CHAPTER 1

INTRODUCTION

1. INTRODUCTION

1.1 Background

The rapid growth of the human population in South Africa has led to a relatively high demand for protein. Meat and eggs are among the most important forms of animal protein in economically developed and developing areas of the world. Poultry meat is the cheapest source of protein compared to animal protein forms and, probably, the most consumed. Medical research also indicates that poultry meat has lower cholesterol content in contrast to red meat.

The poultry sector can be divided into commercial and traditional sub-sectors (Mbugua, 1990). The commercial broiler and layer industries are well developed and established, while the traditional sub sector is commonly a low input-output system and is largely subsistence. The traditional sub-sector comprises of local breeds reared under scavenging systems in remote rural and peri-urban areas. The system is primarily associated with food (meat and eggs) for household consumption (MacDonald and MacDonald, 2000; Ramsey *et al*., 2000). Chickens in this sector are also raised for cash and play a role in cultural events (Sonaiya *et al.,* 1999).

In South Africa, as in other developing countries, chickens are often associated with the poorer households that cannot afford to keep other livestock such as goats, sheep or cattle (Anderson, 2003). Most of the poultry in these operations are indigenous chickens that are considered to be of low productivity (Kitalyi, 1998). In this regard, the locally adapted African chickens have largely been neglected /disregarded, and limited data on these breeds is available in the scientific literature and/or the public domain (Setshwaelo and Adebambo, 1992; Hofmeyr *et al.*, 1998). Most native chickens have not been selected for particular traits such as meat or egg production. There has been more development focused on introducing exotic high yielding breeds than understanding the production potential of native chickens (Rodriguez and Preston, 1997). Furthermore, very little in terms of genetic improvement has been done to improve their productivity.

The genetic resource base of the indigenous chickens could form the basis for genetic improvement and diversification programs to produce breeds adapted to local conditions (Saadey *et al,* 2008). Crossbreeding is one of the tools for exploiting genetic variation. It is the mating of two individuals with different breed make-up. The main purpose of crossing in chickens is to produce superior crosses (i.e. make use of hybrid vigor); to improve fitness and fertility traits and to combine different characteristics of economic importance (Willham and Pollak, 1985; Hanafi and Iraqi, 2001). Crossbreeding is beneficial for two primary reasons which are complementarity and hybrid vigor. Very few studies have been conducted to evaluate crossbreeding as a strategy to improve productivity of the indigenous chickens of South Africa. This study will be conducted to evaluate the potential of crossbreeding in improving the productivity of indigenous chicken breeds.

1.2 Problem statement

Chickens are a good source of animal protein and income (Gondwe, 1994; Safalaoh, 1992; 1997). Despite these attributes, the productivity of indigenous chickens is low when compared to the commercial broiler chickens. Indigenous chickens are characterized by a small body size and lateness in maturity. They are also characterized by low performance in egg numbers (20 to 50), egg size (25 to 45 g) and long pauses between laying of clutches. In Malawi, Kadigi (1996) reported that crossbreeding the local chicken with the Black Australorp improved bird productivity (hatchability of eggs, viability of chicks, rate of growth, egg production) of the local chicken. Very little research has been conducted to evaluate crossbreeding as a strategy to improve productivity of the indigenous chickens in South Africa.

1.3 Motivation of the study

This study will evaluate the extent to which crossbreeding can improve the productivity of indigenous chickens in South Africa. The diallel crossing scheme will assist in the identification of suitable chicken genotypes for commercial exploitation. Results of the study may potentially lead to the development of effective indigenous chicken improvement programs.

1.4 Objectives of the study

The objectives of this study were as follows:

Specific objectives 1: To measure the heterotic effect for body weight in a three way cross between Venda, Naked neck and Ross 308 chicken breeds.

Specific objectives 2: To estimate specific combining abilities for body weight in a three way cross between Venda, Naked neck and Ross 308 chicken breeds

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Specific objectives 3: To estimate general combining ability for body weight in a three way cross between Venda, Naked neck and Ross 308 chicken breeds.

CHAPTER 2

LITERATURE REVIEW

Chicken production plays an important role in many rural households (Kitalyi, 1998). According to Sonaiya *et al.,* (1999), poultry production is popular in most resource-poor countries. Chickens provide supplementary food, extra income and employment for family members. They are an integral part of the farming system, with short life cycles and quick turnovers.

Poultry production in most rural parts of South Africa is characterized by small scavenging operations. Most of the poultry in these operations are indigenous chickens that are considered to be of low productivity. Indigenous breeds are characterized mainly by small body size and lateness in maturing. They are also characterized by low performance in egg numbers, egg size (25 to 45 g) and long pauses between laying of clutches (FAO, 2004). They have a predominant inclination to broodiness and are good mothers (Horst, 1990). Fertility and hatchability are also high in local birds. They are generally well adapted to unfavorable management conditions and are relatively more resistant to diseases, although juvenile and sometimes adult mortality rates can be high in extensive production systems (Yami, 1995).

In Malawi, Kadigi (1996) reported that crossbreeding the local chicken with the Black Australorp improved bird productivity (hatchability of eggs, viability of chicks, rate of growth, egg production) of the local chicken. Crossbreeding indigenous chickens with exotic breeds will go a long way in improving the performance of the indigenous chickens without necessarily losing their adaptive features as their desirable genes are conserved (Ajayi, 2010). In contrast to these findings, however, Knox (1939) found out that crossbreds were inferior to the purebreds as far as egg production and other growth traits are concerned.

The genetic resource base of the indigenous chickens could form the basis for genetic improvement and diversification to produce breeds adapted to local conditions (Saadey *et al,* 2008). The gradual replacement of local genes through cross-breeding and artificial selection has been the basis of initial development in many countries (Omeje and Nwosu, 1986; Coligado *et al.*, 1986).

2.1 Crossbreeding

Crossbreeding is one of the tools for exploiting genetic variation. Crossbreeding, the mating of two individuals with different breed make-ups, is one type of a larger class of mating systems called outbreeding. Outbreeding has the opposite effect of inbreeding and hence results in increased heterozygosity in a population and decreased homozygosity. A crossbreed or crossbred animal usually refers to an animal with purebred parents of two different breeds, varieties, or populations. The intention is often to create offspring that share the traits of both parent lineages, and producing an animal with hybrid vigor.

Crossbreeding is beneficial for two primary reasons. First, a well designed crossbreeding system allows the producer to combine the desirable characteristics of the breeds involved in the cross while masking some of the disadvantages of the breeds. This is frequently referred to as breed complementarity. The second benefit arises from heterosis, which is often referred to as hybrid vigor. In addition to these primary benefits, crossbreeding also enables a producer to change a population rapidly with the introduction of new breeds. The purpose of crossbreeding is to produce progeny which are more disease resistant, healthier and hardier.

2.1.1 Breed Complementarity

Breed complementarity, a major advantage of crossbreeding, is often very important to the success of crossbreeding programmes. It refers to the production of a more desirable offspring by crossing breeds that are genetically different from each other, but have complementary attributes. Breed complementarity is the result of mixing and matching the mean breeding values of different biological types of breeds.

2.1.2 Heterosis

The term heterosis, also known as hybrid vigor or outbreeding enhancement, describes the increased strength of different characteristics in hybrids; the possibility to obtain a genetically superior individual by combining the virtues of its parents. It is a measure of the superior performance of the crossbred relative to the average of the purebreds involved in the cross. The probable cause of most heterosis is combination of genes from different breeds, concealing the effects of inferior genes. Heterosis may result in the crossbred being better than either paternal breed or simply better than the average of the two. Heterosis is measured by crossing populations to produce an F1 generation, which is compared to the parental populations. Theoretically, the magnitude of heterosis is inversely related to the degree of genetic resemblance between parental populations (Wilham and Pollak, 1985) and is expected to be proportional to the degree of heterozygosity of the crosses (Sheridan, 1981). Thus, heterosis is a result of non-additive genetic effects and may be viewed as overall fitness as well as an expression of a specific trait. It is usually greater for reproductive traits than for growth traits (Fairfull, 1990). Heterosis is influenced by maternal and dietary effects (Lui *et al*., 1995) and may vary with regard to complex traits (Gram and Pirchner, 2001). In addition, Lamont and Deeb (2001) reported that heterosis for body weight was age dependant. Generating hybrid vigor is one of the most important, if not the most important, reasons for crossbreeding.

In Egypt, Sabra (1990) found that crossbreds obtained from crossing between local breeds (Silver Montazah and Dandarawi) had positive and high magnitude of heterosis for body weight at different ages. Saadey *et al*., (2008) found that crossbreds obtained from crossing between Sinai (S) and White Leghorn had positive and high heterotic percentage at all ages, except at 2 and 3 months of age. Malik et al. (2005) reported that strain cross pullets were lighter than purebreds at 20 weeks of age while Singh and Singh (2005) reported that crossbreds were superior than purebreds in body weight at 20 and 40 weeks of age.

Most reviewed studies show that body weights of crossbred chickens at different ages are associated with positive heterotic effects for growth traits (Sabri and Hataba, 1994; Khalil *et al.,* 1999; Sabri *et al*., 2000). Iraqi *et al*., (2002) indicated that heterosis estimates were generally positive and high for body weights of crossbreds obtained from crossings between Mandarah and Matrouh chicken strains. Heterosis for body weight was observed in chickens when there were small differences in body weight between parental lines (Yalcin *et al.,* 2000) and when there were large differences between the parental lines used in the cross (Lui *et al*., 1993). Bice and Tower (1939) demonstrated the effects of crossbreeding using the Japanese Shamo Game, a popular meat bird in Hawaii. This local breed was crossed with Rhode Island Reds, Barred Plymouth Rocks and White Leghorns. The four pure breeds were compared with crossbreds resulting from matings of the Shamo Game males to females of each of the other three mentioned breeds. There was definite improvement in hatchability of all crossbreds over the purebreds except in the case of the Rhode Island Reds. The crossbreds in each group had a lower chick mortality rate than the purebreds of the corresponding group. The crossbreds grew more rapidly than any purebred except the Shamo Game and ate less through the first eight weeks than did any of the purebreds. Cole and Hutt (1962) outlined the importance of crossbreeding by crossing two strains of chickens. The offspring of the strain cross laid about 22 eggs per year more than offspring of the pure strains. In addition the hybrids laid larger eggs, matured earlier, and had a larger body size than the pure strain hens.

There are three types of heterosis:

Individual heterosis

Individual heterosis is the advantage of the crossbred individual relative to the average of the purebred individuals.

Maternal heterosis

Maternal heterosis is the advantage of the crossbred mother over the average of purebred mothers.

Paternal heterosis

Paternal heterosis is the advantage of the crossbred sire over the average of purebred sires. Paternal heterosis generally has an effect only on conception rate and aspects of male reproduction. The male parent does not have any direct environmental effect on the survival of the offspring, so the benefits are more limited than those for maternal heterosis. However, the benefit in added conception rate can be substantial, particularly if young males are being used.

2.2 General and specific combining abilities

Combining ability describes the breeding value of parental lines to produce hybrids. Test for good combining abilities is developed by generating a diallel cross, which is a set of possible combination between several genotypes and general populations and analysis of data from such crosses (Hayman, 1954). The combining ability analyses help to identify the desirable combiners that may be utilized to exploit heterosis (Saadey *et al.,* 2008). Gardener and Eberhardt (1966) defined general combining ability (GCA) as an average performance of a line in different hybrid combinations. Lin (1972) also defined GCA as a numerical value expressing the influence of one of the lines on its progeny. The estimates of general combining ability (GCA) reflect the importance of additive gene effects of breeds on body weight at different ages (Afifi *et al.,* 2002). General combining ability (GCA) is a consequence of additive genetic effects, while specific combining ability (SCA) is a consequence of non-additive genetic effects (Etso and Nordskog, 1961). Hill and Nordskog (1958) stressed the importance of general combining ability over specific combining ability. The results of diallel experiments with poultry (Hill and Nordskog, 1958; Goto and Nordskog, 1959; Merritt and Gowe 1960; Redman and Shoffner, 1961; Yao, 1961; and Wearden *et al.,* 1965) suggest that general combining ability variance is the single most important source of genetic variation for most traits, but that specific combining ability and reciprocal effect variances may be important for some traits. Many reports show that general combining ability and therefore, additive variations were high and important to specific combing ability for body weight at different ages (Wearden *et al.,* 1965, Hill, 1959, Kumar, 1979, Kim *et al.,* 1977 and Singh *et al*., 1983). Jain *et al*., (1981) reported that both GCA and SCA were important sources of genetic variation for age at first egg using three strains of White Leghorn.

Specific combining ability is the performance of a parent relatively better or worse than expected on the basis of the average performance of the other parents involved

(Sprague and Tatum, 1942). Specific Combining Ability (SCA) refers to a cross produced by a pair of lines (Adebambo, 2010). The specific combining ability also refers to the degree to which the average performance of a specific cross departs from the additive (Griffing, 1956a,b) and it has been used to denote the degree of non-additive genetic effect in a population (Gardener and Eberhardt, 1966). The variation in SCA is due to non-additive genetic variance; heterosis, dominance, over-dominance and epistasis (Singh and Kumar, 1994). Significant SCA and RE was reported in chickens for 40th week body weight by Hagger (1985).

2.3 Poultry Breeds

2.3.1 Venda breed

The Venda fowl gets its name from the previous province of Venda, now known as the Limpopo province (in South Africa), home to the Venda people, where this breed was first described in 1979 by a veterinarian, Dr Naas Coetzee.

Venda chickens are multi-colored with white, black and red as predominant colors. Rose colored combs and five-toed feet are not uncommon. They are survivors under harsh African village conditions with minimum supplementary feed and are highly disease resistant. The breed’s most preferred characteristic, however, is its good broodiness and mothering characteristics. Hens of this breed lay large pink tinted eggs with a normal production under village scratch conditions of roughly 70 eggs per annum and an average egg weight of 53 g. Males are large colorful birds with an aggressive territorial streak. The Venda fowl reaches sexual maturity at 143 days which is almost five months. At 20 weeks of age Venda cocks weigh approximately 2.00 kg while the hens weigh 1.4 kg (ARC).

2.3.2 Naked Neck breed

The Naked Neck, also known as the Transylvanian Naked Neck, is a breed of chicken that is naturally devoid of feathers on its neck and vent. It was originated in Hungary and was largely developed in Germany. The Naked Neck trait is a dominant one controlled by one gene and is fairly easy to introduce into other breeds (ARC).

Despite its highly unusual appearance, the Naked Neck breed is a dual-purpose utility chicken. It lays a fairly good number of light brown eggs in its lifetime, and is considered desirable for meat production because it does not have many feathers and has a meaty body. Despite its lack of feathers, the breed is also reasonably cold hardy and is a very good forager and immune to most diseases (ARC). Naked Neck roosters carry a single comb, and the neck and head often become very bright red from increased sun exposure.

Scientific studies have indicated that the Naked Neck gene (*Na*) improves breast size and reduces heat stress in chickens of non-broiler breeds which are homozygous for the trait. Horst (1989) further stated that the Naked Neck gene (Na) confers superiority in some production characters in the tropics. Horst (1988) and Mathur and Horst (1990) showed that individuals with the Naked Neck gene were superior to those individuals with normal feathering for egg number, egg mass/weight and forty-week body weight in tropical environments. According to Ibe (1993), naked neck and the frizzed genes are associated with earlier sexual maturity in a tropical environment. The frizzling and the naked genes in particular have been described as adaptability genes acting as sex marker and disease resistant factor (Islam and Nishibori, 2009). Naked neck had higher breast percent than both frizzled and normal feathered birds (Gunn, 2008) but the frizzled and naked neck excelled in weight of other cut parts than the normal feathered chicken. Recent studies on incorporation of naked neck into broiler birds showed the superiority of the same over the normal feathered chicken in terms of growth rate, feed efficiency, dressing percentage and other important broiler traits (Singh *et al.,* 1996; Mathur and Horst, 1990; Ibe, 1993; Yunis and Cahaner, 1999; Ikeobi *et al.,* 1996).

Additionally, in tropical climates, if the Naked Neck trait (*Na*) is bred into broiler strains it has been shown to induce lower body temperature, increase body weight gain, better feed conversion ratios and carcass traits compared to normally feathered broilers (Ndri *et al*., 2006).

2.3.3 Ross 308 breed

The Ross is a breed of chickens raised specifically for meat production. This chicken breed is created from two main poultry breeds, the Ross chicken from Scotland and the Cobb chicken from the United Kingdom or the United States. It is noted for very fast growth rates, a high feed conversion ratio, and low levels of activity. Broilers often reach a harvest weight of 2-3 kg in only eight weeks. Ross chickens have white feathers and a yellowish skin and are also known for their broad chests, white feet, and a ferocious appetite. Broilers are favorable for meat production because they lack the typical "hair" which many breeds have that require slight superficial burning after plucking. Both male and female broilers are slaughtered for their meat.

CHAPTER 3

MATERIALS AND METHODS

3.1 Study site

This study was conducted at the Experimental farm of the University of Limpopo, in the Limpopo Province of South Africa. The farm is located about 10km north-west of the Turf loop campus of the University of Limpopo. Mean temperatures in winter (April to July) range between 10.1 and 28.4 °C and in summer (August to March) between 18 and 36 °C. The annual rainfall ranges between 446.8 mm and 468.4 mm.

3.2 Preparation of the houses

The hatchery and experimental houses were thoroughly cleaned with water, and disinfected with Jeyes fluid from NTK Company in Polokwane, South Africa, and then left to dry for seven days. The houses were left empty for one week after cleaning to break the life cycle of any disease causing organisms that were not killed by the disinfectant. The incubator and all the equipment such as drinkers, feeders and wire separators were cleaned thoroughly and disinfected. The footbath was thoroughly cleaned and a new disinfectant added daily.

3.3 Acquisition of materials and birds

All the required materials (medicines, vaccines and chemicals) for the experiment were purchased in advance, prior to the commencement of the study. Commercial starter and grower diets were purchased at NTK in Polokwane, South Africa. The Venda and Naked Neck chicken breeds used in this experiment were obtained as day old chicks from the University of Limpopo Experimental farm. The commercial Ross 308 chicks were bought from the Eagles Nest Hatchery in Tzaneen as day old chicks and were then reared to twenty-five weeks of age prior the commencement of the study.

3.4 Experimental design, treatments and procedures

Before commencing the experiments, permission from the Animal Ethics Committee of the Senate was obtained. The diallel cross has been defined as the group of all possible crosses among several genotypes (Griffing, 1956b). Two indigenous breeds, namely Venda (V) and Naked Neck (N) and one commercial breed, Ross 308 (R), were used in a 3x3 diallel mating system as shown in Table 1.

Table1. 3x3 Diallel Mating System

	Male			
Female		R	V	N
	R	RR	RV	RN
	V	VR	VV	VN
	N	NR	NV	NN

All possible crosses were made among the three breeds. Ten hens from each breed were assigned randomly to be mated with one rooster of each breed. The eggs were collected and recorded daily according to breeds and crossbreds. The eggs were weighed and hatched separately according to breeds and crossbreds. Accordingly, nine genetic groups of R x R, V x V, N x N, R x V, R x N, V x R, V x N, N x R and N x V chicks were obtained. The hatched chicks were wing banded until 8 weeks of age followed by leg banding to keep their breed and crossbred group identity. The chickens were kept together on a litter floor, in a semi-open house that has been partitioned according to their breeds and crossbreds. They were medicated similarly and were subjected to the same managerial, hygienic and climatic conditions. During the brooding and rearing periods, all chicks were fed *ad libitum* using standard commercial starter (21% CP and 3000 kcal ME/kg) from hatching time to 4 weeks of age, followed by a grower diet (18% CP and 2900 kcal ME/kg) to 13 weeks of age. Water was provided *ad libitum.* Artificial heat (32°C) using infrared lights and continuous light program was provided. Ventilation was controlled using curtain rails.

3.5 Data collection

The data used in the study was collected during an eight month period. Individual body weights of 180 chicks (20 chicks per cross) were measured using an electronic scale and recorded at the end of each one-week period from hatch to 13 weeks of age. Voluntary feed intake was measured by subtracting the difference in weight between the leftovers from that offered per week, and the difference was divided by the total number of birds per pen. Thus, daily feed intake per bird was calculated from these values.

Feed conversion ratio was calculated by dividing the average feed intake by the average weight gain in each pen. This was calculated as the amount of feed consumed divided by the total weight of live chickens plus those of dead or culled chickens minus initial weight of all the chickens in the pen. Mortalities were recorded as they occurred per pen. At 13 weeks of age all the remaining chickens per pen were weighed on an electronic weighing scale to obtain the live weight and then slaughtered.

3.6 Data analysis

Data was analyzed using the General Linear Model (GLM) procedure (SAS, 2008) according to the following linear model. Differences considered to be significant ($P \leq 0.05$) were compared by Duncan's Multiple Range test.

$$y_{ijkl} = \mu + G_i + H_j + Y_k + (GH)_{ij} + (HY)_{jk} + (GHY)_{ijk} + e_{ijkl}$$

where y_{ijkl} is the l^{th} observation on the bird hatched on the k^{th} month in the j^{th} hatch of the i^{th} breed group, μ = the overall mean, G_i = the fixed effect of the i^{th} breed group, H_j = the fixed effect of the j^{th} hatch, Y_k = the fixed effect of the k^{th} month, $(GH)_{ij}$ = the fixed effects of interaction between i^{th} breed group and k^{th} month, $(HY)_{jk}$ = the fixed effect of interaction between j^{th} hatch and k^{th} month, $(GHY)_{ijk}$ = the fixed effect of interaction among i^{th} breed group, j^{th} hatch and k^{th} month and e_{ijkl} = the random error.

Heterosis was calculated according to Fairfull (1990) by application of the following formula: H% = AB- (0.5AA+0.5BB)/ (0.5AA+0.5BB)* 100 where AA is represent the first purebred and BB represents the second breed. General combining ability which is defined as the average performance of a breed, strain or line in a cross combination was calculated. The values of general combining ability for purebreds (R, V, and N) were calculated as means (Falconer, 1988). Specific combining ability was calculated according the following formula: SCA = {(AB) + (BA)}/2 – {GCA (A) +GCA (B)}/2 where AB is a cross between breed A and B and BA is its reciprocal.

Estimates of direct additive genetic effects, maternal breed effects and individual direct heterosis were calculated according to Dickerson (1992) as follows:

1) Direct additive effect (G^I): {[MNxMN- MAxMA]- [MAxMN –MNxMA]}
2) Maternal breed effect (G^M): [MAxMN- MNxMA]
3) Direct heterosis (H^I):{MNxMA+ MAxMN]- [MNxMN+ MAxMA]}

CHAPTER 4

RESULTS

Body weights at different weeks of age differed significantly ($P \leq 0.05$) among the nine genetic groups. Least square means presented in Table 2 show that the indigenous Naked Neck (N) purebred had higher hatch weight in comparison with the other purebreds and crossbreds. However there was no significant difference ($P \leq 0.05$) between Naked Neck purebreds, R x N and V X N at hatch, with weights of 36.44, 34.59 and 34.64 grams respectively. Results also show that in all crosses where the Naked Neck was used as a dam, it yielded heavier body weights during the hatch period. For purebreds, the indigenous Venda (V) purebred was heavier (31.02g) than the commercial Ross 308 (R) purebred (30.81g) at hatch. However, there was no significant difference ($P \leq 0.05$) between the Ross purebred, Venda purebred, R x V, V x R and N x R for body weight at hatch ($P > 0.05$). The V x N had heavier weight (34.64g) when compared to R x N and R x V which had body weights of 34.59g and 32.49g respectively. With respect to reciprocals (V x R, N x R and N x V), there was no difference ($P > 0.05$) between the genetic groups at the hatch period.

The Ross purebred goes from being the one with the least body weight at hatch (30.81g) to being the one with the heaviest body weight (422.23g) on the third week. This highlights the fact that the Ross, a broiler, has greater genetic potential for growth than the indigenous breeds. In the third week, there was no difference ($P > 0.05$) in body weight between the Venda purebred, Naked Neck purebred, V x N and N x V. With respect to crosses, R x V had higher body weight (216.58g) in comparison with the R x N and V x N which had weights of 222.97 and 202.50 respectively. However, the R x V was not different from the N x R. With respect to reciprocals, the V x R had higher body weight (314.03g) in comparison with the N x R and N x V which had weights of 282.83g and 188.79g respectively.

There was no difference between the V x R and N x R from the third week to the ninth week. In week five, Ross 308 had the heaviest body weight in comparison with the other genetic groups. There was no difference between the Venda purebred, Naked Neck, R x N, V x N and N x V. In week eleven, Ross 308 still had the heaviest body weight when compared to the other genetic groups. There was no difference in body weight between the Venda purebreds, Naked Neck, V x N and N x V. The cross R x V and the reciprocal N x R were not different for body weight at week eleven to thirteen. The Naked Neck pure breed went from being the heaviest at hatch to being the lightest at thirteen weeks of age.

Table 2. Least square means for body weight (g) at different growing periods

Genetic groups	Hatch	3weeks	5weeks	7weeks	9weeks	11 weeks	13 weeks
Purebreds							
R x R	30.81^{d}	422.23^{a}	963.63^{a}	1473.06^{a}	2090.95^{a}	2759.00^{a}	3219.70^{a}
V x V	31.02^{d}	181.39^{e}	386.29^{d}	586.48^{d}	786.26^{d}	1023.70^{de}	1191.40^{e}
N x N	36.44^{a}	189.96^{de}	377.90^{d}	583.45^{d}	782.30^{d}	869.80^{e}	1175.60^{e}
Crosses							
R x V	32.49^{bcd}	261.58^{c}	556.97^{c}	924.43^{c}	1308.40^{c}	1691.50^{c}	2131.50^{c}
R x N	34.59^{ab}	222.97^{d}	417.96^{d}	685.43^{d}	897.77^{d}	1178.10^{d}	1518.10^{d}
V x N	34.64^{ab}	202.50^{e}	405.97^{d}	634.66^{d}	828.36^{d}	1044.50^{de}	1202.60^{e}
Reciprocals							
V x R	32.89^{bcd}	314.03^{b}	685.83^{b}	1141.87^{b}	1529.05^{b}	2014.30^{b}	2448.40^{b}
N x R	31.79^{cd}	282.83^{bc}	616.47^{bc}	1025.78^{bc}	1377.62^{bc}	1699.10^{c}	2002.60^{c}
N x V	34.00^{bc}	188.79^{de}	383.78^{d}	568.47^{d}	798.04^{d}	1021.00^{de}	1231.00^{e}

R = Ross 308; V =Venda; N= Naked Neck;
Means bearing similar letters in a column did not differ significantly (P<0.05)

Estimates of direct additive effects for body weight are given in Table 3. The estimates of direct additive effect were all positive for body weight for the crosses R x V. They were also positive for the R x N cross except during the hatch period. They were, however, negative for body weight for the cross V x N during most of the different ages except for 11 and 13 weeks of age. Percentages of the estimates of direct additive effects ranged from low (-63.16) to a high (2528.60) for body weights.

Table 3. Direct additive effects for body weight of chickens at different ages.

Genetic groups	Hatch	3weeks	5weeks	7weeks	9weeks	11 weeks	13 weeks
Crosses							
R x V	0.19	293.29	706.20	1104.02	1525.34	2057.8	2345.20
R x N	-8.43	292.13	784.24	1229.96	1788.5	2410.20	2528.60
V x N	-6.06	-22.28	-13.80	-63.16	-26.36	130.40	44.20

R=Ross; V=Venda; N= Naked neck

Maternal effects (ME) of body weight for the different breeds are shown in Table 4. Data showed that V x N cross achieved moderate positive estimates of ME for body weight at all the studied stages except the 13th week. The R x N cross showed the highest negative estimates of ME for body weight at all studied periods except for the hatch period. Similarly, R x V cross showed negative estimates of maternal effects for body weight at all the studied periods.

Table 4. Maternal effects for body weight of chickens at different ages.

Genetic groups	Hatch	3weeks	5weeks	7weeks	9weeks	11 weeks	13 weeks
Crosses							
R x V	-0.4	-52.46	-128.86	-217.44	-220.66	-322.8	-316.9
R x N	2.8	-59.86	-198.52	-340.36	-479.86	-521.0	-484.5
V x N	0.64	13.72	22.2	66.2	30.32	23.5	-28.4

R=Ross; V=Venda; N= Naked neck

Heterosis estimates for body weight are presented in Figure 1. Results revealed that V x N had positive heterosis at all ages from hatch to 13 weeks of age. R x V and R x N exhibited negative heterosis at all ages except hatch. With respect to reciprocals, the V x R had positive heterosis at all ages while the N x R exhibited negative heterosis at all ages of measurement. N x V showed positive heterosis at all ages except the 7th week.

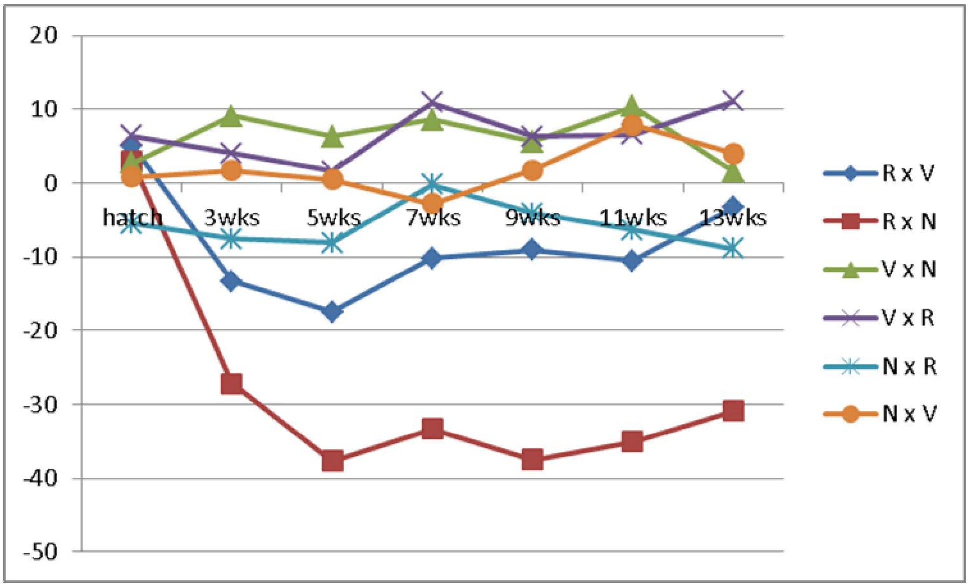

Figure 1. Heterosis (%) of body weight for crosses and reciprocal crosses

The mean squares for general combining ability (GCA), specific combining ability (SCA) and reciprocal effects (RE) is presented in Table 6. The GCA was significant for all periods from hatch to 13 weeks of age. SCA and RE were also significant for all age intervals except for hatch.

Table 5. Mean squares at the different ages of measurement

Parameters	Hatch	3weeks	5weeks	7weeks	9weeks	11 weeks	13 weeks
GCA(3)	11.53*	21428.71*	131082.28*	347915.89*	727244.04*	1365497.90*	1852840.20*
SCA(3)	1.43	1112.97*	9404.15*	12220.08*	30315.39*	59317.57*	81519.55*
RE(3)	1.05	1087.02*	9416.78*	27916.24*	54178.61*	62718.22*	56004.41*

GCA= General combining ability; SCA= Specific combining ability
RE= Reciprocal effects; *= P<0.05

GCA estimates were all positive for all the weight measurements in Ross 308 except for the hatch period while, on the other hand, they were all negative for all the weight measurements in Naked Neck except for hatch (Table 7). GCA estimates were all negative for all the weight measurements in the Venda. SCA estimates were all negative for all the weight measurements in the Rx N while they were all positive for V x N for all weight measurements. In the R x V, all SCA estimates were positive for all the weight measurements except for the 3rd and 5th week. RE estimates were negative for all weight measurements for R x V. They were also negative for all the weight measurements for R x N except hatch. RE estimates were positive for all weight measurements for N x V except the 13th week.

Table 6. Crossbreeding genetic parameters for body weight at different ages of measurement

Parameters	Hatch	3weeks	5weeks	7weeks	9weeks	11 weeks	13 weeks
GCA							
g^R	-1.07	68.82	169.29	275.88	398.82	539.90	633.03
g^V	-0.50	-30.02	-65.88	-107.84	-155.66	-175.26	-225.62
g^N	1.57	-38.80	-103.41	-168.03	-243.16	-364.64	-407.41
SCA							
s^{RV}	1.03	-2.63	-15.41	16.90	13.80	9.90	90.90
s^{RN}	-0.43	-28.75	-82.07	-100.50	-157.20	-215.00	-256.90
s^{VN}	0.10	12.83	30.76	29.20	50.30	94.30	58.10
RE							
r^{RV}	-0.20	-26.22	-64.43	-108.70	-110.30	-161.40	-158.00
r^{RN}	1.20	-29.93	-99.25	-170.20	-262.40	-260.50	-242.00
r^{VN}	0.30	6.85	11.09	33.10	15.20	11.80	-14.20

g= general combing ability; s= Specific combining ability; r= Reciprocal effects;
R= Ross; V=Venda; N= Naked neck

CHAPTER 5

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

Body weights

As shown in Table 2, body weight increased with increase in age for all the different genetic groups. Ross 308, a commercial broiler chicken, went from being the lightest (30.81g) at hatch to being the heaviest (3219.7g) at 13 weeks. On the other hand Naked Neck chicken, an indigenous breed, went from being the heaviest (36.44g) at hatch to being the lightest (1175.6) at 13 weeks of age. These results are in agreement with those reported by Norris *et al*., (2007) who showed that the Naked Neck chicken breed had a higher growth rate, reached maturity earlier but had a lighter mature weight than the Venda breed. They also showed that the Venda breed was late maturing but had a heavier weight at maturity in comparison with the Naked Neck chicken breed. Another study (unpublished) carried out at the Animal Improvement Institute of the Agricultural Research Council (ARC) showed that the Venda breed attained sexual maturity at 143 days of age, reaching a weight of 2.01 kg at 20 weeks, while the Naked neck breed reached a weight of 1.95 kg at 20 weeks and attained sexual maturity at 155 days. Body weights recorded by Mohammed *et al.* (2005) for crossbreds obtained from crossing Rhode Island Red, Bovans, Egyptian Fayoumi, Baladi, Bare-neck and Betwil were lower than those obtained in our study. Body weights in crosses revealed that V x R recorded higher body weight than its reciprocal R x V at all weeks of measurement showing that the Venda as a male parent recorded better body weight in the crossbred than as the female parent. Similarly, N x R recorded higher body weight than its reciprocal R x N at all weeks of measurement showing that the Naked Neck as a male parent recorded better body weight in the crossbred than as the female parent. V x N had heavier body weights than N x V at all weeks of measurement except for the 13^{th} week.

Direct additive effects

Results in Table 3 show that direct additive effects for R x V and R x N were mostly positive while they were mostly negative for the cross V x N. In crossing of Saudi chickens with White Leghorn, Khalil *et al*., (1999) found that percentages of direct additive effect ranged from 4.9 to 10.2% for body weights and from 3.5 to 14.6% for daily gains in weight. These results indicate that crossing of Venda and Naked Neck has a negative effect on direct additive effect for body weight. Thus, the Ross 308 breed could be used as a sire in crossbreeding programs in South Africa to get chicks with heavier weights. El-Sisy (2001) found that Matrouh strain favored as sires when crossed with Matrouh and Mandarah strains. Francesch *et al* (1997) and Koerhuis *et al* (1997) reported that direct additive effects were important for egg traits in crosses obtained from crossing Saudi chickens with White Leghorn.

Maternal effects

Estimates of maternal breed effects for body weight are given in Table 4. Most of these estimates were negative. Similarly, Iraqi et al., (2011) reported estimates of maternal breed effect to be mostly negative for body weight ranging -5.76% to 0.06% for crosses obtained from crossing the Matrouh and Indhas chicken breeds. On crossing Saudi chickens with White Leghorn, Khalil *et al.,* (1999) found that maternal breed effects were in favor of White Leghorn, where the estimates ranged from -7.2 to 1.0% for body weight and from 6.0 to -12.1% for daily gains. Iraqi *et al.,* (2002) found negative maternal breed effects on body weight traits and favored Matrouh dams when crossed Mandarah and Matrouh chickens. Saadey *et al.,* (2008) reported positive estimates for maternal breed effects for body weight for crosses obtained from crossing the Sanai and the White Leghorn. The negative estimates of maternal breed effect in this study indicate that the chicks mothered by Ross 308 breed are preferred for body weight compared to chicks mothered by Venda and Naked Neck breed. Thus, it is recommended to use Ross 308 dams in crossbreeding programs in South Africa to improve body weight of indigenous chicken breeds.

Heterosis

Based on single cross, heterotic effects for body weights in Table 5 were mostly positive and ranged from -37.69 to 11.01% during different age intervals up to 13 weeks. Iraqi *et al*., (2011) found that heterosis for body weight ranged from -5.24% to 9.05 % when crossing occurred between Matrouh and Inshas chicken breeds, although results obtained in this study yielded lower heterotic percentage. Results of this study revealed that V x N had positive but low heterosis at all ages of measurement in comparison to its reciprocal N x V, which also had positive but low heterosis for all ages of measurement except 7 weeks. Similarly V x R had positive low heterosis for body weight at the different weeks of age when compared to its reciprocal R x V which had negative heterosis for body weight at all weeks of measurement except for hatch. This indicates that Venda sires and Ross 308 dams as well as Venda sires and Naked Neck dams gave the highest heterosis for growth traits. These results may be an encouraging factor for the poultry breeders in South Africa to cross these two breeds (Venda male and Ross female), also to the indigenous breeds (Venda male and Naked Neck female) to get hybrid vigor in growth traits. Most reviewed studies showed that body weights of crossbred chickens at different ages were associated with positive heterotic effects for growth traits (Sabri and Hataba, 1994; Khalil *et al.,*1999; Sabri *et al*., 2000). Sabra (1990) found that crossbreds obtained from crossing between local breeds (Silver Montazah and Dandarawi) have positive and high magnitude of heterosis body weights at different ages. Iraqi *et al.,* (2002) indicated that heterosis estimates were generally positive and high for body weights of crossbreds obtained from crossing between Mandarah (MN) and Matrouh (MA) strains. Saadey *et al*., (2008) found that crossbreds obtained from crossing between Sinai and White Leghorn had positive and high heterosis (ranging from -7.9% to 30.1%) at all ages, except at 2 and 3 months of age. As shown in Table 4, crosses between R x V and R x N and it reciprocal N x R resulted in negatively moderate heterotic percentage except for hatch. The Ross sires and Naked Neck dams gave the highest negative heterotic effect ranging from -37.69 to 2.86% from hatch up to 13 weeks of age. Therefore a cross of this nature must be avoided in any program of crossing. Saadey *et al*., (2008) found negative moderate heterosis for body weight from crossing White Leghorn (WL) with Fayoumi (F) and Rhode Island Red (RIR) with Fayoumi (F) (ranging between -52.70% and -5.1%, -35.3% and -3.90% respectively) although results obtained in this study yielded higher heterotic percentage. Reddy *et al*., (1999) observed heterosis in either direction among different single crosses of White Leghorn strains. Utilizing three strains of White Leghorn (IWH, IWI and IWK), Malik *et al.,* (2005) reported that strain cross pullets were lighter than purebreds at 20 weeks of age while Singh and Singh (2005) reported that crossbreds were superior than purebreds in body weights at 20 and 40 weeks of age.

GCA

General combining ability was a significant source of variability (Table 5) among purebred groups (P≤0.05) on body weights at the studied time periods. This significance indicated the importance of additive components and refers to the way of selection applicable to improve body weight in juvenile stages. The result is supported by the work of Mekki *et al*., (2005) who found general combining ability estimates more important and of higher value than specific combining ability in determining body weight at maturity of exotic cockerels. This means, the exotics had lower gene variation for body weight (Adebambo *et al.,* 2010). Sharma *et al*., (1992) reported significant GCA, SCA, reciprocal effects for body weight using three strains of White Leghorn while Singh *et al*., (1998) reported significant SCA and reciprocal effects for body weight. Laxmi *et al*., (2009) also reported significant (P≤0.01) GCA, SCA and RE for body weight at 20 weeks in White Leghorn, while only GCA and SCA effects were significant (P≤0.01) for body weight at 40 weeks. Significant GCA, SCA and RE were reported by Wolf and Knizetova (1994) for early body weights in lines of White Pekin ducks. GCA, SCA and sex-linked effect for juvenile body weight was reported by Nath *et al*., (2007) in meat type chicken. Significant GCA and SCA for 10^{th} week body weight in chickens was also reported by Aggarwal *et al*. (1979).

Results showed that Ross 308 (R) breed the highest (best) positive effect of general combining ability (Table 6) on all ages of measurement except for hatch. Mekki et al., (2005) also found that the exotic commercial birds had higher GCA values than the indigenous. Figures of Naked Neck as an indigenous breed were highly negative for general combining ability at all the weeks of measurement except for hatch.

SCA

Estimates of SCA, given in Table 6, indicate that V x N gave positive estimates of SCA for body weight during the different weeks of measurement. On the other hand, R x N had high negative estimates of SCA for body weight at all the ages of measurement. Similar results were reported by Saadey *et al*., (2008) in a cross of the Fayoumi and

White Leghorn. R x V also had positive SCA estimates for body weight during the different weeks of measurement, except week 3 and 5.

Reciprocal effect or sex linkage

Reciprocal effects are the deviations between the crosses of two parental strains or breeds in which their roles as male of female parents are reversed. Gowe and Fairfull (1982) and Fairfull *et al.,* (1983) reported important reciprocal effects for most traits of commercial significance in white egg stocks of chickens. Sharma *et al*., (1992) reported the significance of reciprocal effects for age at first egg using three strains of White Leghorn. Cook *et al.,* (1972) described that difference among male progeny of reciprocal crosses to be attributable to maternal effects and not to sex-linkage, because the homogametic males in reciprocal crosses have comparable sex chromosomes. Hence, for Cook *et al*., (1972), reciprocals test the possibility that sex-linkage is operative when significant differences are found among female progeny because each female receives its sex chromosome from its sire. Sabri *et al*., (2000) reported that the magnitude of sex linkage effects is expected to be influenced by the breeds implicated in the crossbreeding scheme. Reciprocal effect was a significant source of variability ($P \leq 0.05$) for body weight among the crossbred groups during the different weeks of measurement except hatch (Table 7). Constants of sex linkage effects for different breed crosses in Table 3 were positive for N x V at all weeks of measurement except for the 13th week. RE effects were all negative for the cross V x R at all weeks of measurement. For the cross N x R, RE effects were also negative for all weeks of measurement except at hatch.

Conclusion

Results of heterosis estimates indicated that crossing between the Venda sires and Ross 308 dams as well as between the Venda sires and Naked Neck dams gave the highest heterotic effect for body weight. It may be important to consider developing a composite chicken breed based on the estimates of heterotic, GCA and SCA. The study has shown the importance of considering the estimates of heterotic effects, GCA, SCA, maternal breed effect and sex linkage before planning any crossbreeding program.

CHAPTER 6

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