Kedu* and *Nunukan* respectively) reared under the intensive system and fed commercial ration (Sartika and Noor, 2002).

There were no significant genotype effects on both initial and final body weights, an observation which disagrees with the findings of Mahrous *et al*. (2008) on impacts of naked-neck and frizzle genes on growth performance and imunocompetence. In their work they found the Na/naF/f genotypes to be significantly heavier at 14 weeks than the other genotypes. This might be due to the assertion that when the two genes are

combined, heat dissipation is much improved as a result of the reduced feather mass and exposed skin cover, leading to a relatively higher heat tolerance thereby resulting in better weight gain under high ambient temperatures. Weight gain was not significantly affected by genotype. This disagrees with the findings of Younis and Cahaner (1999) who 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 gene-gene interaction between the naked-neck and frizzle genes on body weights and growth rates. They found the heterozygous naked-neck frizzle genotypes to be heavier than their sibs with different genotypes in terms of body weights. At fourteen weeks of age the birds were found to be still showing signs of growth. The temperature within which the study was carried out was not challenging enough (see Appendix), hence the birds with the naked-neck and frizzle genes not outperforming their sibs of different genotypes. This suggests that the genes may be useful under challenging environments (hot and humid environments).

In terms of mortality, there was no significant genotype effect. Post-mortem results however, did not show any signs of infection. Most of the deaths were as a result of cockerels pecking themselves thereby causing injury and eventually death. According to Tweneboah (2002) feather pecking is associated with poor management, breed or strain of bird. He also reported that hybrid strains are susceptible to feather pecking. The crossbred cockerels in this study were hybrids and this might have resulted in the incidence of feather pecking.

5.3.1 Feed Intake and Utilization

The results obtained for feed intake for the genotypes disagree with those of Mahrous *et al*. (2008), that the double heterozygous genotypes consumed significantly ($P<0.05$) more feed than the other genotypes expressing the heat-tolerant genes in the single state or those that did not have the genes at all. They found that the birds expressing the heat-tolerant genes consumed significantly more feed than their normally feathered counterparts. Galal and Fathi (2001) also concluded that under high ambient temperature (above 30^0C), the heat tolerant genes were associated with higher feed consumption compared with the normally feathered birds.

At elevated ambient temperatures as pertained in the tropics, faster heat dissipation by the naked-neck or frizzle genotypes permits sufficient feed intake resulting in higher growth rate. The feed conversion values obtained showed no significant genotype effects on feed conversion. The insignificant difference between the single heterozygote and the normally feathered cockerels is in disagreement with the findings of Yalcin *et al*. (1997) and Patra *et al*. (2002) that under high temperatures, birds carrying the naked-neck gene had better feed conversion ratio than their normally feathered counterparts.

According to Merat (1986) the naked-neck and frizzle genes are most useful at high ambient temperatures of 30^0C and above where most of the advantages like higher growth rate, higher feed efficiency, slaughter yield and meat yield became pronounced. Horst (1989) also reported that the *Na* and *F* genes interacted well to improve the performance of stocks reared under heat stress. The crossbred cockerels in this study

were found to be better converters of feed (3.17-3.24) compared to developed breeds like Sonali (4.37) and Fayoumi (4.61).

5.3.2 Carcass Characteristics

The observation that the double heterozygous cockerels had significantly ($P<0.05$) lower feather weights than their counterparts was because the heat-tolerant genes are responsible for the reduction in feather weight thereby, facilitating better heat dissipation. Again the feather coverage of the naked-neck gene was further reduced by the inclusion of the frizzle gene. The insignificant ($P<0.05$) difference between the single heterozygous and the normally feathered cockerels in terms of carcass yield was in contrast with findings of Merat (1986) who found gains of 1.5-2.0 percent to 2.5-3.0 percent for *Na/Na* and *Na/na* as against their normally feathered (na/na) sibs.

The higher percent breast, leg and thigh observed in the crossbred double heterozygous cockerels than their counterparts that expressed the genes in the single segregation state or their normally feathered counterparts confirm the findings of Younis and Cahaner (1999) that combining the naked-neck genes with another heat-tolerant gene like frizzle resulted in a very favourable additive effect on both productive and carcass yield characteristics. This was explained by Merat (1986) that less feather or reduced feather production leaves more protein for synthesis of other tissues (muscle and meat). Also reduced plumage ensures lower carcass fat content as a result of higher proportion of lipids being used for thermoregulation.

5.4 Crossbred Layers Reared On-Station

This section is devoted to the interpretation of results obtained from the crossbred pullets that were reared on-station. There were four main genotypes (double heterozygous, single heterozygous comprising naked-neck and frizzle and normally feathered pullets).

5.4.1 Egg Production of the Crossbred Layers Reared On-Station

Results obtained on the effect of the heat-tolerant genes on egg production were in agreement with the findings of Horst (1989) and Haaren-Kiso *et al.* (1988) who proposed the use of the *Na/naF/f* in hot humid environments. They also found the double heterozygotes to be advantageous in terms of egg production under hot and humid conditions (temperatures above 30^0C). The mean weekly room temperature during the experimental period ranged between 25.5^0C and 32.0^0C, which would generally stress normally feathered birds, hence birds possessing the heat-tolerant genes performing better in terms of egg production than their counterparts that did not possess the genes.

The higher egg production from the birds showing the naked-neck and frizzling traits as compared to their counterparts that were homozygous recessive for the genes is a confirmation that the genes are associated with increased egg production under. The results also agree with the findings of Merat (1986), Yushimura *et al*. (1997), Barua *et al*. (1998) and Abdel-Rahman (2000) that the naked-neck genotype is superior to it normally feathered sibs in terms of egg production and feed efficiency in a hot humid

environment. Results on egg production from this study confirm the observations by Mahrous *et al.* (2008) that combining the two alleles in the heterozygous state (*Na/naF/f*) resulted in a better performance of laying hens compared to normally feathered (*na/naf/f*) birds and birds heterozygous only for one of these genes (*Na/naf/f* and *na/naF/f*).

The crossbred double heterozygous layers laying at a significantly higher rate than their sibs belonging to the other genotypic group is a confirmation that the heat-tolerant genes confer on the bird positive additive effect in terms of egg production. The results also confirm the findings of Mahrous *et al*. (2008) that naked-neck gene in combination with frizzle resulted in higher rate of lay when the birds are raised under hot and humid conditions. The insignificant differences in rate of lay disagree with the observations made by Merat (1986), Horst and Rauen (1986), Garces *et al.* (2001) and Younis and Galal (2006) that at high temperatures the naked-neck hens had a better rate of lay than their normally feathered counterparts. The percent rate of lay values recorded means the crossbred layers can produce between 159-183 eggs annually, which are more than the annual egg production for improved local birds (80-99 eggs/year/bird) reared under intensive management system (Tadelle *et al*., 2000). The projected annual egg production of the crossbred hens is also higher than those reported by Kitalyi (1998) for intensively raised *Fayoumi* (150), *Dandarawi* (140) and *Baladi* (151), all improved local breeds of chicken in Egypt.

Body weights at the onset of laying for *Na/naF/f* genotypes were significantly heavier than the single heterozygotes or normally feathered. This confirms the observation by Younis and Galal (2006) that birds which possess the heat-tolerant genes in the double segregation state are heavier at sexual maturity than their sibs which are naked-neck only or frizzle only. Again, the genes reduce the amount of feathers that cover the body thereby giving the double heterozygous better heat dissipation. This will help the birds preserve the energy that could otherwise have been used in heat dissipation, albeit directing this energy into productive functions like growth and weight gain. The better body weights and weight gain of the combined naked-neck frizzle genotypes are in agreement with findings of Pech-Waffenschmidt (1992) that combining the two 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 birds heterozygous only for one of the genes. The author further observed that when layers of four genotypes (*na/na f/f*, *na/na F/f*, *Na/na f/f*, and *Na/na F/f*) were exposed to a constant high ambient temperature of 34^0C, feed consumption, body weight and egg production were higher for the double heterozygote.

The double heterozygotes had significantly less mortalities as compared to other genotypes even though they all segregated from the same parents. This agrees with the results by (Barua and Howlider, 1990; Merat, 1990; Kitalyi, 1998 and Fraga *et al*., 1999) that the heat-tolerant genes are associated with higher disease resistance. Some of the deaths were as a result of pecking due to the exposure of the skin of the naked-neck and frizzle genotypes. This confirms the observations of Njenga (2005) that due to their

exposed skin frizzle feathered and naked-neck phenotypes suffered more from pecking when they are reared intensively. As a result of that the naked-neck and frizzle phenotypes had to be debeaked more times than their normally feathered counterparts. Though the crossbred pullets were not vaccinated against the Marek's disease, there was no death from Marek's disease as post-mortem examination results attributed the biological cause of death to coccidiosis.

The birds that possessed the heat-tolerant genes laid their first egg significantly earlier than their sibs which were homozygous recessive for the genes. According to Merat (1990) the naked-neck gene is associated with early sexual maturity when the birds are reared in both moderately warm and hot, humid environment. The results obtained in this study agree with the findings of Merat (1990), Horst (1988), Haaren-Kiso *et al*. (1988) and Abdel-Rahman (2000) that naked-neck or frizzle feathered pullets reached sexual maturity earlier than their normally feathered sibs. Birds that lay earlier are able to lay more eggs during the laying cycle than those that attain sexual maturity late in life. This makes the birds with thermoregulatory genes most appropriate to be reared under tropical conditions where the average temperature is above 25^0C coupled with high humidity. The age at first lay of the crossbred pullets in this study are comparable to those found by Kitalyi (1998) for intensively kept local chicken ecotypes (*Yukur*, 173 days; *Melata*, 204 days; *Kei*, 166 days; *Gebsima*, 230 and *Netch*, 217 days) in Ethiopia. The average age at first lay of the crossbred genotypes in this study is an improvement over intensively kept local chickens which laid their first eggs at 177 days in Ghana, (Dankwa and Nelson, 1995) and 196 days in Tanzania (Katule, 1992).

5.4.2 Feed Intake and Efficiency

Though the birds with the heat-tolerant genes were expected to have consumed significantly more feed than their normally feathered counterparts, since the genes are associated with high feed intake during periods of high temperatures (above 30^0C) Merat (1990), the results proved otherwise. This is in sharp contrast with the observations by Rauen *et al*. (1985) that feathering intensity and feather structure could increase heat loss, and so indirectly increased feed intake and productivity, which might lead to an improved productive adaptability of laying hens under hot-environmental conditions. The insignificant difference in feed consumption among the genotypes also disagrees with the findings of Pech-Waffenschmidt (1992) that when four genotypes (*Na/naF/f, Na/naf/f, na/naF/f* and *na/naf/f*) were exposed to a constant high ambient temperature of 34^0C, the double heterozygous birds (*Na/anF/f*) exhibited the highest feed consumption among the four genotypes.

The double heterozygous birds were able to convert feed into egg production better ($P<0.05$) than the other genotypes. This might be due to the fact that during periods of high temperature, naked-neck or frizzle feathered birds are able to dissipate heat better and as a result preserve more energy that could otherwise have been used for heat dissipation, for other productive functions like egg production (Yalcin *et al.*, 1997; Patra *et al.*, 2002). Again, it is possible the genes are linked to other genes for egg production, hence naked-neck and frizzle birds benefiting from gene linkage. The two genes have been reported to have pleiotropic effects resulting in better feed conversion to egg production The results of this study also agree with the findings of Horst and

Mathur (1992) and Younis and Cahaner (1999) that combining the naked-neck allele with other tropically relevant alleles such as frizzle resulted in a favourable additive effect to various productive parameters like egg production, egg weights and feed efficiency.

5.4.3 Internal and External Egg Characteristics

Results obtained showed no significant effects of the genes on internal and external egg parameters measured. These results disagree with the findings of Abdel-Rahman (2000), Nwachukwu *et al.* (2006) and Islam and Nishibori (2009) that the genes responsible for feather reduction (*Na* and *F*) in layers provided relative heat tolerance under hot climate with naked-neck and frizzle layers outperforming their counterparts which had complete feather cover in terms of internal and external egg characteristics. Another contrasting observation was made by Mahrous *et al*. (2008) that 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* genotypes. They also observed that the presence of the *Na* gene in combination with *F* gene significantly increased egg shell weight and thickness compared to their normally feathered counterparts.

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

from mechanical damage (Sergeyeva, 1986). The average shell thickness of 0.35mm for the crossbred pullet genotypes in this study means the birds produced eggs with thinner shells as compared to 0.67mm for Mecha chickens and 0.77mm for Debre-Elias chickens in Ethiopia (Mogesse, 2007) and 0.58mm for Fulani ecotype chickens in Nigeria (Fayeye *et al*., 2005). However the shell thickness of the crossbred pullets in this study was similar to the average shell thickness of 0.33mm for Rhode Island Red and Fayoumi crossbreeds reported by Zaman *et al*. (2004).

Albumen quality, which is the most important egg quality criterion, is determined by its height. Hence, the larger the albumen height, the better the albumen quality would be. Albumen height varied between 1.5mm for low quality eggs and 11.5mm for good and fresh eggs (TSS, 1980). According to Crawford (1990) albumen quality is influenced by both genetic and non-genetic factors such as breed, age of hen, length of storage and season of lay. The mean albumen height and Haugh unit values obtained for the crossbred pullets in this study (8.19mm and 78.5%) are better than values obtained for local Fulani chickens (4.92mm and 73.43%) by Fayeye *et al*. (2005) and local hens of Ethiopia (2.8 to 4.15mm and 60.35 to 74.70%) by (Mogesse, 2007).

The colour of the yolk is mainly dependent on the type of ration and the management systems of the chickens, with scavenging chickens producing eggs with higher yolk colour intensity because they have free access to green plants and other feed sources rich in xanthophylls. However, under the intensive system the crossbred chickens in this

study had lower egg yolk colour (Table 4.7) because the commercial layer mash given to them did not contain yellow maize which is rich in xanthophylls.

5.4.4 Hen-Day Egg Production and Egg Weights

The age at which egg production declined was not the best because egg production is reported to peak when the birds are between 30 and 40 weeks of age (Nwachukwu, *et al*., 2006). The laying pattern observed in this study was as a result of broodiness expressed by some of the birds, diseases (coccidiosis) as well as cannibalism especially for the birds showing the heat-tolerant genes. In all the stages of egg production, the double heterozygotes were found to be superior (Figure 4.2), confirming the observations made by Horst (1988), Haaren-Kiso *et al.* (1988), Pech-Waffenschmidt (1992) and Mahrous *et al*. (2008) that combining the naked-neck and the frizzling genes in the double heterozygous state (*Na/naF/f*) resulted in better hen-day egg production as compared to genotypes which were single heterozygous or homozygous recessive for the genes. However, with intensive selection the broody nature in the local chicken can be reduced to the barest minimum so as to increase the egg production potential of the local chicken to an appreciable level.

Egg number and weights are major traits of economic interest in commercial egg production. The size of the egg determines to a large extent its market price. Egg size is affected by feed consumption, breed, and age of the bird and to some extent the prevailing environmental conditions. There is a positive genetic correlation between body size and egg size, with heavier birds laying bigger eggs and vice versa. Egg

weights of all the crossbred genotypes (Fig. 4.3) increased gradually from the beginning of lay and then sharply when the birds were 35 weeks of age till they were 50 weeks of age when egg size started to decline slightly. In all these, the double heterozygotes maintained their superiority in terms of egg size, confirming the observations made by Horst (1988), Haaren-Kiso *et al.* (1988), Pech-Waffenschmidt (1992) and Mahrous *et al*. (2008) that the presence of the naked-neck and frizzle genes in combination significantly increased egg weight.

The insignificant difference in egg weight between the single heterozygote and the normally feathered was in contradiction with studies by Yushimura *et al*. (1997) Garces *et al.* (2001) and Younis and Galal (2006) who reported that the presence of the naked-neck or frizzle genes resulted in bigger egg weights of layers reared under tropical conditions as compared with their normally feathered sibs.

The average egg size of the crossbred genotypes in this study are comparable to *Tilili* and *RIR* hens which had average egg weights of 41.75g and 47.56g respectively (Mogesse, 2007). The eggs laid by the crossbred layers in this study were bigger than those obtained for local chickens (43.5g) (Dankwa and Nelson, 1995). The results in this study agree with the findings of Omeje and Nwosu (1988) that crossbreeding of the small indigenous chickens with an exotic breed tended to improve the egg size of the crossbred progeny.

5.5 Performance of the Crossbred and the Local Pullets

Improvement of the local poultry industry is beset with numerous constraints; prominent among them are unimproved breeds for the environment, diseases, management and predators (Bagust, 1994). Genotype and environment interaction plays a major role in the development of the rural chicken. Therefore every stock that is developed must be able to thrive well under the existing rural conditions. It is against this background that the crossbred pullets in this study were tested under the semi-scavenging system to evaluate their egg production performance and also to compare their performance with that of the farmers' own local stocks of similar age.

5.5.1 Crossbreeding Effects

There were significantly more deaths recorded among the crossbred pullets than the local hens. According to Sall (1990) the indigenous chickens tend to be robust and are well adapted to the harsh environmental conditions such as hot or cold weather, rain and periodic feed shortages. The significantly higher mortality recorded in the crossbred birds were through accidents their inability to escape predators which the local birds were good at. Some farmers also reported of incidences of theft which they added to loss of birds. Poor housing in some of the villages was found to be a contributing factor as far as mortality was concerned, as this exposed the birds to unfavourable environmental conditions like cold.

The crossbreeds were found to lay significantly more eggs than the local stock. According to Dankwa *et al*. (2000), the productivity of the village chicken is low with

annual egg production per hen ranging from 20-100. The crossbred hens laid eggs at a significantly higher rate than the local breeds probably due to crossbreeding effects, as reported by Nawar and Abdou (1999) that crossbred chickens have a higher rate of lay than purebred chickens in a commercial production system. Akhtar (2005) also reported a higher rate of lay for crosses between Fayoumi and Rhode Island Red than their pure breeds. The lower rate of lay among the local stock is also due to the broody nature of most of the birds which made them go off lay for some period. There was a significant difference in attainment of age at sexual maturity between the crossbreeds and the local ecotype. The crossbred stocks laid their first egg about five weeks earlier than the local ecotypes. This confirms the findings of Akhtar (2005) that crossbred chickens attain sexual maturity earlier than their pure breeds.

Again, a study by Omeje and Nwosu (1988) on the level of heterosis between the Gold-Link breed and the indigenous chicken revealed that the indigenous chickens and the indigenous-sired backcross attained sexuality about 10 days earlier than the pure-bred Gold-Link breed and its backcross. Katule (1992) also reported of crossbred F_1 generation birds maturing earlier than any of their parental lines indicating the existence of heterosis for sexual maturity. Though the crossbred pullets were reared under the semi-scavenging system, there was an improvement in terms of age at sexual maturity.

Body weights at sexual maturity and at 60 weeks of age were significantly higher for the crossbred pullets than for the local ecotypes. Fast growing birds have been found to reach market value early thereby reducing production costs. According to Omeje and

Nwosu (1988) crossing the indigenous chickens with the exotic breeds improves live weights, hence the developed crossbred strains being heavier than the local stocks. Egg weights throughout the entire laying period were significantly higher in the crossbred chickens than the local stocks. Under the semi-scavenging system, the crossbred pullets laid averagely bigger eggs than those recorded by Dankwa and Nelson (1995) for local chickens (43.5g) that were given supplementary diets. According to Fairful (1990) body weight is positively correlated with egg weight and this was observed in this study with heavier birds laying bigger eggs (Table 4.9). Sorensen *et al.* (1980) also observed that there is a high genetic correlation between egg weight and adult body weight in White Leghorns. The bigger egg weights of the crossbred chickens were also as a result of hybrid vigour because one of the parents of the crossbreeds (Lohman Brown) has been intensively selected for bigger egg size. The results also confirm the assertion that older birds lay bigger eggs as egg weights increased with increase in age.

The local hens produced eggs that had significantly thicker shells than the crossbred pullets (Table 4.10). This might be due to differences in genotype as was reported by Rose *et al.* (1986) that there are breed and strain differences with regard to egg shell thickness. The thicker egg shell thickness recorded for the local pullets confirm the observation by Sergeyeva (1986) that the local chickens laid eggs with thick shells, which is an important bio-economic trait during egg storage since it encouraged the best use of the nutrients in the egg by the embryo.

There was no significant difference in Haugh unit among the various pullet genotypes. However the Haugh unit values fall within the acceptable range of 70% which is generally considered a high quality egg (FAO, 1961). The yolk colour observed at the beginning was low but getting to the latter part of the experiment the colour score increased. The difference is associated with the change in feeding pattern. The birds had little access to green grass at the beginning of the assessment since this period coincided with the dry period where grasses had dried up but the second assessment was done during the wet period when there was abundance of grass.

5.5.2 Location Effects

This section is devoted to the interpretation of the results obtained from the crossbred birds (double and single heterozygous pullets) that were distributed to the farmers. The objective of this work was to find out if there was any genotype-environment interaction among the crossbred genotypes.

The districts or location where the crossbred double and single heterozygous pullets were reared did not significantly affect the number of eggs laid, age at first lay or percent rate of lay during the entire laying period. This agrees with the findings of Akhtar (2005) that there was no significant difference in egg production and age at sexual maturity of birds reared at various locations in Kenya. However, Rahman *et al*. (1997) reported a significant location effect on egg production in the same country. The absence of significant differences in this study might be due to similar environmental conditions pertaining during the period of the study. There were however significant

differences in mortality rates among the birds reared at the various locations; with significantly more crossbred double and single heterozygous birds dying in Amansie East and Sekyere East districts than in the rest of the locations. There was a disease outbreak in some villages in the two districts where the birds were sent to, resulting in the death of some of the birds. Some of the causes of loss of flock were later found to be as a result of theft and predation which the farmers included in the calculation of mortality, thereby increasing the percent mortality in those districts.

Location significantly ($P<0.05$) affected body weight at age of sexual maturity; however the birds did not differ significantly in weight at the end of the experimental period. This agrees with the findings of Akhtar (2005) that location had significant effect on body weight. Njenga (2005) also found significant difference in body weights of birds collected at different locations in Kenya. The differences in body weight at age of sexual maturity might be due to differences in management practices carried out by the care-takers and the availability of scavengable feed resource base in the various locations. According to Kitalyi (1998) the productivity of village chickens is determined by the relationship between the biomass of the chicken population and the scavengable feed resource base (SFRB). The SFRB is affected by the human population and the closeness of the households. The significant difference in age at sexual maturity consequently resulted in a significant difference in weight gains for the double heterozygotes at the different locations.

There were significant location effects (P<0.05) in 46-week egg weights of the birds but no significant differences in egg weights were observed at other stages of growth of the birds. The differences in egg weights in the various locations might be due to differences in scavengable feed resource base at the various locations and also differences in body weights of the birds, because heavier birds lay bigger eggs and vice versa. There were significant location effects on egg shell thickness, yolk diametre and yolk colour score at the end of lay for the double and single heterozygous birds. This agrees with the results by Akhtar (2005) that showed significant location effects on egg shell thickness and yolk colour for indigenous chickens in some selected villages in Kenya. The differences in feed resource base in the different locations might have resulted in differences recorded.

5.6 Heterotic Effect

The negative heterotic effects obtained in this study with the mean main crossbreeds could be attributed to the greater genetic distance between the two lines used. The negative effects for the studied characters are indications of superiority of the mean parents in relation to the mean crossbreed. With parents results (Table 4.13) obtained showed that the naked-neck were better in terms of total eggs produced and laid their first egg earlier than the frizzle parents. These results are in agreements with that of Merat (1986), Haaren-Kiso *et al*. (1995) that naked-neck birds lay their first egg earlier than frizzle birds. With respect to the crosses, it could be noticed that the F X Na cross was better than Na X F in all the traits measured. This confirms the observation by

Nwachukwu *et al.* (2006) that the cross between frizzle and naked-neck is better that its reciprocal cross.

Heterotic estimates for body weights, egg weights and egg production parameters computed on mid-parents are presented in Table 4.14. Results within crosses revealed that F X Na had positive and high heterotic percentage at all ages. These results may be encouraging to poultry breeders in the country to use frizzle as male lines and naked-neck as female lines in their crossbreeding programmes. According to Willham and Pollack (1985) the magnitude of heterosis is inversely related to the degree of genetic resemblance between parental populations and is expected to be proportional to the degree of heterozygosity of the crosses (Sheridan, 1981). According to the Fairfull (1990) heterosis is brought about by non-additive gene action and may be viewed as overall fitness as well as expression of a specific trait.

Heterosis for body weight is observed in chickens when there are small (Yalcin *et al.*, 2000) and large (Liu *et al.*, 1993) differences in body weight between the parental lines and in this case between the frizzle and naked-neck genotypes. It is usually greater for reproductive traits than for growth traits (Fairfull, 1990), and is also influenced by maternal and dietary effects (Liu *et al*., 1995). Generally, all the two types of crossing benefited from double heterosis, this is because the parents used for the crossing were all products of a cross between local naked-neck and frizzle cocks and lohmann brown hens.

5.7 Genotype-environment interaction

Results on genotype-environment interaction for age at first lay, rate of lay, mortality and total eggs laid are presented in Table 4.15. The results revealed a genotype-environment interaction for rate of lay with Na/naf/f and na/naF/f genotypes laying at different rates in different environments. The double heterozygotes could not maintain their superiority when they were kept under the semi-scavenging environment. The single heterozygotes did better than the double heterozygote under the farmers' environments in terms of mortality. This means the improvement in the genetic constitution of a stock (through crossbreeding) must be backed by the improvement in the management so as to explore the full genetic potential of the developed stock.

5.8 Behavioural studies and observation

5.8.1 Broodiness

The broody behaviour of hens consists of termination of egg production, the incubation of eggs and the care of the young ones. The local hens were found to show signs of broodiness. In three out of the five locations the farmers reported that their local birds were either sitting on the eggs or trying to sit on the eggs laid. This accounted for the relatively lower number of eggs laid by the local hens. The broody nature of the local hens is in agreement with the observation by Mukherjee (1990) that the indigenous chicken has an instinctive inclination to broodiness after about eight eggs are laid. It was in only Atwima-Mponua district that the farmers reported of the crossbred pullets showing signs of broodiness.

5.8.2 Scavenging, Scratching and Picking Behaviour

All the genotypes reared at the villages were found to be scavenging, scratching and picking feed. During the course of scavenging, the local hens walked comparatively longer distances in search of feed and were also very aggressive in their search for feed. Initially the crossbred pullets were docile but as time went on they began to learn of the aggressiveness with which they searched for their feed.

5.8.3 Cannibalism

The birds with showing the naked-neck and frizzle traits were found to be pecking themselves due probably to their exposed skin, especially the frizzle birds. This observation confirms that of Njenga (2005) that naked-neck and frizzle cocks are prone to feather pecking. To overcome this, the naked-neck and frizzle birds must be constantly debeaked. According to Tweneboah (2002) red colour seems to attract maximum attention by birds, and this might have caused the neck pecking of the naked-neck birds due to their exposed neck. Again, Tweneboah (2002) observed that such which show obvious inheritance of nervousness are prone to feather pecking and eventually cannibalism.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

1. It could be concluded that the naked-neck and frizzle phenotypes are likely to go into extinction in the villages surveyed because of the very low frequencies of the naked-neck and frizzle genes observed in the population studied.
2. It can also be concluded that there is positive interactive effects between the two genes (*Na or F*) even in moderately warm environments as evidenced by the better egg production performance of *NanaFf* genotypes compared to their *Nana* or *Ff* or *nanaff* sibs.
3. There was a genotype-environment interaction for mortality, rate of lay and total eggs laid; an indication that if the environment is not improved, the phenotype's full genetic potential might not be realized.
4. Egg production performance of the crossbred naked-neck and frizzle pullets were better than the normally feathered local pullets, an indication that crossbreeding has the potential of improving egg production in the local chickens.
5. Estimate of heterosis showed that the use of frizzle as sire line and naked-neck as dam line in crossbreeding programme is recommended due to the high and positive heterotic effects observed in all the traits measured.

From the limitations encountered and the results obtained the following recommendations are worth making.

1. It is recommended that *Na* and *F* genes be incorporated either singly or in combination into commercial chicken lines that are to be reared under hot and humid environments.
2. Further studies should be done to evaluate the performance of birds homozygous for the two genes.
3. There is the need to conserve and preserve the naked-neck and frizzle genes so that they can be used in future breed improvement strategies.
4. Due to the better performance of birds with combined naked-neck and frizzle genes, any future breed development strategy in the local chickens must involve the utilization of the two genes (Na and F).
5. This must be backed by the improvement in the management of local chickens so as to ensure the exploitation of the full potentials of the genes.
6. Due to the difficulty in identifying the frizzling at day-old, it is recommended that Marker Assisted Selection (MAS) be used in future to select the genotypes early in life.

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APPENDICES

Analysis of Variance Tables

Variate: Weight at day old

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	0.15922	0.05307	2.30	0.155
Residual	8	0.18500	0.02312		
Total	11	0.34422			

Variate: 1wk body weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	3.1705	1.0568	8.53	0.007
Residual	8	0.9907	0.1238		
Total	11	4.1612			

Variate: 2wk body weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	3.47130	1.15710	11.78	0.003
Residual	8	0.78587	0.09823		
Total	11	4.25717			

Variate: 3wk body weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	36.700	12.233	2.35	0.148
Residual	8	41.629	5.204		
Total	11	78.328			

Variate: 4wk body weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	85.745	28.582	9.42	0.005
Residual	8	24.275	3.034		
Total	11	110.021			

Variate: 5wk body weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	107.261	35.754	19.78	<.001
Residual	8	14.461	1.808		
Total	11	121.722			

Variate: 6wk body weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	107.261	35.754	19.78	<.001
Residual	8	14.461	1.808		
Total	11	121.722			

Variate: 7wk body weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	57.474	19.158	2.85	0.105
Residual	8	53.747	6.718		
Total	11	111.222			

Variate: 8wk body weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	94.085	31.362	5.12	0.029
Residual	8	48.963	6.120		
Total	11	143.048			

Variate: 9wk body weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	1767.8	589.3	1.92	0.204
Residual	8	2450.9	306.4		
Total	11	4218.7			

Variate: 10wk body weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	1782.7	594.2	1.92	0.204
Residual	8	2469.7	308.7		
Total	11	4252.5			

Variate: 11wk body weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	1916.4	638.8	1.93	0.203
Residual	8	2643.9	330.5		
Total	11	4560.3			

Variate: 12wk body weigt

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	1921.5	640.5	1.95	0.201
Residual	8	2633.6	329.2		
Total	11	4555.1			

Variate: 13wk body weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	1786.6	595.5	1.90	0.209
Residual	8	2511.6	313.9		
Total	11	4298.1			

Variate: 14wk body weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	1794.4	598.1	1.90	0.207
Residual	8	2513.2	314.1		
Total	11	4307.6			

Variate: Feed Intake wk I-8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	3.2633	1.0878	1.65	0.253
Residual	8	5.2667	0.6583		
Total	11	8.5300			

Variate: Feed Intake wk9-14

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	1265.7	421.9	2.69	0.117
Residual	8	1254.2	156.8		
Total	11	2519.9			

Variate: Feed Conversion Ratio wk1-8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	1.602	5.341	3.96	0.053
Residual	8	1.079	1.349		
Total	11	2.681			

Variate: Feed Conversion Ratio wk 9-14

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	5.219	1.740	2.66	0.119
Residual	8	5.230	6.538		
Total	11	1.045			

Variate: Weight Gain

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	59.943	19.981	4.12	0.048
Residual	8	38.755	4.844		
Total	11	98.698			

Variate: Weight Gain wk 9-14

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	3.554	1.185	0.82	0.521
Residual	8	11.627	1.453		
Total	11	15.181			

Variate: blood%

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	31.45667	10.48556	740.16	<.001
Residual	8	0.11333	0.01417		
Total	11	31.57000			

Variate: breast%

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	29.2567	9.7522	10.40	0.004
Residual	8	7.5000	0.9375		
Total	11	36.7567			

Variate: dressed wt

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	11521.3	3840.4	9.18	0.006
Residual	8	3345.5	418.2		
Total	11	14866.8			

Variate: dressing%

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	21.7667	7.2556	16.68	<.001
Residual	8	3.4800	0.4350		
Total	11	25.2467			

Variate: feather%

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	13.6733	4.5578	14.62	0.001
Residual	8	2.4933	0.3117		
Total	11	16.1667			

Variate: leg%

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	2.0892	0.6964	3.63	0.064
Residual	8	1.5333	0.1917		
Total	11	3.6225			

Variate: live wt/kg

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	6043.3	2014.4	15.29	0.001
Residual	8	1054.2	131.8		
Total	11	7097.6			

Variate: mortality

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	192.000	64.000	6.86	0.113
Residual	8	74.667	9.333		
Total	11	266.667			

Variate: thigh%

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	4.4292	1.4764	6.09	0.018
Residual	8	1.9400	0.2425		
Total	11	6.3692			

Variate: total feed intake

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	1577.3	525.8	1.80	0.225
Residual	8	2337.3	292.2		
Total	11	3914.6			

Variate: wing%

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	0.95000	0.31667	3.80	0.058
Residual	8	0.66667	0.08333		
Total	11	1.61667			

Variate: Averge daily gain

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	0.0015773	0.0005258	1.80	0.225
Residual	8	0.0023373	0.0002922		
Total	11	0.0039146			

Genotype effects on egg laying

Variable: Age at sexual maturity, days

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	78.000	26.000	11.55	0.007
Residual	8	18.000	2.25		
Total	11	96.000			

Variable: albumen height, mm

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	0.00076	0.00025	0.02629	0.971
Residual	8	0.07605	0.009506		
Total	11	0.07681			

Variate: Feed Conversion Ratio

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	0.057187	0.019062	15.79	0.003
Residual	8	0.009656	0.001207		
Total	11	0.066843			

Variate: Feed Intake

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	7.506	2.502	3.0305	0.103
Residual	8	6.605	0.8256		
Total	11	14.110			

Variate: mortality, %

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	38.5992	12.8664	17.856	0.002
Residual	8	5.7645	0.72056		
Total	11	44.3637			

Variate: haugh unit/%

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	12.216	4.072	0.753	0.474
Residual	8	43.259	5.407		
Total	11	55.476			

Variate: rate of lay

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	49.556	16.518	19.82	0.002
Residual	8	6.667	0.8334		
Total	11	56.222			

Variate: shell thickness, mm

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	0.0008167	0.0002722	0.4916	0.602
Residual	8	0.0044293	0.0005537		
Total	11	0.0052460			

Variate: total eggs/bird, no.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	425.092	141.697	63.229	<.001
Residual	8	26.728	3.341		
Total	11	451.820			

Variate: yolk colour score

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	0.4083	0.1361	0.391	0.663
Residual	8	2.7845	0.34806		
Total	11	3.1928			

Variate: yolk diametre, mm

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	1.243	0.41433	0.1803	0.822
Residual	8	18.383	2.2978		
Total	11	19.626			

Variate: yolk ht, mm

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	2.6223	0.8741	2.19	0.165
Residual	8	3.1880	0.3985		
Total	11	5.8103			

Phenotype and location effects for birds reared on-farm

Variate: Egg weight at 36 weeks, g

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	1.200	0.400	0.108	0.596
Districts	4	14.800	3.700	3.1025	0.485
Interaction	12	14.311	1.19258	1.9563	0.501
Residual	20	74.038	0.6096		
Total	39	109.316			

Body weight at 26 weeks, g

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	67.5	22.5	0.34	0.568
Districts	4	338.3	84.6	0.43	0.789
Interaction	12	645.0	53.75	0.81	0.535
Residual	20	3581.7	27.98		
Total	39	4667.5			

Body weight at 36 weeks, g

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	653	217.67	0.13	0.723
Districts	4	72580	18145	3.60	0.025
Interaction	12	35347	2945.587	1.76	0.182
Residual	20	90620	4531		
Total	39	207980			

Body weight at 46 weeks, g

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	30	10	0.00	0.945
Districts	4	127620	31905	5.22	0.006
Interaction	12	48603	4050.25	1.99	0.140
Residual	20	110022	6112		
Total	39	305120			

Body weight at 56 weeks, g

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	908	302.67	0.14	0.716
Districts	4	17664	4416	6.67	0.002
Interaction	12	70505	5875.41	2.66	0.066
Residual	20	119188	6622		
Total	39	389688			

Body weight at 60 weeks, g

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	908	302.67	0.14	0.716
Districts	4	176642	4416	6.67	0.002
Interaction	12	70505	5875.41	2.66	0.066
Residual	20	119188	6622		
Total	39	389688			

Age at first lay, days

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	1.63	0.543	0.02	0.881
Districts	4	240.53	60.13	0.85	0.515
Interaction	12	86.53	21.63	0.30	0.871
Residual	20	1280.60	7.21		
Total	39	1733.37			

Hen-day, %

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	6.482	2.1607	1.93	0.182
Districts	4	39.544	9.886	2.94	0.049
Interaction	12	18.410	1.534	1.37	0.283
Residual	20	60.453	3.359		
Total	39	138.866			

Albumen height, mm

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	0.0013	0.00043	0.01	0.918
Districts	4	1.0447	0.2612	2.16	0.116
Interaction	12	0.3287	0.0273	0.68	0.616
Residual	20	2.1813	0.1212		
Total	39	3.8680			

Body weight at 20 weeks, g

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	7.5	2.5	0.04	0.848
Districts	4	1145.0	286.2	1.44	0.262
Interaction	12	1205.0	100.42	1.51	0.241
Residual	20	3585.0	199.2		
Total	39	5974.2			

Haugh unit, %

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	1.36	0.453	0.08	0.775
Districts	4	272.77	68.19	4.22	0.014
Interaction	12	5.44	0.4533	0.08	0.986
Residual	20	291.16	16.18		
Total	39	629.49			

Mortality, %

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	187.5	62.5	1.60	0.023
Districts	4	1427.1	356.8	3.04	0.045
Interaction	12	177.1	14.758	0.38	0.822
Residual	20	2114.6	117.5		
Total	39	3979.2			

Rate of lay, %

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	100.833	33.611	88.39	<0.001
Districts	4	34.000	8.500	7.45	0.001
Interaction	12	13.333	1.111	2.92	0.050
Residual	20	20.533	1.141		
Total	39	172.167			

Total eggs per bird, no.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	799.70	266.57	54.00	<0.001
Districts	4	472.61	118.15	7.98	<0.001
Interaction	12	107.80	8.95	1.82	0.169
Residual	20	266.55	14.81		
Total	39	1651.77			

Weight gain, g

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	750	250	0.12	0.733
Districts	4	202387	50597	8.10	<0.001
Interaction	12	83333	6944.4	3.34	0.033
Residual	20	112385	6244		
Total	39	422337			

Yolk colour beginning

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	0.4083	0.1361	1.76	0.201
Districts	4	0.3913	0.0978	0.42	0.791
Interaction	12	0.9967	0.2492	1.07	0.398
Residual	20	4.1767	0.2320		
Total	39	6.2897			

Yolk diametre, mm

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Genotype	3	0.1333	0.0444	0.14	0.713
Districts	4	15.6667	3.9167	4.11	0.015
Interaction	12	44.8667	11.2167	11.78	<0.001
Residual	20	17.1333	0.9519		
Total	39	78.0000			

Yolk colour end

Source of variation	d.f.	s.s.	m.s.	v.r.	F.pr.
Genotype	3	0.07500	0.025	2.28	0.149
Districts	4	0.85133	0.21283	6.46	0.002
Interaction	12	2.74333	0.68583	20.81	<0.001
Residual	20	0.59333	0.03296		
Total	39	4.46300			

Yolk height, mm

Source of variation	d.f.	s.s.	m.s.	v.r.	F.pr.
Genotype	3	0.936	0.312	0.49	0.494
Districts	4	5.317	1.329	0.69	0.608
Interaction	12	4.769	1.192	0.62	0.654
Residual	20	34.615	1.923		
Total	39	46.455			

HETEROTIC EFFECT

Variate: BW26

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Breed	3	581.67	193.89	6.69	0.014
Residual	8	232.00	29.00		
Total	11	813.67			

Variate: BW36

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Breed	3	34300.92	11433.64	256.94	<.001
Residual	8	356.00	44.50		
Total	11	34656.92			

Variate: BW46

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Breed	3	21524.67	7174.89	214.18	<.001
Residual	8	268.00	33.50		
Total	11	21792.67			

Variate: BW56

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Breed	3	22164.2	7388.1	37.49	<.001
Residual	8	1576.7	197.1		
Total	11	23740.9			

Variate: totaleggpdn

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Breed	3	219.422	73.141	9.89	0.005
Residual	8	59.166	7.396		
Total	11	278.588			

Variate: EW30

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Breed	3	89.834	29.945	20.60	<.001
Residual	8	11.628	1.453		
Total	11	101.462			

Variate: EW40

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Breed	3	67.520	22.507	11.38	0.003
Residual	8	15.817	1.977		
Total	11	83.337			

Variate: EW50

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Breed	3	25.6251	8.5417	12.48	0.002
Residual	8	5.4743	0.6843		
Total	11	31.0994			

Variate: EW60

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Breed	3	30.5884	10.1961	61.82	<.001
Residual	8	1.3195	0.1649		
Total	11	31.9079			

Variate: age_at_first_lay

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Breed	3	400.917	133.639	32.07	<.001
Residual	8	33.333	4.167		
Total	11	434.250			

Variate: rateof_lay

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Breed	3	36.555	12.185	9.89	0.005
Residual	8	9.857	1.232		
Total	11	46.412			

Temperature (^{0}C) and humidity (%) recorded during the brooding period

		Average temp. (^{0}C)		*Average humidity (%)*	
Period	**Wk**	**9am**	**3pm**	**9am**	**3pm**
Apr 9-15	1	34.5	33.5	83	58
Apr 16-22	2	33.3	30.2	84	59
Apr 23-29	3	31.4	30.1	86	55
Apr 30-May 6	4	30.6	29.4	82	58
May 7-13	5	29.5	29.7	85	65
May 14-20	6	27.7	30.3	84	67
May 21-27	7	26.5	30.2	82	59
May 28-Jun 3	8	26.2	30.3	84	63

Temperature (^{0}C) and humidity (%) recorded during the growing period

		Average temp. (^{0}C)		*Average humidity (%)*	
Period	**Wk**	**9am**	**3pm**	**9am**	**3pm**
Jun 4-10	1	26.6	29.8	85	65
Jun 11-17	2	25.5	29.6	84	65
Jun 18-24	3	25.8	28.8	82	66
Jun 25-Jul 1	4	25.2	28.2	80	67
Jul 2-8	5	24.3	27.3	86	72
Jul 9-15	6	25.0	27.8	86	71

Temperature (^{0}C) and humidity (%) recorded throughout the laying period

		Average temp. (^{0}C)		*Average humidity (%)*	
Period	**Wk**	**9am**	**3pm**	**9am**	**3pm**
Sep 24-30	1	26.2	28.8	78	66
Oct 1-7	2	26.7	28.3	77	64
Oct 8-14	3	27.1	29.0	71	62
Oct 15-21	4	27.2	29.3	70	62
Oct 22-28	5	27.2	29.1	70	64
Oct 29-Nov 4	6	27.5	29.8	69	60
Nov 5-11	7	26.4	29.0	71	61
Nov 12-18	8	26.8	29.1	72	59
Nov 19-25	9	26.5	29.2	72	58
Nov 26-Dec 2	10	26.3	28.4	71	62
Dec 3-9	11	26.2	30.8	70	63
Dec 10-16	12	25.5	30.4	74	64
Dec 17-23	13	22.3	32.4	77	65
Dec 24-30	14	23.6	30.3	76	67
Dec 31-Jan 6	15	22.4	32.9	76	64
Jan 7-13	16	21.4	33.0	80	71
Jan 14-20	17	21.7	32.5	86	67
Jan 21-27	18	22.4	32.9	78	66
Jan 28-Feb 3	19	24.4	33.1	78	69
Feb 4-10	20	24.3	32.8	72	71

Feb 11-17	21	25.2	32.0	72	67
Feb 18-24	22	25.1	31.9	78	60
Feb 25-Mar 2	23	24.5	30.6	76	61
Mar 3-9	24	27.7	30.2	74	40
Mar 10-16	25	28.3	31.2	75	55
Mar 17-23	26	28.9	30.2	74	54
Mar 24-30	27	28.7	30.4	72	56
Mar 31-Apr 6	28	28.4	30.2	72	58
Apr 7-13	29	27.3	30.8	71	52
Apr 14-20	30	27.3	30.8	70	53
Apr 21-27	31	27.2	31.4	70	50
Apr 28-May 4	32	27.1	31.2	69	50
May 5-11	33	27.3	32.0	68	49
May 12-18	34	27.3	29.2	71	53
May 19-25	35	26.3	28.8	72	52