CHAPTER 1

Introduction and Literature Review

1.1 Introduction

1.1.1 Background

Chicken rearing is one of the most suitable activities to improve the livelihoods of the poor due to the advantages it has in terms of the small amount of capital required and the relative ease to set-up such a production system in the rural communities (Ogunlade and Adebayo, 2009; Ja'afa-Furo and Gabdo, 2010). Amos (2006) also indicated that a small-scale poultry enterprise has a quick monetary turnover. Currently, the population of chickens in Lesotho is composed of the exotic commercial (broilers and layers) and the indigenous free-range chickens. Indigenous chickens remain predominant in the rural areas regardless of the introduction of exotic birds. Village (indigenous) chicken production systems are based on scavenging chickens which is supplemented on maize or sorghum grains and sometimes fed on table scraps (Kitalyi, 1998). Halima (2007) also reported that the majority of farmers in North-West Ethopia practice supplementary feeding which is depended on the crop grown in the area as well as the season. The similar sentiments were shared by Moges *et al.* (2010) who indicated that the majority of chicken owners Ethopia use grains and kitchen leftovers as the major kinds of feedstuffs to supplement.

Indigenous chickens are kept for meat, eggs, income and socio-cultural roles (Ssewannyana *et al.,* 2001 and Halima, 2007). Poultry meat is preferred over most types of meat since it is the second most consumed meat, globally, having overtaken beef-veal in 1996 (William, 1999; European Commision, 2006). Magdelaine *et al.* (2008) also reported that poultry meat has become a mass consumer product throughout the world regardless of the region and the level of development. The human consumption of poultry meat is well attested (Ogunlade and Adebayo, 2009). Poultry is clearly the most dynamic livestock species in terms of gaining a market share (highly demanded); adapting technology for breeding, feeding, production, processing, and marketing; and being in a position to benefit from major consumer food trends as elaborated by William (1999). Despite the important role of chickens, indigenous chickens are generally considered to have poor genetic potential for both egg and meat production. Indigenous chickens have low output expressed in terms of low egg production, small egg size, and slow growth rates as well as poor survival of chicks (Aganga *et al.,* 2003). Due to their low productivity, the Department of Livestock Services of the Ministry of Agriculture in Lesotho has introduced Koekoek chickens in order to improve locally adapted chickens for household poultry production. Their feed requirements for maintenance are higher and if not given additional feed to take account of this, they will lose body condition rapidly. In order to obtain good results in terms of production of Koekoek chickens in Lesotho, the focus should be on delivering adequate management to address the needs of this specific type of bird.

Strategies to improve poultry breeds suitable for small scale farmers is an important focal point in developing countries and this is why the improvement of management strategies of Koekoek chickens in Lesotho is crucial. Since the introduction of Koekoek chickens in Lesotho, no scientific research has been done on the productive and reproductive performance of Koekoek chickens under local conditions.

There is little or no documentation on the nutritional management of Koekoek chickens in Lesotho at both rearing and laying periods based on research findings, which can serve as guidelines for farmers. The main focus of this study was therefore to investigate the productive and reproductive efficiency of this locally adaptable genetic resource under different feeding regimes in different seasons of the year.

1.1.2 Justification

Lesotho is faced with a decrease in food production and as a result, the majority of the people in the rural villages live under the poverty line. The prevailing drought conditions in southern Africa have severely affected Lesotho during the last decade to a point that 400,000 to 500,000 people required food assistance in the 2007/2008 season (UNICEF, 2008). This situation is aggravated by the escalating prevalence of HIV/AIDS. Lesotho has the third highest prevalence rate in the world with 23.2 % of adults aged 15 to 49 years infected, and peaking at over 43 % in women aged 35 to 39 years (UNICEF, 2008). The problem of poverty is taken so seriously that the Prime Minister of Lesotho in 2007 has declared Lesotho as being under a state of emergency due to poverty. In an attempt to address the problem of poverty, the Ministry of Agriculture through the Department of Livestock Services started to promote the production of short cycle animals as source of animal proteins. Koekoek chickens fall within this category of short cycle animals that the Ministry of Agriculture is promoting.

Under prevailing circumstances, it was important to investigate the feeding level that would result in improved reproductive and production performance of Koekoek chickens in Lesotho for sustainable egg and meat production in different seasons in the rural areas.

1.1.3 Objectives

1.1.3.1 Overall Objective

To investigate the effect of feed restriction and season on the productive and reproductive characteristics of Koekoek chickens under small scale farming conditions in Lesotho.

1.1.3.2 Specific Objectives

a) To determine the effect of feeding (restricted versus full-fed) and season on the weight gain of chickens from 8 to 32 weeks of age.
b) To determine the effect of feeding and season on the feed intake and feed conversion efficiency of the chickens.
c) To determine the effect of feeding and season on the number of days to reach puberty.
d) To determine the effect of feeding and season on oviduct and ovary weights.
e) To determine the effect of feeding and season on laying percentage.
f) To determine the effect of feeding and season on egg size and egg abnormalities.
g) To determine the effect of feeding and season on hatching percentage.
h) To determine the effect of feeding and season on the mortality rate of chicken.
i) To determine the effect of feeding and season on age at which chickens reach different stages of egg production.
j) To determine the effect of feeding and season on carcass characteristics and carcass chemical composition.

1.1.4 Impact of the expected results

The information obtained from this research will provide vital information on the full rearing, production and reproductive potential of Koekoek chickens under different feeding management conditions in Lesotho. The results of the present study will assist small-scale chicken farmers in Lesotho to adopt the feeding procedures that would enhance profitability in different seasons of the year.

1.2 Literature Review

1.2.1 Introduction

The chicken industry is one of the most dynamic components of the world agribusiness trade (Oyedeji *et al.,* 2007). African livestock population statistics for 1995 indicated that poultry was the most numerous species of farm animals. More than 80 percent of poultry rearing is found in the rural areas and this contributes substantially to the annual egg and meat production (Aganga *et al.,* 2003). In the rural areas, women and children play an important role in the management of chickens as stated by Gueye (1998). In a survey study that was done in Ethopia, Halima (2007) also reported that women took a larger part in chicken rearing compared to men. Aganga *et al.* (2003) reported that poultry keeping in the rural villages is a sideline occupation because of the other farming activities farmers are engaged in. Any attempt to improve egg production includes the manipulation of feeding regimes and diets. Faulty feed and feeding methods are sometimes responsible for reduced egg production, small egg size, reduced shell quality, reduced growth, excess fat storage, overfeeding and high mortality (Oyedeji *et al.,* 2007). Among other problems, Halima (2007) identified poor nutrition as one of the major constraints in chicken production.

Bruggeman *et al*. (1999) reported that the management practice of broiler breeder females includes the restriction of feed allowance during both rearing and breeding to limit body weight gains, reduce the incidence of obesity and improve egg production. Despite the fact that chickens subjected to restricted feeding reaching sexual maturity later, the advantages of restricted feeding outweigh this delay in the onset of laying. These advantages include an increased egg production, increased fertility, hatchability, egg quality, reduced number of double-yolked or malformed eggs and reduced mortality (Robinson *et al.,* 1978 and Bruggeman *et al.,* 1999).

1.2.1.1 Restricted versus unrestricted feeding in chickens

Unrestricted feeding in laying hens leads to over-consumption of energy that enhances excessive accumulation of abdominal fat predisposing layers to heat stress. *Ad libitum* feeding also results in high mortality in laying hens (Oyedeji *et al.,* 2007). If breeding flocks were fed *ad libitum*, they would become obese and suffer thermal discomfort, a high incidence of lameness and high mortality due to skeletal disorders (Savory and Maros, 1993). According to Crounch *et al.* (2002a), restricted feeding in turkeys at 30 weeks produced similar total number of eggs and increased poultry production compared to hens fed *ad libitum*. Klein-Hessling (1994) also found that physical feed restriction significantly affects tissue growth on an absolute weight but not on a relative percentage basis. Crounch *et al.* (2002a) revealed that quantitative feed restriction reduces body weight and feed consumption without reducing egg production.

In all situations, feed represents the major cost ranging between 65-80% of production costs of poultry meat and eggs (Kabir *et al.,* 2007; Oyedeji *et al.,* 2007). Apart from reducing the rearing costs, restricted feeding in the rearing period often yields benefits in the laying period concerning egg size, more sustained laying ability and lower mortality (Robinson *et al.,* 1978). Many techniques have been proposed for restricting nutrient intake during the rearing phase. Such techniques involve alternating periods of access to feeds with periods of no access and the technique can be attributed to reduced feeding quantity on a daily basis (Robinson *et al.,* 1978). Reports seem to disagree on the best timing of restricted feeding. According to Bruggeman *et al*. (1999), some researchers concluded that feed restriction should cover almost the entire of rearing and breeding period while others suggested that feed restriction should only be necessary during the rearing phase.

1.2.1.2 Seasonal effects on the performance of chickens

The effects of season on the performance of chickens have been studied in some detail and previous studies indicate significant differences in most productive and reproductive traits from one season to another. High temperatures during the summer season reduce the feed intake drastically and hence the reduction in body weight and body weight gain (Akyuz, 2009). This was confirmed by Yalcin et al. (1997a) who stated heat stress as a source of reduced body weight gain in poultry. The high temperature has a negative effect on egg production, egg weight and egg quality (Garces *et al.,* 2001; Mashaly *et al.,* 2004). The weights of reproductive organs (ovaries and oviducts) were found to be low in chickens that were exposed to high environmental temperatures (Chen *et al.,* 2007; Rozenboim *et al.,* 2007). The development of the combs and wattles responds positively to the low winter environmental temperatures (Lamoreux, 1943). Eggs from chickens that are raised in summer had a low hatching percentage and fertility compared to the ones kept in winter (Ozcelik *et al.,* 2006). Temperature significantly affects the carcass parameters in chickens. Aksit *et al.* (2006) reported a reduced breast weight in chickens that were subjected to high temperatures. The weights of the liver, gizzard and intestines were lower when it was hot compared to that recorded during cool conditions

(Rosa *et al.,* 2007; Rajini *et al.,* 2009). Birds that were kept in summer accumulate more abdominal fat (Blahova *et al.*, 2007). The chemical composition of the birds was not significantly affected by the season except the crude fat content, which seemed to have a positive correlation with the temperature (Bianchi *et al.,* 2007; Rosa *et al.,* 2007).

1.2.1.3 Description of Koekoek chickens

The Potchefstroom Koekoek is a South African registered chicken breed developed in the 1950's at the Potchefstroom Agrcultural College by the late Chris Marais. It is considered as a composite breed of White leghorn, Black Austrorp and Bared Plymouth Rock (Fourie and Grobbelaar, 2003). Grobbelaar and Molalakgotla (2010) reported the meat of Koekoek chicken as being popular and mostly preferred by local communities over that of commercial broiler breeders. The carcass is attractive with deep yellow coloured skin. The breed has characteristic black and white speckled colour patterns, also described as barred, which is present in about nine poultry breeds hence why the chicks are sexable soon after hatching (Nthimo, 2004; Van Marle-Köster and Nel, 2000). Joubert (1996) pointed out that Koekoek chicken is considered as a heavy breed with an average mature weight of 3-4kg and 2.5-3.5kg for cocks and hens respectively. Koekoek chickens are known to have a large body size and higher egg production compared to indigenous breeds (Joubert, 1996; Van Marle-Köster and Casey, 2001). Van Marle-Köster and Casey (2001) reported the total egg production of 204 eggs in a 51 weeks laying period. The birds attain their first oviposition at 130 days with an average egg weight of 55.7g (Nthimo, 2004).

Figure 2.1: The example of Koekoek chickens used in the study

1.2.3 Growth performance of chickens

1.2.3.1 Effect of restricted feeding on body weight performance

The research findings of Van Marle-Köster and Casey (2001) indicate Koekoek chickens weight of 1114 grams at 11 weeks and the average hen weight of 2100 grams under *ad libitum* feeding. Chickens fed *ad libitum* gain significantly more weight than those raised on restricted feeding. The use of quantitative feed restriction during the growing phase significantly ($p<0.05$) affected the weight of birds at 20 weeks of age (Sekoni *et al.,* 2002). According to Crounch (2002a) physical feed restriction significantly affects the tissue growth on an absolute weight but not on a relatively basis in turkeys. Robinson *et al.* (1978) also reported that commercial broiler chickens on restricted feeding were significantly lighter in weight as compared to birds raised on *ad libitum* feeding. Tumova *et al.* (2002) reported that weight gain in turkeys subjected to restrict feeding was 20 to 60 percent higher than in turkeys fed *ad libitum*. Early feed restriction results in accelerated growth in the second half of the growth period several weeks after restriction (Tumova *et al.*, 2002).

The differences in weight between the three different strains of egg type pullets occurred when birds were fed *ad libitum* during the rearing phase. These birds were also heavier than all restricted birds (Abu-Serewa, 1979). During the rearing, excess feed showed up excess body weight when feed allocations are grossly excessive, females will deposit fat in the abdominal fat pad depot. In some cases, overweight birds may reach sexual maturity earlier than normal weight counterparts (Robinson *et al.*, 1978) may. Controlled feeding programmes are designed to control the growth of young pullets in order to reach specific targets in weight and age in preparation for egg production. Body weight has an important role in the development of the hen and the emphasis should be on an undisturbed growth rate during the first eight weeks of a hen's life (Rodriquez *et al.*, 2005). Summers (1991) elaborated that there is a relationship between the stage of sexual development and body weight. The report further indicated a little weight gain in hens after the first oviposition as the bird would have reached its mature weight at the the beginning of the laying phase. The type of feeding programme employed will influence it. Breeder pullets must obtain a minimum body weight to initiate egg production, although the full-fed birds may obtain this body weight by 14 or 15 weeks, they do not begin laying until they are 24 or 25 weeks old, suggesting that an age threshold must be achieved (Melnychuk *et al.*, 2004).

The physical characteristics such as comb development can be used in determining the first stage of sexual maturity (Summers, 2008). The birds at this stage are beginning to change from juveniles to adults. This initial stage of the onset of sexual development may be a matter of body size or composition. Body weight at this stage can be considered to be that of a mature pullet (Leeson and Summers, 1983). During this transformation period, major physiological changes take place especially in the oviduct and liver as the pullet gets ready to start her egg laying cycle (Summers, 1991). Summers (1991) also indicated that during this transformation time birds would increase body weight by 200 to 300 grams. The feeding programme has a greater effect on body weight at maturity than the timing of photostimulation. Under *ad libitum* conditions, some strains were significantly heavier at sexual maturity. However, under a common feed restriction programme, laying was initiated at a similar weight in all strains (Melnychuk *et al.*, 2004).

According to Lopez and Leeson (1994), broiler breeder hens have the potential to become overweight and this situation is associated with low egg production and low fertility. Lopez and Leeson (1994) further more reported that there are different methods of controlling body weight in hens with the aim of delaying sexual maturity of birds raised under natural conditions. Lee (1981) concluded that feed restriction delays maturity and reported a correlation between the degree of feed restriction and delay in sexual maturity. There was a direct relationship between the degree of feed restriction and the length of the delay in the onset of lay. Pullets on the low body weight profile entered lay 7 days later than hens on the high body weight profile (Renema *et al*. 2009b). The findings of Renema *et al*. (2009b) revealed that the sexual maturation profile of the low treatment started to rise later than for the other groups but exhibited the steepest rise once it started. Pullets on the *ad libitum* feeding regime reached sexual maturity 25.3 days after photostimulation compared to 38.9 days for restricted fed birds. About 27% of birds in both feeding regimes came into production at a similar rate. However, 58% of *ad libitum* fed birds reached sexual maturity in the subsequent 6 days compared to 6 percent of restricted fed birds (Renema *et al.*, 1999a). The study by Lopez and Leeson (1994) suggests 2.3 to 2.7 kg as the minimum body weight for onset of commercial egg production. Pearson and Herron (1980) stated that body weight gain has been related to excessive intake of energy rather than protein intake. A body weight gain of 1.1 kg from 21 to 36 weeks of age has been associated with optimum production (Lopez and Leeson, 1994).

Growth of male and female quail was significantly reduced due to restricted feeding (Hassan *et al.*, 2003). Hassan *et al*. (2003) also pointed out that unlike in chickens, quail may be less adversely affected by feed restriction. Robinson *et al.* (1978) reported that at week 32, birds that were under *ad libitum* feeding were heavier than those under feed restriction with a mean difference of 6%. From week 32 onwards, highly significant differences in body weight occurred between *ad libitum* and restricted fed birds reflecting a positive correlation between weight gain and feed intake in the laying period. The reason for underweight pullets is usually due to underfeeding, caused by feed restriction as a management procedure, by low feed intake resulting from high environmental temperatures, or by pullets stimulated into production using a particular photoperiod pattern, at too young a physiological age (summers, 1991). Full-fed chickens are dependent on reaching a critical age to initiate sexual development as opposed to feed-restricted birds that are dependent on reaching a critical body weight and body composition threshold (Melnychuk *et al.*, 2004).

According to the findings of Sandilands *et al*. (2005) the desired growth curve of broiler breeders to 20 weeks can be achieved via an *ad libitum* feeding regime, meaning that quantitative feed restriction as presently practiced in chickens, may not be required to avoid the negative health, welfare and reproduction consequences that are associated with fast growth. In broiler breeder flocks reared as a group, aggressive birds are found to grow larger and more quickly whereas passive birds remain smaller and under more severe restriction condition due to reduced feed access and this suggests that eating behavior could also contribute to the variability in flock body weight (Renema *et al.*, 1999a). Sun *et al.* (2006) concluded that body weight was increased with age in both *ad libitum* fed chickens and feed-restricted chickens.

1.2.2.2 Effect of season on body weight performance

It has been reported that high temperatures affect the growth rate of poultry in a negative manner and this reduction is more evident in birds that have rapid growth (Reem and Cahaner, 1999). Yalcin *et al.* (1997a) listed climate as the chief contributor in limiting the production of broilers in terms of body weight and body weight gain. A reduced body weight and body weight gain of about 23% and 33.5% respectively at seven weeks of age on commercial broilers were observed due to the natural heat stress in summer (Yalcin *et al*., (1997b).

Yalcin *et al*. (1997b) further more explained that chickens would suffer because their feather coverage prevents internal heat dissipation, which will ultimately result in increased body temperature. Yalcin et al. (1997b) also reported a higher body weight in naked neck chickens in the warm summer climate compared to spring.

Deeb and Cahaner (1999) found a negative effect of elevated temperature on growth rate and meat yield in naked neck broilers. In another study weight loss correlated positively with feed conversion in broiler chickens (Deeb and Cahaner, 2001a). The findings by Aksit *et al*. (2006) also demonstrated a significantly reduced body weight in broiler chickens at 4 to 7 weeks of age at 34 ^{0}C. Plavnik and Yahav (1998) concluded that the body weight of chickens declined progressively with an increase in temperature.

In a study done on turkeys it was also found that a higher temperature resulted in lower body weight gain. Overall, the body weight of turkeys that were raised under high temperatures was 19.7% lower compared to those reared under low temperatures (Veldcamp *et al.*, 2005). Veldcamp *et al.* (2000) showed that the weight gains were not influenced by either diet or the interaction between temperature and diet. Lu *et al.* (2007) compared Arbor Acres chickens and local Beijing You chickens under different ambient temperature levels. In that experiment it was established that the final body weight and body weight gain of heat exposed birds (34^{0}C) performed significantly less than those kept at a temperature of about 21^{0}C in case of commercial Arbor Acres chickens. With respect to local Beijing You chickens, Lu *et al*. (2007) concluded that there was no difference between chickens exposed to different levels of temperatures with regard to final body weight and body weight gain. The broiler chickens that were kept at 32^{0}C and fed *ad libitum* resulted in 500 grams less than the chickens that were reared at an ambient temperature of 22^{0}C (Bonnet *et al*. 1997).

1.2.3 Egg production

1.2.3.1 Effect of restricted feeding on egg production

The advantages of restricted feeding over full feeding during the rearing period are usually considered to be greater the longer the laying flock is kept (Robinson *et al.*, 1978). Robinson *et al.* (1978) also reported that it appears that the level of feed restriction imposed in the laying period is more critical than that imposed in the rearing period. Regardless of the length of the laying period, feed restriction in the rearing period consistently increased the hen-house production of laying periods. Bruggeman *et al.* (1999) showed that generally chickens restricted during the rearing period (7-15 weeks) had the highest average weekly egg production whereas chickens fed on *ad libitum* intake throughout the periods showed the lowest egg production per week. The study conducted by Sekoni *et al*. (2002) indicated that quantitative feed restriction did not have any significant effect on hen day egg production. Feed restriction delays onset of egg production by approximately two days as compared to control (full fed) in quail production (Hassan *et al.*, 2003). Early feed restriction does not significantly affect first egg weight and the number of eggs produced from 6 to 13 weeks of age in quail as reported by Hassan *et al.* (2003).

The report by Crounch *et al.* (2002b) indicated that restricted feeding reduced body weight and total feed consumption without reducing egg production. Feed restriction during egg production resulted in significantly higher egg production with a lower incidence of abnormal eggs. Feed restriction has significant effects on circulating levels of key metabolic hormones before the onset of egg production since pullets that are on restricted feeding for 21 weeks before being switched to *ad libitum* feeding exhibited dramatic changes in the levels of insulin, glucagons and T_3 (Richards *et al.*, 2003). According to Crounch *et al*., (2002a) hens that received the restricted feeding treatments (from 3 to 24 weeks and 3 to 16 weeks) had a significantly higher peak egg production than hens on *ad libitum* feeding from 3 to 24 weeks and 3 to 16 weeks. Hens that were under feed restriction from 3 to 16 weeks produce significantly more eggs from 1 to 5 weeks of lay than those fed without restriction (Crounch *et al.*, 2002a). Peak egg production did not differ among groups. It took restricted fed chickens slightly longer to reach peak than full-fed chickens. The *ad libitum* fed birds reached the maximum rate (84.5%) of lay at 28 weeks of age and the birds under restricted feeding attained their peak egg production (85%) at the age of 35 weeks (Onagbesan *et al.*, 2006). Onagbesan *et al.* (2006) more further recorded significant differences in the laying percentages after peak lay.

Melnychuk *et al.* (2004) showed that chickens on a moderate increase in feed intake had 10 more eggs than those on s generous feed increase. The feeding programme during rearing especially around photo-stimulation can have significant effects on subsequent egg production (Melnychuk *et al.*, 2004). During the three periods of lay, egg production level in the *ad libitum* fed birds was less than that of restricted fed birds (Onagbesan *et al.*, 2006). The findings by Robinson *et al*. (2007a) illustrated that varying feed intake before, during, and immediately after sexual maturation can result in a difference of one extra large yellow follicle, with a concomitant 10 egg reduction. The same findings further more reflected that even small degrees of over or under feeding might negatively affect egg and chick production. However, Leeson *et al.* (1996) suggested that laying performance is only marginally affected by diets given to hens prior to maturity.

1.2.3.2 Effect of season on egg production

According to Garces *et al.* (2001), high environmental temperatures limit the performance of chickens irrespective of whether they are kept intensively or extensively. The results reported by Garces *et al.* (2001) indicate that climatic environment is one of the primary factors that affect egg production and this is testified to by the fact that chickens that started laying in summer produced fewer eggs as compared to the chickens that started laying in winter.

Mashaly *et al.* (2004) explained that the eggs from hens housed in a hot chamber were significantly fewer than the number of eggs produced in controlled chambers meaning that egg production was inversely related to level environmental temperature. This was confirmed by the fact that in an experiment conducted by Star *et al.* (2008) the hens that were exposed to a high temperature had a laying percentage that ranged from 83.6 to 83.8 as compared to the birds in the control group which had a laying production of 93 to 93.2%. In support of other researchers, Hsu *et al.* (1998) demonstrated that high ambient temperatures normally depress egg production as a result of low feed intake when it is hot. Smith (2005) also reported that the temperatures that exceed 32^{o}C would normally result in a decline in egg production. The report by Usayran *et al.* (2001) highlighted that egg production of chickens under a constantly high temperature was 74.7% while the ones that were kept at an average ambient temperature had an egg production of 79.1%.

Rozenboim *et al.* (2007) stated that a significant reduction of 20% was observed in the laying production of the chickens that were exposed to heat as opposed to their control counterparts. Contrary to other studies, the results from Persia *et al.* (2003) established insignificant differences in egg production caused by heat stress.

1.2.4 Egg quality and weight

1.2.4.1 Effect of restricted feeding on egg quality and weight

The egg quality was not significantly affected by the different feeding regimes in chickens (Ukachukwu and Akpan, 2007). In a study done on turkeys Crounch *et al.* (2002a) showed that for the entire lay period, cracked and soft-shelled egg production percentage was greater for the birds that were fed restricted from 3 to 16 weeks of age. There was also no effect of feed restriction treatment on percentage of double yolked and large egg production. Percentage of eggs cracked in the incubator was also significantly higher from hens that were under restricted feeding during the rearing period compared to hens subjected to other regimes (*ad libitum* feeding from 3 to 24 weeks; *ad libitum* feeding from 16 to 24 weeks and feed restriction from 3 to 24 weeks) as reported by Crounch *et al.* (2002b). Crounch *et al.* (2002b) further more added that the hens that were under restricted feeding and those fed *ad libitum* during the laying period produced significantly lighter eggs. The same report also indicated no differences in shell weight or shell thickness (mm) between feeding treatments.

Richards *et al.* (2003) indicated low incidences of abnormal eggs in restricted fed hens compared to birds exposed to feeds without restriction. Oyedeji *et al.* (2007) concluded that egg weight is significantly better for hens that were given unrestricted access to feed over those rationed either once or twice a day. In a study done on quails, Hassan *et al.* (2003) revealed that early feed restriction did not affect first egg weight, mean egg weight, or number of eggs produced. Egg specific gravity was improved by early feed restriction on Japanese quails as compared to those on full feeding (Hassan *et al.*, 2003). Settable egg production was defined as total eggs weighing 50 grams or more minus soft shelled, double yolked, or cracked eggs.

According to Bruggeman (1999), the highest number of settable eggs was observed in hens that were under feed restriction during 7 to 15 weeks of age period and the lowest was observed in the birds that had access to unrestricted feeding throughout. Robinson *et al.* (1978) indicated that *ad libitum* fed birds can have as many as 12 to 15 large yellow follicles. A high proportion of those follicles are destined to become double yolked eggs. Sometimes two ovulations may occur in a single day, but both eggs have poor shell quality. Miles and Jacqueline (2000) showed that a feed restriction programme would result in a slight decrease in egg size that is of less consequence once the majority of the eggs are in the large category.

A significantly larger numberof eggs heavier than 60 grams and significantly fewer eggs lighter than 45 grams were produced in each period by the birds that had been restricted during rearing than those that had not. On the other hand, restrictive feeding in the laying period depressed egg size (Robinson *et al.*, 1978). According to Renema *et al.* (1999a), the early sexual maturity of *ad libitum* fed chickens compared to restricted fed ones throughout rearing is believed to be nullified by production of small eggs early in the laying period. The report by Robinson *et al*. (1978) further indicated that the proportion of cracked eggs tended to decrease with increasing severity of feed intake restriction in the laying period. Specific gravity of eggs was also markedly increased by feed intake restriction in the rearing period and tended to increase with increasing severity in the laying period. Feeding level contributed substantially to egg size (Renema *et al.*, 2007). Van Marle-Köster and Casey (2001) reported the average egg weight of 52.1 grams for Koekoek chickens under *ad libitum* feeding for a period of 51 weeks.

1.2.4.2 Effect of season on egg quality and weight

A decline in egg weight is mainly due to the impact of heat stress rather than reduced feed intake. High temperatures also contribute significantly to the weight loss in egg yolk and egg albumen (Smith, 2005). The findings of Usayran *et al*. (2001) as well as Rozenboim *et al*. (2007) support these results as they suggested the reduced egg weights were one of the consequences of exposing chickens to heat. The report of Hsu *et al.* (1998) also demonstrated a significant decrease in reduced egg weight due to high temperatures rather than the level of feeding. The same report explained that ambient temperature has the potential of altering the other components of the egg such as egg albumen and egg yolk. High temperatures are capable of greatly reducing the weights of the egg yolk, egg albumen and shell weight but their relative weights to the egg weight were not affected by the temperature.

Egg weight was reduced by 5.2 g in birds that were exposed to heat compared to chickens that were under control treatments and the effect of heat stress was more evident 18 days after the birds were subjected to heat stress. The chickens that commenced their laying in summer produced lighter eggs compared to the chickens that started their laying cycle in winter (Garces *et al.*, 2001). The findings of Mashaly *et al.* (2004) revealed that in addition to the weights of the egg yolk, egg albumen and the shell weight high temperature could significantly lower the shell thickness and specific gravity. The eggs from birds that are exposed to heat stress are also reported to have a higher Haugh Units rating compared to birds that were under control. In contradiction to the findings of other researchers, Lin *et al*. (2002) concluded that the difference between the chickens that were exposed to high temperature and the ones that were under control was not significant in terms of egg weights.

1.2.5 Feed intake and efficiency

1.2.5.1 Effect restricted on feed intake and efficiency

Feed is the most expensive item in poultry production and one of the ways of reducing this cost is to restrict feed in the early life of chickens (Tumova *et al.*, 2002). The findings by Tumova *et al*. (2002) reflected that feed intake was reduced by restrictive feeding and resulted in an improvement of feed efficiency in comparison with a control group fed *ad libitum*. In the realimentation period, female turkeys consumed less feed. The report also suggests that feed efficiency is not affected by feeding regimens. Robinson *et al.* (1978) indicated that there is little tendency for feed restricted birds to over-consume feed. Robinson *et al.* (1978) further indicated that irrespective of the length of the laying period, the ratio of the amount of feed (kg) eaten to the quantity of eggs produced declined with successive increases in laying feed restriction.

Crounch *et al.* (2002a) reported that there were differences in feed consumption during the growing phase of hens until 24 weeks of age. As birds were subjected to a phase of physical feed restriction, their feed intakes were reduced. The findings further indicated that as hens were placed back on *ad libitum* feeding, there was a subsequent and immediate large increase in feed consumption consistent with feeding behaviour after restriction. According to Crounch *et al*. (2002a) savings on feed consumption were recorded due to feed restriction.

During the growing period (9 to 20 weeks), birds fed unrestrictedly consumed significantly more feed than the feed restricted groups. The most restricted group consumed about 30 percent less feed than birds fed *ad libitum* which is a substantial saving in terms of feed cost per kilogram weight gain. Feed restriction treatment did not significantly affect the efficiency of feed utilization (Sekoni *et al.*, 2002). The finding by Sekoni *et al*. (2002) concluded that quantitative feed restriction did not have any significance on feed consumption and efficiency of feed for egg production. The same study of feed restriction on Japanese quail showed a non-significant difference in feed conversion efficiency among treatments during feed restriction periods (Hassan *et al.* 2003). Hassan *et al.* (2003) also explained that a higher feed conversion value following feed restriction would probably mean that feed restriction retards growth, and therefore reduces feed efficiency although Plavnik and Hurtzwitz (1985) illustrated that feed restriction induces a higher efficiency of maintenance. At the age of 11 weeks Koekoek chickens are capable of consuming 3680 grams of feeds with an average feed conversion ratio (FCR) of 3.3 when given commercial feeds unrestrictedly (Marle-Koster and Casey, 2001).

1.2.5.2 Effect of season on feed intake and efficiency

An ambient temperature is reported to depress the feed intake and feed efficiency of broiler chickens (Plavnik and Yahav, 1998). In a study conducted by Veldkamp *et al.* (2000a; 2005) a higher feed intake was observed on birds that were subjected to low temperature throughout the rearing period with the explanation that the increased feed intake was due to the temperature whereas diet did not affect the feed intake. In respect to feed conversion ratio (FCR) the experimental results demonstrated by Veldkamp *et al.* (2000a) showed the feed conversion ratio to be better in turkeys that are under high temperature treatment as opposed to the ones on low temperature. However, the findings by Veldkamp *et al.* (2005) reported an improved overall feed gain ratio on birds raised on low temperature compared to the ones on high temperature. There was also an interaction between temperature and the level of energy in broiler chickens and this suggested that the better results in feed conversion ratio were more evident when accompanying increased energy level with low temperature as compared with the high temperature regimes.

In a study conducted by Bonnet *et al.* (1997), a decrease of 30% in feed consumption was discovered during the summer season. It was also revealed in the same study that the feed conversion ratio (FCR) was higher in birds reared on higher temperature. Bonnet *et al.* (1997) suggested that chickens would have ample water intake irrespective of any type of diet when exposed to high temperature. In line with other researchers, Lu *et al.* (2007) confirmed that the feed intake and feed gain ratio were lower in birds that were on higher temperature (34^0C) compared to those on controlled temperature (21^0C) irrespective of the breed or strain of the chickens used.

1.2.6 Reproductive organs and secondary sex characteristics

1.2.6.1 Effect of restricted feeding on oviduct, ovarian, comb and wattle characteristics

i) Oviduct weight

On the issue of the oviduct weight, Melnychuk *et al*. (2004) emphasized feeding as one of the main factors influencing the weight of the oviduct, hence the full-fed hens being recorded as having heavier oviducts compared to restricted fed hens in absolute terms. Crounch *et al.* (2002b) reported the significant differences in oviduct weight with hens allotted to restricted feeding treatment having significantly heavier oviducts compared to full-fed hens. This was confirmed by Melnychuk *et al.* (2004) who stated that restricted fed birds had significantly greater oviduct weight when expressed as the percentage of the body weight compared to *ad libitum* fed birds. However, in their investigations Yildiz *et al*. (2006) found that feed restriction at rearing phase hindered the development of the oviducts. The absolute weight of the oviduct at sexual maturity did not differ due to feeding regime or due to body size. The average weight of the oviduct was 60 grams (Renema *et al.*, 1999a; 2007; Tesfaye *et al*., 2009). Renema *et al.* (1999b) indicated that oviducts were heavier in birds having lower body weight at sexual maturity. At 18 weeks of age, absolute oviduct weight was not different among strains, but it was heavier in birds with high body weight profile compared to those with low body weight profile. Oviduct weight can be very responsive to feed allocation (Robinson *et al.,* 2007).

ii) Ovarian weight

The stroma of the ovary is the stock of small, estrogen producing follicles from which follicles are recruited into the hierarchy (Melnychuk *et al.,* 2004). At the age of first oviposition, absolute weights of the ovary in the different groups of feeding regimes did not differ and this suggests that a threshold of ovary weight must be achieved before the attainment of sexual maturation irrespective of the feeding regime practiced (Bruggeman *et al.,* 1999). Bruggeman *et al.* (1999) indicated that the difference was observed when the weight was expressed as percentage of the body weight.

The ovary weight of *ad libitum* fed hens was 38 percent greater than that of the restricted fed hens and this difference was also seen in the relative ovary weights (Renema *et al.,* 1999b). The difference indicates that overfeeding may have altered ovarian morphology at the level of prehierachieal follicles. Differences in ovary weight between full-fed hens and restricted fed hens were due to the number of long yellow follicles (LYF) as explained by Renema *et al.* (1999b). Ovary weight is influenced by body weight profile and possibly by level of fatness (Robinson *et al.* 2007).

In a study done by Melnychuk *et al.* (2004) full fed hens had significantly higher stroma weights at sexual maturity on an absolute basis compared with feed restricted birds, but there were no differences in stroma weights in terms of relative weight. It was also noticed that this increased number of follicles might be physiologically important since the *in vitro* androstenedione production of small white follicles from full fed hens was significantly greater from that of feed restricted hens (*Yu et al.*, 1992b). The maturing ova were heaviest for the hens that were feed restricted during rearing phase compared to hens that were fed *ad libitum* during the rearing phase at 39 weeks (Crounch *et al.*, 2002b).

Renema *et al.* (2007) further stated that ovary weight was influenced by body weight profile and was an indication that presumably this effect was related to the level of feed intake during the time of follicle formation rather than to level of feed restriction during weeks 16 to 20. If pullets are subjected to decreasing feed intake during this time, they enter lay with a reduced number of large yellow follicles (LYF) and fewer multiple follicles, suggesting that follicular development is closely related to feed intake rather than body weight alone (Renema *et al.*, 2007). Cassy *et al*. (2004) affirmed that restricted feeding would limit the formation of the excessive ovarian yellow follicles arranged in the multiple hierarchies.

iii) Comb and wattle size

Comb and wattle sizes (height and length) in chickens begin to increase rapidly five weeks prior to first oviposition (Joseph *et al.*, 2003). Comb size is being correlated with the age at first oviposition for chickens and the correlation seemed to be higher for *ad libitum* fed chickens compared to the chickens that are restrictedly fed (Joseph *et al*., 2003).

1.2.6.2 Effect of season on oviduct, ovarian, comb and wattle characteristics

i) Oviduct weight

In a study conducted by Chen *et al*. (2007), it was discovered that the oviduct weights were similar in chickens that were exposed to different photoperiods. Allee and Lutherman (1940) concluded that chickens that were kept in a cool environment had heavier oviducts than those that were under warm environmental conditions.

ii) Ovarian weight

Heat stress resulted in a reduction of ovary weight as well as the number of large follicles and this was observed in six days after chickens were exposed to heat up to the end of the study (Rozenboim *et al.*, 2007). In supporting their own findings, Rozenboim *et al*. (2007) explained that the heat stress was found to reduce lutenizing hormone (LH) levels and hypothalamic gonadotropin releasing hormone-1 content. The ovary weight was similar in pullets that were exposed to dissimilar hours of light in a day (Chen *et al.,* 2007). The ovaries have a tendency of being heavier at lower temperature compared to warm temperature yet the differences were not statistically significant (Allee and Lutherman, 1940).

iii) Comb and wattle size

In studying the reproductive performance of chickens Kesharvarz (1998) reported that chickens that were exposed to a constant eight hours of light in a day had evidently larger size of comb and wattle as compared to the ones that were subjected to a step-down light regimen. The study by Lamoreux (1943) reveals that the comb size increased greatly in winter, which was assumed to have been caused by the reduced hours of sunlight.

1.2.7 Carcass characteristics

1.2.7.1 Effect of restricted feeding on the carcass characteristics

i) Breast muscle weight

Breast meat is the most valuable product in the chicken industry (Melnychuk *et al.,* 2004). In a study conducted by Renema *et al.* (1999a) the absolute weight of the breast muscle was reported to be 9.6 percent higher in *ad libitum* fed chickens compared to feed restricted chickens. However, restricted fed birds registered a greater relative weight of the breast muscle (Renema *et al.,* 1999a). The findings of Robinson *et al.* (2007) illustrated that at 18 weeks of age, variability in percentage of breast muscle weight resulting from a diverse feed allocations needed to achieve body weights profiles was greater than the genetic variability among different lines. At sexual maturity, the proportion of breast muscle in the high treatment was greater than in the low treatment (Renema *et al.* 2007).

Melnychuk *et al.* (2004) found that full-fed birds had significantly heavier breast muscle than feed restricted birds, even though in terms of percentage of body weight, restricted fed birds outperformed the *ad libitum* fed birds. It appears that even under conditions of limited feed, chickens use available nutrients efficiently for breast deposition (Melnychuk *et al.*, 2004). Restricted fed birds had higher breast muscle at 16 and 30 weeks of age. The birds that were feed restricted very early in their lives had poor performance in terms of breast weight up to 39 weeks of age and beyond (Crounch *et al.*, 2002c). But in terms of body weight percentage the restricted fed chickens performed better than full-fed chickens in breast muscle weight as illustrated by Crounch *et al.* (2002c). In an investigation done in turkeys Crounch *et al.* (2002c) indicated that the control fed hens had the greatest percentage loss of breast muscle from 30 weeks onwards whereas hens restricted for the longest period of time gained breast muscle tissues from 39 to 54 weeks.

ii) Shank length and circumference

Analyses of body weight profiles need to consider the relative allocation of nutrients early in life, because they affect the establishment of carcass frame and fleshing and later in rearing during the development of the reproductive system (Robinson *et al.*, 2007). Birds of all strains were limited to a common frame size for most of the rearing period once the feed restriction programmes were imposed (Robinson *et al.*, 2007a). The findings of Robinson *et al.* (2007) further indicated that feed restriction practices limit frame size.

Body weight based differences in shank length, fat pad size, and reproductive organs were similar to those observed in birds subjected to various levels of feed restriction (Renema *et al.*, 1999b). The findings by Crounch *et al.* (2002c) revealed that the shank length and circumference were reduced in restricted fed hens throughout the study and the reduction was greatest for those hens restricted for the longest period. Beginning from the 8th week throughout the rearing programme, feed restriction program limited keel length in all strains. Body weight affected keel length in similar fashion to shank length; standard feed restriction practices limit both indicators of frame size. The range of feed allocation is enough to influence frame development at a young age (Robinson *et al.*, 2007).

iii) Intestinal weight

The broiler chickens that were shifted from restricted feed to *ad libitum* feeding had heavier weights of the intestines compared to either the chickens that were fed without any restriction or the ones that were fed restrictedly for the entire study period (Novele *et al*., 2008). Broiler chickens that were fed high fibrous diet as a form of feed restriction only at initial stage of growth resulted in a higher intestine weight score compared to those feed restricted by 35% and later shifted to *ad libitum* feeding were second in performance (Yagoub *et al*., 2008). Those that either were fed *ad libitum* or restrictedly for the entire study had lighter intestine weights (Yagoub *et al*., 2008).

iv) Liver and gizzard weights

The liver weight was similar (p>0.05) in *ad libitum* and restricted fed broiler breeder hens (Melnychuk *et al*., 2004). Yagoub *et al*. (2008) noted that even in chickens that were shifted to *ad libitum* feeding at later stage of development their liver weights were not significantly different from the rest of chickens in other treatments. However, Renema *et al.* (1999a) concluded that giving chickens 37.2 % of *ad libitum* intake would result in a reduced liver weight. Pishnamazi *et al*. (2008) also discovered that the liver weight was greater in chickens that were fed *ad libitum* as a percentage of body weight in comparison to the chickens that were under restricted feeding.

Ramlah *et al.* (1996) reported increased liver and gizzard weights in broilers that were feed restricted at two and three weeks of age respectively compared to the *ad libitum* fed ones. However, the study of Yagoub *et al*. (2008) showed that the similar gizzard weights in birds that were under different feeding regimes and the premise for the similarities could be due to the muscular nature of the gizzard which normally had a slight or no change in its volume. Mahmood *et al.* (2007) also indicated that the insignificant differences in the liver and gizzard weights in spite of whether chickens were fed *ad libitum* or restrictedly.

1.2.7.2 Effect of season on the carcass characteristics

i) Breast muscle weight

The results by Bogosavljevic- Boskovic *et al.* (2006) concluded that season did not have a significant effect (p>0.05) on the proportion of all meat classes in broiler chickens that were raised either under a semi-intensive or intensive production system. In broilers that were kept in door, the highest carcass yield was achieved in broilers that were exposed to a temperature of 22°C with the ones that were under high temperature (34°C) having their breast weights decreased by 1.5 percent (Aksit *et al*., 2006). Alleman and Leclercq (1997) who stated that a reduced breast weight in chickens is a result of heat stress put forward a similar argument. In egg type chickens that were reared under the battery cage system, Chen *et al.* (2007) found that the weight of the breast weight is not a function of the number of light hours chickens are exposed to in a day.

ii) Shank length and circumference

Mcgovern *et al.* (2000) declared that the fluctuation in temperatures failed to produce significant differences in the shank length of chickens. The chickens that were kept at low temperature (18°C) had heavier leg weights compared to the ones that were maintained at approximately 30°C being regarded as high temperatures (Leeson and Caston, 1993). Bruno *et al.* (2007) revealed that the birds that were reared in a thermo-neutral environment had higher tibia weights compared to the ones that were either exposed to low or high environment. N'dri *et al.* (2007) made an observation of an increased leg yield only in French "label" meat type broilers that were subjected to hot conditions.

iii) Intestinal weight

In an experiment in which Keshavarz (1998) compared the effects of short day and step-down light regimen on the performance of pullets it was discovered that the length of the small intestines was large in a short light day regimen (8 hours light per day) compared to a step-down light regimen (pullets were exposed to 23 hours light and 1 hour darkness per day during the first week and thereafter the light was reduced by 1 hour per week until the light was reduced to 8 hours per day). In a study done in India, Rajini *et al.* (2009) stated that the length of the intestines was greater in winter compared to summer in chickens that were fed pellet feeds.

iv) Liver and gizzard weights

The large liver size was reported in chickens that were subjected to the short light day regimen compared to step-down light regimen and this was mainly because of the greater rate of lipogenesis to supply growing follicles with lipoproteins (Keshavarz, 1998). The liver weight of the chickens that were exposed to 17 hours of light was statistically similar to the ones that were exposed to fewer hours per day (Chen *et al.*, 2007). The study by Rosa *et al.* (2007) stated that exposure to heat would result in decreased weights of liver and gizzard. Blahova *et al.* (2007) emphasized that the liver weight was considerably increased at low environmental temperature shared similar results. Rajini *et al.* (2009) who pointed out that the liver weight of the chickens were significantly higher during the winter season also confirmed this.

The larger gizzard size was observed in birds that were in step-down light regimen and this is the result of the extended time of feeding due to more daily light up to 15 weeks of age (Keshavarz, 1998).

1.2.8 Abdominal fat pad

1.2.8.1 Effect of restricted feeding on abdominal fad pad weight

The two major depots for lipids from the liver during puberty are the abdominal fat pad and the ovary (Melnychuk *et al.*, 2004). Some researchers stated a significantly positive relationship between the liver weight and the weight of the abdominal fat pads and ovaries during puberty that reflect the increase in lipid synthesis and mobilization (Renema *et al.*, 1999b; Melnychuk *et al.*, 2004 and Robinson *et al.*, 2007). Renema *et al.* (1999b) indicated that the lean body mass is also more related to measures of ovarian development at sexual maturity, as number of large yellow follicles, than to measures which include carcass lipid.

Feed restricted birds were leaner at sexual maturity than their full-fed counterparts. Full feeding at the time of photostimulation in birds that have not reached the age threshold for sexual maturity results in higher levels of fat deposition (Melnychuk *et al.*, 2004). The study by Melnychuk *et al.* (2004) reflected that the effect of estrogen from developing ovary, lipid mobilization is increased through the liver. It was also expressed that the livers of the full-fed birds were significantly heavier on an absolute and relative basis compared with livers of the restricted fed birds. Robinson *et al.* (2007) showed that decreasing fat allocation at 18 to 24 weeks of age did not result in decrease in abdominal fat on high body profile birds.

The abdominal fat pad weighed 124 grams in *ad libitum* fed birds compared to 55 grams in restricted fed birds. A large difference was also present in the relative abdominal fat pad weight with *ad libitum* fed hens having fat pads representing 3.7 percent of body weight compared to 2 percent in restricted fed hens (Renema *et al.*, 1999a). Richards *et al.* (2003) stated that feed restriction during egg production resulted in significantly ($p<0.05$) lower body and abdominal fat pad weights compared to unrestricted feeding. Abdominal fat percentage was only different at 54 weeks of age; restricted fed birds had less fat than *ad libitum* fed chickens (Crounch *et al.,* 2002c). Richards *et al.,* (2002) explained that feed restriction resulted in significantly lower body weight and abdominal fat pad weight compared with unrestricted feeding hens.

Hens characterized by the greatest amount of breast muscle fleshing had the lowest proportion of abdominal fat pad (Renema *et al.,* 2007). The treatment of hens that were most severely feed restricted during rearing had the smallest fat pads. It would appear that fat pad mass at sexual maturity is more indicator of long-term nutrient availability, whereas liver mass is more an indicator of short-term nutrient availability (Renema *et al.,* 2007).

1.2.8.2 Effect of season of abdominal fat pad weight

The abdominal fat pad was similar in Hyline commercial chickens that were reared in different number of hours of light per day (Chen *et al.,* 2007). The broilers that were reared in hot environmental conditions accumulated more fat due to the reduction on basal metabolism and physical activity, which are influenced by the increase of plastimatic corticosterone and decrease in plastimatic triidothironine (Rosa *et al.,* 2007). The findings of Blahova *et al.* (2007) are also in agreement with other researchers as they stated that the low environmental temperature resulted in a lesser fat pad weight. In their arguments Blahova *et al*. (2007) explicated that the lower fat pad weight in birds exposed to cool environment would be as a consequence of more energy being dissipated as heat hence chickens would not accumulate more fat pad weight.

Mcgovern *et al*. (2000) pointed out that the fluctuations in temperature did not have any significant effect on the fat pad weight in chickens. The birds that were kept in summer scored heavier fat pad weight compared to the ones that were reared during the winter season regardless of the water drinker system used even though the differences were insignificant (Wabeck *et al.,* 1994).

1.2.9 Carcass composition

1.2.9.1 Effect of restricted feeding on the carcass composition

i) Dry matter content

In a study conducted by Santoso (2001) it was found that feed restriction had no effect on the dry matter in broiler chickens. Early feed restriction resulted in significantly higher carcass moisture levels in Large White turkey breeder hens at 16 weeks of age and this was observed throughout the study (Crounch *et al.*, 2002). Ocak and Erener (2005) found a higher dry matter content in Japanese quails that fed without restriction.

ii) Crude fat percentage

The lower body weight birds had lower lipid content and higher water content compared to high body weight birds. The reduced lipid stores of low weight birds compared to birds of larger size groups may relate to the reduced size of their reproductive tract relative to high body weight birds (Renema *et al.*, 1999b). Carcass fat was lower in turkeys that were physically feed restricted during the rearing compared with full-fed hens throughout life (Crounch *et al.*, 2002c). The percentage of lipid was directly related to severity of early feed restriction (Renema *et al.*, 2007). Ocak and Erener (2005) pointed out that feed restriction failed to affect carcass fat content in Japanese quails.

iii) Crude protein percentage

Renema *et al.* (2007) showed that moderate and high body weight hens had greater proportions of carcass protein and ash than low body weight hens. In a study done on commercial egg type pullets Chen *et al*. (2007) reported similar carcass crude protein content between the different feeding regimes.The findings of Ocak and Erener (2005) revealed that feed restriction decreased the protein content in Japanese quails.

iv) Ash content

The findings of Santoso (2001) show a higher ash content in broiler chickens that were feed restricted. However, Renema *et al.* (1999a) reported that the ash content and the protein percentage were similar between the full fed and restricted fed broiler breeder hens. Similar results were obtained by Chen *et al.* (2007) but in commercial egg type pullets.

1.2.9.2 Effect of restricted feeding on the carcass composition

i) Dry matter content

In a study conducted by Chen *et al*. (2007) it was noted that moisture content did not differ significantly between the chickens that were subjected to different number of sunlight hours in a day. It was also observed that the moisture contents of chickens that were either heat acclimatized or not were similar (Barbour *et al.*, 2010). Contrary to other researchers, Aksit *et al*. (2006) found the moisture content of the chicken thighs to be lower in chickens that were exposed to temperature of 34°C compared to the thighs of the chickens that were kept in a temperature ranging from 22 to 28°C. Bianchi *et al.* (2007) stated that chicken meat produced in summer would have high moisture content.

ii) Crude fat percentage

The increased ether extract was noticed in broilers because of the direct effect of the temperature (Rosa *et al.*, 2007). In an investigation conducted by Barbour *et al.* (2010) it was revealed that birds that were heat acclimatized had a significantly higher fat content compared to the ones that were not acclimatized to heat. The broilers that were kept in summer experienced a higher percentage of lipid in breasts, thighs and drumsticks than in chickens that were reared in spring season (Bogosavljevic-Boskovic *et al.*, 2006). However, in a research study conducted by Chen *et al.* (2007) it was reported that the total carcass lipid content did not differ significantly between birds that were subjected to dissimilar photoperiods. The research conducted by Bianchi *et al.* (2007) also reported higher lipid content in chickens that were reared in summer than the ones that were kept in winter although the difference was not significant.

iii) Crude protein percentage

The relative percentage of carcass protein did not differ significantly between chickens that were subjected to different numbers of sunlight hours in a day (Chen *et al.*, 2007). The findings by Barbour *et al.* (2010) disclosed that chickens would have a similar percentage of crude protein regardless of whether they were heat acclimatized or not acclimatized to heat. The protein level from the breasts was found to be lower in chickens that were produced in summer (Bianchi *et al.*, 2007). This is in accordance with the results attained by Blahova *et al*. (2007) which disclosed that chickens that were kept in lower environmental temperature resulted in increased level of total proteins, uric acid and phosphorus. Bogosalvjevic-Boskovic *et al.* (2006) reported a significant interaction of season and rearing system on crude protein content even though the effect on protein was more pronounced in chicken thighs.

The results obtained by Aksit *et al*. (2006) revealed that the content of protein was negatively correlated with the amount of heat allotted to chickens. The results of Rosa *et al.* (2007) also suggested that the lower carcass crude protein in broilers was mainly due to the direct effect of increased temperature.

iv) Ash content

The ash content from the breast meat in chickens was not affected by the level of temperature at which the chickens were kept but the ash percentage seemed to decrease with the increase in temperature especially when the temperatures reach 34^{o}C (Aksit *et al.*, 2006). The findings achieved by Persia *et al.* (2003) discovered that the high temperature did not affect the tibia ash percentage in laying hens. According to the findings of Chen *et al.* (2007), it was discovered that the relative ash percentage did not differ among the groups of chickens reared under different photoperiods. The chicken meat produced in summer had a lower ash content compared to the one produced during winter (Bianchi *et al.*, 2007).

1.2.10 Fertility and hatchability

<u>1.2.10.1 Effect of restricted feeding on egg fertility and hatchabilty</u>

In a study that was conducted in Japanese quails it was reported that feed restriction at 70 and 85% of *ad libitum* feed intake did not significantly decrease fertility between 6 and 13 weeks of age (Hassan *et al.*, 2003). Hassan *et al.* (2003) also discovered that males fed 85 percent of their feed intake and those fed *ad libitum* had greater average semen volumes than volumes produced by 70 percent restricted fed males. Crounch *et al.* (2002b) reported insignificant differences between the restricted fed and full-fed Large White turkey hens in terms of fertility.

Hatchability of fertile eggs from the *ad libitum* fed and restricted fed Japanese quails did not differ significantly. Hatchability maintained in feed restricted Japanese quails could result from lower embryonic mortality (Hassan *et al.*, 2003). Crounch *et al.* (2002b) indicated that cumulative mean hatchability of fertile eggs was significantly greater in turkeys that were feed restricted during the rearing phase than in turkeys that were fed *ad libitum* during the rearing phase.

1.2.10.2 Effect of season on fertility and hatchability

Temperature of the storage area is directly related to albumen quality changes as stated by Brake *et al.* (1997). It was discovered by the same researchers (Brake *et al.*, 1997) that a relative increase in temperatures of the nest box, storage area and presetting area reduce egg hatchability especially in old breeder hens compared to young ones. In a study conducted by Babiker and Musharaf (2008) it was observed that there was no significant difference between the two seasons in terms of egg fertility of which infertile eggs might have been fertilized but the embryos died at initial stage of development.

Abdou *et al.* (1977) reported no significant differences in fertility and hatchability between the inbred chicken lines that were reared in summer and winter. However, the fertility was high in almost all the inbred chicken lines in winter as compared to the fertility of the chickens that were kept in summer. It was discovered that the laying date also play a significant role in the fertility and hatchability of eggs in Red –Legged partridge hens as the fertility and hatchability peaked between mid February and late March and the eggs that were incubated between late April and May months had a lower fertility and hatchability (Gonzalez-Redondo, 2006). The investigation of Ozcelik *et al*. (2006) illustrated that the lowest egg fertility appeared to have been in June compared to other months with the explanation that the temperatures appeared to have been higher during the month of June in 2001 and 2002. It was also noticed that the hatchability was low in the months when the temperatures were high (Ozcelik *et al.*, 2006).

1.2.11 Embryonic Mortality

The findings of Crounch *et al.* (2002b) showed that Large White turkeys that were feed restricted earlier (during rearing phase) and changed to *ad libitum* feeding in the laying phase had significantly higher levels of embryonic mortality compared to other feeding groups of birds. Eggs produced from turkey hens that were feed restricted from 3 to 16 weeks of age had a mean embryonic mortality of 3.9% which is significantly higher than in groups that were subjected to other feeding regimes (Crounch *et al.*, 2002b).

Total embryonic mortality to 17th day of incubation was reduced by early feed restriction. Mortality for the full-fed birds was 56 percent more than mortalities from 15 or 30% feed restricted quails (Hassan *et al.*, 2003). Hassan *et al.* (2003) reported that the differences in embryonic mortality were due to differences in late dead embryos because both early dead and piped dead were not significantly different among regimens. Eggs containing early dead embryos exhibited the greatest weight loss and therefore, early feed restriction that affected embryo mortality might also suggest that egg specific gravity would be affected as observed in some studies (Hassan *et al.*, 2003).

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