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EFFECTS OF SEASON AND RESTRICTED FEEDING DURING REARING AND LAYING ON PRODUCTIVE AND REPRODUCTIVE PERFORMANCE OF KOEKOEK CHICKENS IN LESOTHO

By

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ABSTRACT

This research project consisted of five experiments**.** The main objective of this study was to determine the effects of restricted feeding and season on growth, carcass characteristics, meat chemical composition, reproduction and egg laying performance of Koekoek chickens. Feed restriction lowered the body weight, weight gain, feed intake and improved the feed conversion efficiency during the rearing phase. During the laying phase, chickens that were in the RA treatment had higher body weights, weight gains and lower FCR. Chickens that were reared in summer had a higher body weight, weight gain and FCR, while total feed intake and mortality rates were high in winter. Feed restriction reduced the slaughter weight, defeathered weight, dressed weight, skin weight, breast muscle weight, shank width, chest width and heart girth during the rearing phase. The intestine, liver and abdominal fat pad weights were higher in chickens that were fed *ad libitum*. Chickens that were reared in summer had higher shank width, slaughter weight, defeathered weight, chest width, heart girth, breast muscle weight, skin weight, abdominal fat pad weight, intestine weight, liver weight and the relative skin percentage at the age of 18 weeks. During the laying phase, abdominal fat pad weight, abdominal fat pad percentage, intestine percentage, liver weight, gizzard weight and gizzard percentage were higher in the *ad libitum* fed chickens. Unrestricted feeding during the rearing phase increased the development of combs, wattles, pubic bones, ovaries and oviducts more than restricted feeding while at the age of 32 weeks, enhanced growth of the reproductive organs was seen in chickens that were fed *ad libitum* only during the laying phase (RA). The cold winter conditions hindered the growth of the combs, wattles, pubic bones, oviducts and ovaries. Restricted feeding during the laying phase reduced the laying percentage, egg weights and improved the hatching percentage. *Ad libitum* feeding during the rearing phase resulted in the attainment of puberty at an earlier age in chickens. Chickens that were produced in summer reached puberty first as well as 20%, 50% and 80% egg production, and had a higher average laying percentage and egg weights.

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DECLARATION

I, Setsumi Motšoene Molapo do hereby declare that this thesis submitted for the degree of Doctor of Philosophy is the result of my original work. The authors cited in this thesis have been acknowledged. This work has not been submitted to the University of Pretoria or any academic institution of higher learning for the award of the degree. The views expressed are mine.

S.M. Molapo

Date: -------------------------------

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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

<u>1.1.3.1 Overall Objective</u>

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.

<u>1.1.3.2 Specific Objectives</u>

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^{o}C with the ones that were under high temperature (34^{o}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^{o}C) had heavier leg weights compared to the ones that were maintained at approximately 30^{o}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

<u>1.2.8.1 Effect of restricted feeding on abdominal fad pad weight</u>

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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CHAPTER 2

Effect of restricted feeding and season on the growth performance of Koekoek chickens

Abstract

The main objective of this study was to determine the effects of restricted feeding and season on growth performance of Koekoek chickens. Two hundred and seventy Koekoek chickens were randomly allocated to four feeding level treatments in a completely randomized factorial design. The deep litter system was used. The four treatments were AA (full feeding throughout the study), AR (full feeding for rearing and feed restriction for laying, RA (feed restriction for rearing and full feeding for laying phase) and RR (restricted feeding throughout the study). The data was subjected to the General Linear Model procedure of Statistical Package for Social Sciences (SPSS 17.00). The study was done in summer and winter for 32 weeks per season. The final body weights of Koekoek chickens in the rearing phase were 1.58, 1.58, 1.19 and 1.19 kg in AA, AR, RA and RR treatments respectively. The total weight gains during the rearing for birds that were in AA, AR, RA and RR treatments were 917.8, 924.9, 529.4 and 537.4g respectively. The feed intake of chickens that were full-fed (AA and AR) was 83g/day while for restricted fed birds (RA and RR) it was 58g/day. The average feed conversion ratios in the rearing phase were 5.5, 5.4, 6.79 and 6.7 for chickens in AA, AR, RA and RR treatments respectively. During the laying phase, final body weights of chickens in AA, AR, RA and RR treatments were 2.4, 1.8, 2.6 and 1.9kg respectively. Chickens under RA treatment gained 1126g followed by birds under AA, RR and AR treatments that gained 721.7, 501.9 and 164.6g respectively. The feed conversion ratio of chickens under AA, AR, RA and RR treatments were 15, 46.3, 9.4 and 15.8 respectively. Mortality observed in AA, AR, RA and RR treatments were 2.5, 1.6, 1.6 and 1.9% respectively. Chickens that were subjected to summer performed better in weight for age, average weight gain and feed conversion ratio. The total feed intake and the number of chicken deaths were higher in winter.

Key words: Koekoek chickens, feed restriction, full-fed, season, temperature weight gain, feed intake, feed conversion ratio, mortality rate.

2.1 Introduction

The current price spike in Agricultural commodities especially cereals caused by among other things climate change has significantly contributed to the higher cost of livestock feeds. This increase in the cost of animal feeds makes it difficult for the poor farmers in the rural areas to rear chickens as chicken diet is largely based on grains. In an effort to reduce the increased feeding costs one of the management strategies that could be employed is feed restriction. Restricted feeding has been reported to improve the feed utilization efficiency in chickens (Banalve, 1984). Crounch *et a*l. (2002a) reported that quantitative feed restriction reduces the body weight and feed consumption of Large White turkeys without necessarily affecting the egg production. Chickens that have been restricted fed early in the production and fed *ad libitum* at a later stage resulted in a compensatory growth (Bruggemen *et al.,* 1999). Apart from saving the quantity of feed given to chickens, feed restriction has been reported by several researchers in reducing mortality of chickens (Naraharl *et al.,* 1975; Lippens *et al.,* 2000 Tolkamp *et al.,* 2005 and Robert, 2009).

Season also plays an important role on the growth performance of chickens. Despite the fact that the Koekoek chicken has been developed to be adaptive under local conditions, this genetic potential cannot be achieved unless the extreme temperature problems have been adequately addressed. Exposure of chickens to extreme temperatures (low or high) during any phase of production has a negative impact on the body weight, body weight gain, FCR and mortality (Olanrewaju *et al.,* (2010). Increased temperatures experienced during the summer are capable of affecting negatively the body weight and weight gain of chickens, which is a net effect of reduced feed intake (Yalcin *et al.,* 1997a and Akyuz, 2009). On the other hand, low temperatures influence the performance of broiler chickens negatively because of the high feed intake, decreased body weight gain and feed efficiency (Blahova *et al.,* 2007). An improved feed conversion ratio (FCR) was found in birds that were kept in low temperatures as opposed to high temperatures (Veldkamp *et al.,* 2005 and Lu *et al.,* 2007). The extreme temperatures are a problem when chickens are kept in a house that cannot protect them from either hot or cold temperatures.

Although some work has been done on the effect of restricted feeding and season on chickens, still more studies are required to discover the appropriate rearing time and the feeding strategy management that can maximize genetic potential of Koekoek chickens without increasing the costs. As Koekoek chickens are classified under heavy dual purpose breeds (Nthimo, 2004), it is possible that they can benefit from restricted feeding the same way as broiler breeders. This study was aimed at investigating the effect of feeding level and season on the growth performance of Koekoek chickens.

2.2 Materials and Methods

2.2.1 Study site

This study was conducted at the experimental farm of the Faculty of Agriculture, National University of Lesotho (NUL) based in Roma.

2.2.2 Management of Birds

Two hundred and seventy (270) Koekoek hens and twenty-seven (27) Koekoek cocks at the age of eight weeks were bought from the Government Poultry National Hatchery in Maseru. The birds were from the same hatching batch and therefore they were of the same age. Prior to arrival at NUL, chickens were raised at the Poultry National Hatchery for seven weeks. They were raised on the deep litter system. They were given starter mash and water ad *libitum*. Sexing and new castle disease vaccine were done at the Hatchery. During the experiment, birds were raised on floor pens littered with dry grass (deep litter system). The floor space for each pen was 2.5m^2 and each pen accommodated 10 birds. The wall from the floor to the height of 1.5m was made of corrugated iron sheets. The wall height up to the roof was made of chicken wire mesh and the structure was roofed with corrugated iron sheets. The shelter was constructed in such a way to allow for good ventilation. Feeds were provided in suspended feeders and the cocks and hens shared the same feeders. Water was supplied in suspended drinkers *ad libitum*. Koekoek chickens were fed a pullet grower diet from the age of 8 to 18 weeks followed by laying mash feeding until the end of the research study (32 weeks). All Koekoek chickens were given a stress pack dissolved in water on arrival. Chickens that showed any sign of illness or diarrhoea were treated accordingly.

2.2.3 Experimental Design

The experiment was conducted using a completely randomized factorial design with feeding regime and season being factors as outlined by Steel and Torrie (1980).

Table 2.1: Experimental design of the research project

	Summer				Winter			
Pre- experimental phase (1-7 weeks)	Full-fed				Full-fed			
Rearing phase (8-18 weeks	**A**A Full-fed	**A**R Full-fed	**R**A Restricted	**R**R Restricted	**A**A Full-fed	**A**R Full-fed	**R**A Restricted	**R**R Restricted
Laying phase (19-32 weeks)	A**A** Full-fed	A**R** Restricted	R**A** Full-fed	R**R** Restricted	A**A** Full-fed	A**R** Restricted	R**A** Full-fed	R**R** Restricted

2.2.4 Treatment allocation

Two experiments were conducted to evaluate the effect of feeding level on the production and reproductive performance of Koekoek chickens under small scale farming conditions. The first experiment started from September 2008 to February 2009 while the second experiment was from March to August 2009 in order also to quantify seasonal effects. Each experiment had the same number of birds being 270 hens and twenty-seven (27) cocks.

Table 2.2: Temperature (^{o}C) conditions at Roma location from September 2008 to August 2009

Month	Minimum temperature (^{o}C)	Maximum temperature (^{o}C)
September	12	16
October	16	18.5
November	16.5	22
December	15	25
January	15	24.5
February	14.5	25
March	11.5	18
April	10	17
May	4	12
June	-1	7.5
July	0	6
August	3	13

Footnote:

Data on temperature is supplied by the Department of Geography of the National University of Lesotho weather station.

Two hundred and seventy (270) hens and twenty seven (27) cocks of age eight weeks were divided into four feeding regimes (levels) denoted as groups AA, AR, RA and RR with each treatment replicated seven times with the exception of birds in RR treatment which were replicated six times making a total of 27 experimental units. Each feeding regime treatment served 70 hens and 7 cocks in AA, AR and RA while the RR treatment had 60 hens and 6 cocks. Ten hens and one cock were kept in a pen. Chickens in group AA treatment were full-fed during the rearing and the laying phase. Birds in the AR treatment were full-fed during the rearing phase and were shifted to restricted feeding during the laying phase. Chickens in the group RA feeding regimen were on restricted feeding in the rearing phase and placed on full feeding during the laying period while in the last group (RR) the birds were subjected to feed restriction during both rearing and laying phases.

The restricted feeding was 70 percent of the total daily feed intake of the bird per day during both growing and laying periods. The feeding programme for chickens under restricted feeding during the rearing phase is shown on Table 2.2.

Table 2.3: The feeding program of Koekoek chickens under restricted feeding

Age of birds (weeks)	Daily feed intake/bird (grams)	70 percent of daily feed intake/bird (restricted feeding)
8	50	35
9	53	37
10	60	42
11	62	43
12	65	46
13	68	48
14	70	49
15	70	49
16	73	51
17	75	53
18	93	65

The average daily feed intake (Table 2.2) was based on records from the National Hatchery Poultry plant of the Ministry of Agriculture in Lesotho. This was also confirmed by the on-farm pilot study done at Roma Valley. Three farms were used in this pilot study in order to establish the Koekoek chickens feed intake. Ten chickens were given to each farmer. During the laying period, birds on restricted feeding were fed 84 grams of laying mash that is about 70 percent of their average daily feed intake (120g).

The feed used was a complete rearing and laying chicken diet bought from the commercial feed manufacturer (M) of which grower mash and layer mash composition was constituted as follows:

Table 2.4: Nutrient composition of grower mash and layer mash that was fed Koekoek chickens.

Nutrient	Grower mash (g/kg)	Layer mash(g/kg)
Crude protein	150.0	130.0
Moisture	120.0	120.0
Fibre (maximum)	65	70.0
Calcium (minimum)	27	27.0
Calcium (Maximum)	45.0	45.0
Phosphorus (minimum)	5.0	5.0
Lysine (minimum)	5.0	5.0

The chemical composition of the feed was confirmed by means of proximate analysis at the Nutrition Laboratory of the University of Pretoria.

Table 2.5: Analyzed nutrient composition of grower mash and layer mash

Nutrient	Grower mash	Layer mash
Crude protein (g/kg)	170.2	110.9
Moisture (g/kg)	100.0	95.0
Fat (g/kg)	22	24
Phosphorus (g/kg)	4.5	5.0

2.2.5 Data Collection

Throughout the experimental period Koekoek chickens (hens) were weighed on a weekly basis by choosing a random sample of 21 birds in the AA, AR, RA treatments and 18 birds in the RR treatment in order to establish their average weight for age, weight gains, feed intake and feed conversion ratio (FCR) with effect from the 10th week. The first two weeks were not included with the understanding of allowing adaptation period of chickens to the treatments. Feeding was done on daily basis at 7:00 am. The remaining feed was measured every day at 6:30 pm. The feed intake was taken as the difference between the total feed given to chickens in the morning and the remaining feed in the evening. The chickens FCR was calculated by dividing the total feed intake for every two weeks by the weight gain during a period of two weeks. All mortality was recorded.

2.2.6 Experimental Model

$$\mathbf{Y_{ij} = \mu + F_i + S_j + (F{*}S)_{ij} + E_{ij}}$$

Where:

$\mathbf{Y_{ij}}$ = Observation for Koekoek growth performance parameters

$\mathbf{\mu}$ = Overall mean

$\mathbf{F_i}$ = Effect of feed

$\mathbf{S_j}$ = Effect of season

$\mathbf{(F{*}S)_{ij}}$ = Interaction between the i^{th} feed and j^{th} season

$\mathbf{E_{ij}}$ = Error component

The arrival weights at 8 weeks were used as covariates in the model in order to correct the weekly weights of chickens up to 32 weeks.

2.2.7 Data analysis

Data was recorded in excel spreadsheet and averages were calculated. Data was tested for normal distribution. The analyses were done on transformed data. Multifactorial ANOVA was used to separate the effects of feeding level and season on body weights, body weight gain, feed intake, feed conversion ratio and mortality. If significant, treatment effects were analysed and differences between treatments were tested by Duncan's new multiple-range test (Duncan, 1955). The General Linear Models Procedure; SPSS (17.00) was used. Threshold for significance was $p < 0.05$.

2.3 Results and Discussion

The results of the growth performance of Koekoek chickens are presented in Table 2.6 and Figure 2.1. The results obtained from Table 2.6 indicate that during the rearing phase, birds that were full-fed (AA and AR) had higher ($p<0.05$) body weights than restricted fed groups (RA and RR). A critical analysis of the results from the 10^{th} to the 18^{th} week indicates that the difference between the mean weights of birds that were full-fed and the restricted fed group increases with the birds' age. This can be proved by the fact that the mean difference between birds that were on restricted feeding and full feeding increased by 22.2% from the age of 10 to 18 weeks (Figure 2.1). Full feeding increased the weight of the chickens by approximately 390g at the age of 18 weeks.

Table 2.6: Effects of restricted feeding on weight (g) for age of Koekoek chickens

	Treatment				
Age (wks)	**AA**	**AR**	**RA**	**RR**	**S.E**
Rearing phase (10 - 18 weeks)					
(Weights, g)					
10	774.6^a	775.1^a	729.7^b	735.7^b	1.36
11	888.8^a	891.7^a	809.4^b	808.1^b	3.47
12	1005.0^a	1004.0^a	829.7^b	900.9^b	2.68
13	1137.0^a	1140.0^a	957.6^b	970.9^b	2.80
14	1182.0a	1168.0^a	991.3^b	996.3^b	2.62
15	1329.0^a	1320.0^a	1109.0^b	1098.0^b	5.95
16	1399.0^a	1395.0^a	1090.0^b	1099.0^b	3.40
17	1506.0^a	1503.0^a	1209.0^b	1206.0^b	7.33
18	1575.0^a	1582.0^a	1187.0^b	1195.0^b	3.95
Laying phase (19 - 32 weeks)					
(Weights, g)					
19	1690.0^a	1648.0^b	1435.0^b	1389.0^b	5.10
20	1786.0^a	1690.0^b	1522.0^c	1394.0^d	4.39
21	1831.0^a	1638.0^b	1693.0^c	1539.0^d	5.14
22	1933.0^a	1751.0^b	1768.0^c	1544.0^d	4.73
23	2020.0^a	1667.0^b	1950.0^c	1677.0^d	5.47
24	2095.0^a	1818.0^b	2033.0^c	1678.0^d	4.69
25	2185.0^a	1735.0^b	2153.0^a	1801.0^b	5.96
26	2243.0^a	1867.0^b	2253.0^a	1780.0^b	4.76
27	2227.0^a	1814.0^b	2235.0^a	1871.0^b	6.40
28	2323.0^a	1852.0^b	2426.0^a	1853.0^b	4.75
29	2212.0^a	1808.0^b	2201.0^a	1858.0^b	7.29
30	2369.0^a	1808.0^b	2498.0^c	1875.0^d	5.21
31	2379.0^a	1819.0^b	2526.0^c	1887.0^d	6.04
32	2411.0^a	1812.0^b	2561.0^c	1891.0^d	5.00

^{Abcd} Means within a row with no common superscript differ significantly (p<0.05).

Footnote:

AA-Full feeding during rearing and laying. AR-full feeding during rearing and restricted during laying, RA-restricted feeding during rearing and full feeding during laying, RR-restricted during rearing and laying, S.E-standard error.

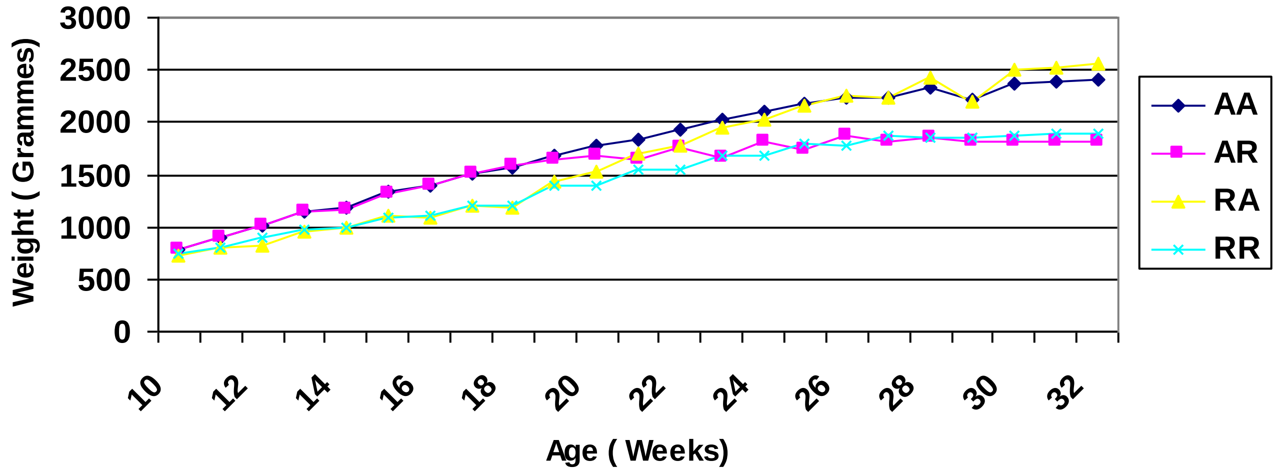

Figure 2.1: Growth curve of Koekoek chickens raised under different feeding levels

AA-Full feeding during rearing and laying. AR-full feeding during rearing and restricted during laying, RA-restricted feeding during rearing and full feeding during laying, RR-restricted during rearing and laying,

In the laying phase, birds that were full-fed during both phases (AA) continued to grow faster ($p<0.05$) than those in all other treatments (AR, RA and RR) up until birds reached 24 weeks of age. Koekoek chickens that were transferred from restricted to full feeding in the laying phase (RA) were seen to grow out birds that were under restricted feeding treatments (AR and RR) in the laying phase and this was seen to be effective from the 21st week of age. This means that it took almost 14 days for birds under RA treatment to adjust and respond to unrestricted feeding. Koekoek chickens that were under RA treatment seemed to accelerate their growth rate from the 21st week up to the end of the experimental trial, which was 32 weeks of age. Due to the compensatory growth, birds in the RA treatment were 133 to 155g heavier than birds that were under AA treatment for the last three weeks of the experimental period. At 25 weeks of age the results indicate no significant ($p>0.05$) differences between Koekoek chickens that were in the AR and RR treatments. The same trend was observed between the two restricted fed treatments during the laying phase until Koekoek chickens reached an age of 29 weeks. The body weights in the RR and AR treatments were increased by approximately 16g and 4g respectively during the last three weeks of the study. This could also be because birds that were feed restricted throughout the experiment (RR) were adapted to the situation as compared to birds that were restricted only in the laying phase (AR).

The results obtained from this research project are in agreement with the results of Tesfaye *et al*. (2009) who indicated that the growth of hens is reduced by feed restriction. Mahmood *et al*. (2007) also said that feed restriction reduced adult body weight of chickens by 20% compared with *ad libitum* fed chickens. Mahmood *et al.* (2007) and Tasfaye *et al.* (2009) also reported a reduced weight gain in feed restricted birds. The explanation of the lower body weight in feed restricted birds could probably be attached to the lower amount of feed intake compared to full-fed birds. The results obtained from this study agree with the findings of Fontana *et al*. (1992); Lippens *et al*. (2000); Mahmood (2007); Khetani *et al*. (2008) and Sogut and Kalpak (2009) who reported lower feed intake in feed restriction than *ad libitum* in the feeding programme. In a study that was conducted in quails, Hassan *et al*. (2003) found the similar results. They continued to enphasize that birds will later exhibit an accelerated body weight gain when allowed access to unrestricted feeds. Mahmood *et al*. (2007) also indicated that birds with retarded growth due to poor nutrition could achieve a growth rate higher than normal for chronological age after removal of the feed restriction. The previous findings explained that compensatory growth or catch up growth exhibited by restricted fed birds allows the recovery of body weight at slaughter age and sometimes a higher body weight than that of birds fed *ad libitum* as was the case with this research project. The results of this research study showed that RR treatment reduced the average body weights by 400, 310 and 130g than AA, AR and RA treatments respectively at the age 20 weeks ($p<0.05$). In a study that was conducted on quails, Hassan *et al*. (2003) indicated that the body weight at first egg is significantly less in restricted fed groups compared to the ad *libitum* fed groups.

Koekoek chickens that were reared in summer had higher ($p<0.05$) weights from the start of the experiment until the end of the rearing period (18 weeks) as shown in Table 3.6. The results revealed a difference of 178.7g between the birds that were kept in summer and in winter at the age of 10 weeks. The similar trend of the results was observed up until birds were 18 weeks being the expected age for puberty in Koekoek chickens. At 18 weeks of age, the mean body weight of Koekoek chickens that were kept in summer was 25% higher than in winter.

During this second phase of growing in Koekoek chickens the results clearly showed that Koekoek chickens raised in summer had higher ($p<0.05$) body weights compared to those reared in winter.

Table 2.7: Weight (g) for age of Koekoek chickens reared in either summer or winter during both rearing and laying phases

	Seasons		
Age (wks)	**Summer**	**Winter**	**S.E**
Rearing phase (10 - 18 weeks)			
(Weights, g)			
10	843.1^{a}	664.4^{b}	5.76
11	1003.0^{a}	695.8^{b}	6.99
12	1121.0^{a}	780.1^{b}	6.07
13	1170.0^{a}	933.1^{b}	5.59
14	1230.0^{a}	938.6^{b}	5.82
15	1333.0^{a}	1095.0^{b}	11.87
16	1402.0^{a}	1088.0^{b}	7.43
17	1442.0^{a}	1270.0^{b}	14.60
18	1547.0^{a}	1223.0^{b}	7.30
Laying phase (19 - 32 weeks)			
19	1722.0^{a}	1359.0^{b}	10.21
20	1725.0^{a}	1471.0^{b}	9.03
21	1780.0^{a}	1571.0^{b}	10.33
22	1881.0^{a}	1617.0^{b}	8.92
23	1998.0^{a}	1659.0^{b}	10.84
24	2071.0^{a}	1740.0^{b}	8.94
25	2137.0^{a}	1800.0^{b}	12.23
26	2220.0^{a}	1851.0^{b}	9.10
27	2165.0^{a}	1908.0^{b}	2.91
28	2312.0^{a}	1916.0^{b}	9.98
29	2096.0^{a}	1942.0^{b}	14.93
30	2344.0^{a}	1931.0^{b}	10.77
31	2384.0^{a}	1922.0^{b}	12.48
32	2373.0^{a}	1965.0^{b}	10.40

^{ab} Means within a row with no common superscript differ significantly ($p<0.05$).

The results as indicated in Table 2.7 reflect the effect of interaction between the feeding level and season. The body weights of Koekoek chickens that were in the AA, AR, RA and RR treatments in summer were 195, 194, 160 and 166g higher than their counterparts in winter at the age of 10 weeks. This shows that birds on the AA and AR performed much better in summer compared to winter. On the RA and RR feeding regimes, birds raised in summer were still heavier than those raised in winter though the differences were not comparable with the other two feeding regimes. At 18 weeks of age the body weights of chickens that were under the AA, AR, RA and RR treatments during the summer were higher than the ones in winter by 21.8%, 21.6%, 20.2% and 19.6% respectively. The final body weights of chickens raised in summer were heavier than the ones in winter despite the level of feeding. The differences between weights of chickens during the summer and winter on the AA, AR, RA and RR treatments were 496, 226, 641 and 270g respectively. This means that birds in the RA followed by the ones in the AA treatment in summer performed much better than those in winter. Similarly, birds on the AR and RR treatment in summer still performed out their counterparts in winter though the differences were lower compared to those that were full-fed during the laying phase.

It was difficult to compare this study with previous ones because of the different environmental temperatures involved. The previous researchers (Bonnet *et al.*, 1997; Plavnik and Yahav, 1998; Yalcin *et al.*, 1997a; Deeb and Cahaner, 1999; Reem and Cahaner, 1999; 2001 and Aksit *et al.*, 2006) regarded high temperatures to be above 32^0C while in this case the summer temperatures ranged from 17 to 24^0C. The winter temperatures in Lesotho can go below 0^oC, whilst the previous researchers were considering 21^0C as a cooler season (Lu *et al.*, 2007). It is therefore believed that the low temperatures in winter had negatively affected the growth of Koekoek chickens because birds utilized some energy from the feeds to generate heat. Summer temperatures in Lesotho did not have a negative effect on the eating pattern of the Koekoek chickens. This could be true because Koekoek chickens were fed in the morning (7.00 am) while the temperatures were still low. However, in a study that compared the performance of birds under different environmental temperatures, Lu *et al.* (2007) reported insignificant differences with respect to final body weights between the local Beijing You chickens. Lu *et al.* (2007) also pointed out that the commercial Arbor Acres chickens that were subjected to high temperatures performed significantly lower than those that were kept at a low temperature. Some studies also concluded that the higher temperatures adversely affect the body weights of commercial chickens (Bonnet *et al.*, 1997; Plavnik and Yahav, 1998; Yalcin *et al.*, 1997a; Deeb and Cahaner, 1999a; 1999b; Reem and Cahaner, 1999; 2001 and Aksit *et al.*, 2006). In a study done in turkeys Veldcamp *et al*. (2005) also indicated that the body weight of turkeys that were exposed to a higher temperature were 19.7% lower than those that were kept at a lower temperature.

Table 2.8: Effect of the interaction between feeding level and season on weight (g) for age of Koekoek chickens

	Treatment*season															
Age (wks)	**SAA**	**S.E**	**WAA**	**S.E**	**SAR**	**S.E**	**WAR**	**S.E**	**SRA**	**S.E**	**WRA**	**S.E**	**SRR**	**S.E**	**WRR**	**S.E**
10	872.1^{a}	6.67	677.1^{b}	7.84	872.1^{a}	8.23	678.1^{b}	7.47	809.4^{a}	7.34	649.9^{b}	8.24	818.8^{a}	7.34	652.6^{b}	8.18
11	1058.0^{a}	22.14	719.5^{b}	20.02	1071.0^{a}	20.99	712.5^{b}	19.07	942.3^{a}	18.75	676.6^{b}	21.41	941.6^{a}	18.95	674.6^{b}	20.87
12	1209.0^{a}	17.18	801.5^{b}	15.45	1202.0^{a}	16.19	805.6^{b}	14.17	1032.0^{a}	14.47	753.9^{b}	16.23	1043.0^{a}	14.62	759.2^{b}	16.11
13	1267.0^{a}	17.82	1006.0^{b}	16.12	1279.0^{a}	16.90	1001.0^{b}	15.36	1055.0^{a}	15.10	860.0^{b}	16.94	1077.0^{a}	15.26	865.1^{b}	16.82
14	1348.0^{a}	16.68	1015.0^{b}	15.08	1330.0^{a}	15.81	1006.0^{b}	14.37	1119.0^{a}	14.13	863.9	15.85	1123.0^{a}	14.28	869.9^{b}	15.73
15	1483.0^{a}	37.92	1175.0^{b}	34.30	1458.0^{a}	35.95	1182.0^{b}	32.67	1207.0^{a}	32.12	1012.0^{b}	36.04	1184.0^{a}	32.47	1011.0^{b}	35.78
16	1577.0^{a}	21.63	1220.0^{b}	19.57	1571.0^{a}	20.50	1218.0^{b}	18.64	1228.0^{a}	18.35	951.7^{b}	20.56	1233.0^{a}	18.52	963.9^{b}	20.41
17	1591.0	4667	1421.0	42.22	1593.0	44.25	1412.0	40.21	1300.0	39.54	1118.0	44.36	1283.0	39.96	1128.0	44.07
18	1768.0^{a}	25.18	1382.0^{b}	22.78	1774.0^{a}	23.88	1391.0^{b}	21.70	1320.0^{a}	21.34	1053.0^{b}	23.94	1325.0^{a}	21.56	1065.0^{b}	23.76
19	1863.0^{a}	32.47	1517.0^{b}	29.38	1784.0^{a}	30.79	1512.0^{b}	27.98	1659.0a	27.51	1210.0^{b}	30.87	1579.0^{a}	27.81	1198.0^{b}	30.64
20	1948.0^{a}	27.93	1624.0^{b}	25.26	1875.0^{a}	26.48	1506.0^{b}	24.06	1603.0^{a}	23.66	1440.0^{b}	26.54	1475.0^{a}	23.91	1313.0^{b}	26.35
21	1950.0^{a}	32.76	1711.0^{b}	29.64	1638.0^{a}	31.06	1638.0^{b}	28.23	1846.0^{a}	27.76	1541.0^{b}	31.14	1684.0^{a}	28.05	1394.0^{b}	30.91
22	2108.0^{a}	30.13	1758.0^{b}	27.25	1898.0^{a}	28.56	1604.0^{b}	25.96	1900.0^{a}	25.52	1636.0^{b}	28.64	1618.0^{a}	25.80	1470.0^{b}	28.43
23	2250.0^{a}	34.87	1790.0^{b}	31.55	1664.0^{a}	33.06	1670.0^{b}	30.05	2207.0^{a}	29.54	1693.0^{b}	33.15	1872.0^{a}	29.86	1482.0^{b}	32.91
24	2295.0^{a}	29.89	1895.0^{b}	27.04	1977.0^{a}	28.34	1658.0^{b}	25.75	2243.0^{a}	25.32	1822.0^{b}	28.41	1771.0^{a}	25.59	186.0^{b}	28.20
25	2422.0^{a}	37.96	1948.0^{b}	34.34	1732.0^{a}	35.99	1739.0^{b}	32.70	2406.0^{a}	32.16	1899.0^{b}	36.08	1989.0^{a}	32.50	1613.0^{b}	35.82
26	2448.0a	30.32	2037.0^{b}	27.45	2034.0^{a}	28.74	1701.0^{b}	26.12	2501.0^{a}	25.68	2005.0^{b}	28.82	1897.0^{a}	25.96	1663.0^{b}	28.61
27	2375.0^{a}	40.80	2080.0^{b}	36.91	1872.0^{a}	38.68	1755.0^{b}	35.15	2379.0^{a}	34.56	2090.0^{b}	38.78	2035.0^{a}	34.93	1707.0^{b}	38.49
28	2546.0^{a}	30.25	2101.0^{b}	27.36	2008.0^{a}	28.68	1697.0^{b}	26.06	2702.0^{a}	25.62	2151.0^{b}	28.75	1990.0^{a}	25.90	1715.0^{b}	28.54
29	2290.0^{a}	46.44	2134.0^{b}	42.02	1896.0^{a}	44.04	1718.0^{b}	40.02	2220.0^{a}	39.35	2182.0^{b}	44.15	1979.0^{a}	39.77	1736.0^{b}	43.83
30	2608.0^{a}	33.17	2131.0^{b}	30.01	1953.0^{a}	31.45	1663.0^{b}	28.58	2803.0^{a}	28.10	2193.0^{b}	31.53	2012.0^{a}	28.40	1738.0^{b}	31.30
31	2653.0^{a}	38.43	2105.0^{b}	34.79	1969.0^{a}	36.47	1669.0^{b}	33.14	2867.0^{a}	32.59	2850.0^{b}	36.56	2045.0^{a}	32.94	1729.0^{b}	36.30
32	2659.0^{a}	31.82	2163.0^{b}	28.78	1925.0^{a}	30.17	1699.0^{b}	27.41	2882.0^{a}	26.96	2241.0^{b}	30.24	2026.0^{a}	27.25	1756.0^{b}	30.02

^{ab} Means within a row with no common superscript differ significantly ($p<0.05$).

Footnote:

SAA-full feeding during rearing and laying in summer season. SAR-full feeding during rearing and restricted during laying in summer season, SRA-restricted feeding during rearing and full feeding during laying in summer season, SRR-restricted during rearing and laying in summer season, WAA-full feeding during rearing and laying in winter season. WAR-full feeding during rearing and restricted during laying in winter season, WRA-restricted feeding during rearing and full-feeding during laying in winter season, WRR-restricted during rearing and laying in winter season, S.E-standard error

Table 2.9: Body weight gain (g) of Koekoek chickens subjected to different feeding level treatments

	Treatment				
Age (wks)	**AA**	**AR**	**RA**	**RR**	**S.E**
Rearing phase (10 - 18 weeks)					
(Weights, g)					
10	117.1[a]	117.6[a]	72.2[b]	78.2[b]	1.36
12	230.4[a]	228.7[a]	163.0[b]	165.2[b]	2.97
14	176.6[a]	163.9[a]	98.6[b]	95.34[b]	2.35
16	217.3[a]	227.0[a]	98.4[b]	102.3[b]	2.57
18	176.3[a]	187.8[a]	97.2[b]	96.3[b]	2.62
8-18	917.8[a]	924.9[a]	529.4[b]	537.4[b]	3.95
Laying phase (20 - 32 weeks)					
(Weights, g)					
20	211.1[a]	107.8[b]	334.9[c]	199.4[d]	3.10
22	146.7[a]	60.4[b]	246.3[c]	149.5[a]	2.71
24	161.8[a]	67.0[b]	264.4[c]	134.7[d]	2.22
26	147.9[a]	49.8[b]	220.5[c]	101.8[d]	3.25
28	80.8[a]	-14.9[b]	173.4[c]	72.3[a]	2.75
30	45.8[a]	-44.6[b]	71.5[c]	22.1[d]	1.96
32	42.3[a]	4.6[b]	63.0[c]	16.0[d]	4.99
19-32	721.7[a]	164.6[b]	1126.0[c]	501.9[d]	6.54
8-32	1754.0[a]	1155.0[b]	1904.0[c]	1234.0[d]	4.99

[abcd] Means within a row with no common superscript differ significantly ($p<0.05$).

Footnote:

AA-full feeding during rearing and laying. AR-full feeding during rearing and restricted during laying, RA-restricted feeding during rearing and full feeding during laying, RR-restricted during rearing and laying, S.E-standard error.

Results in Table 2.9 show that Koekoek chickens that were full-fed during the rearing phase had higher body weight gains ($p<0.05$) compared to those that were feed restricted. Koekoek chickens that were in the AA and AR treatments gained 41.9g more weight than those in the RA and RR treatments at 10 weeks of age. When looking at the cumulative body weight gain for the period covering 10 to 18 weeks, birds in the full-fed group gained significantly more weight than the feed restricted group with an average weight difference of 42.1%. These results suggest that both feeding level groups of Koekoek chickens demonstrated a continuous growth from the 10th week up to the 18th week, which is the expected age for first oviposition. The results from this study displayed a positive correlation of r=0.76 between the total feed intake and the weight gain during the rearing period. This reveals that the more feed the chickens are consuming the faster they will gain weight.

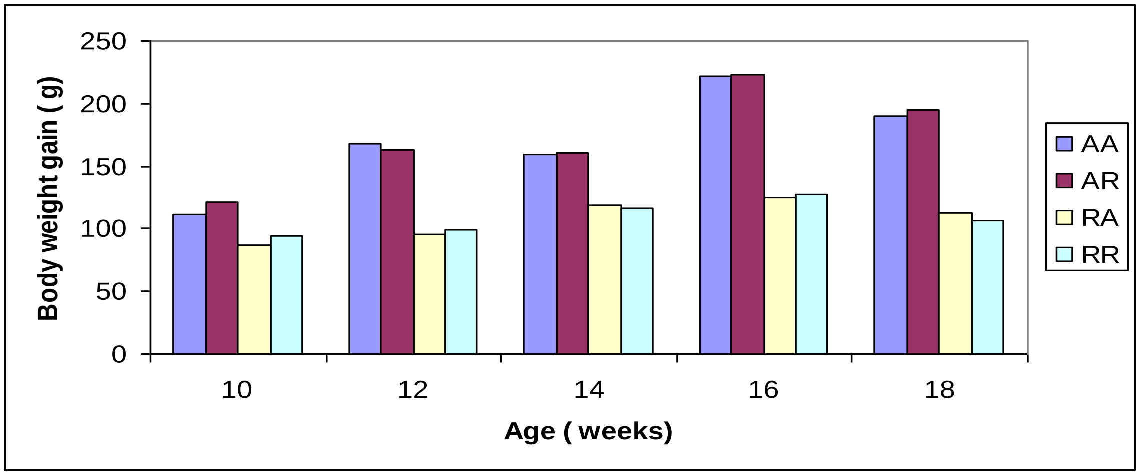

Figure 2.2: Body weight gain of Koekoek chickens subjected to different feeding levels from 10 to 18 weeks
Footnote:
AA-full feeding during rearing and laying. AR-full feeding during rearing and restricted during laying, RA-restricted feeding during rearing and full feeding during laying, RR-restricted during rearing and laying,.

During the laying phase, Koekoek chickens that were subjected to early feed restriction and shifted to unrestricted feeding in the laying phase (RA) gained 34%, 67.8% and 40.5% more ($p<0.05$) weight than those in the AA, AR and RR treatments respectively. Chickens in the AA, RA and RR treatments gained weight throughout the trial period as against those in the AR treatment, which lost body weight effectively from the age of 28 weeks up to the 30th week of the experiment. When considering cumulative body weight gain between the four treatments it can be noticed that the weight gain diferences between birds in the RA treatment and those in the AA, AR and RR treatments were 404.3, 961.4 and 624.1g respectively. The results of this study showed a similar pattern even on the grand commutative weight gains (8 to 32 weeks) with the birds in the AR treatment gaining 599, 749 and 79g less compared to those in the AA, RA and RR treatments respectively. The weight gain was 6.8% among the restricted fed (AR and RR) and 20% between the full-fed ones. A higher weight gain difference was noticed between the full-fed and restricted fed chickens in the laying phase. A positive correlation ($r=0.59$) was experienced between the total feed intake and the grand body weight gain of chickens.

The findings of this study are in agreement with the results of Mahmood *et al.* (2007) who found that a reduced weight gain in restricted fed birds is the result of a reduced feed intake compared to *ad libitum* fed birds. The results of Eitan and Soller (2001) also indicated that the body weight of restricted fed birds was significantly less at first egg compared to those in the control group. Birds that were under restricted feeding reached sexual maturity at a lower body weight than those under *ad libitum* feeding. This is in line with Colin *et al*. (1992) who suggested that feed restriction should be practiced on heavy breeds in order to avoid the excessive amount of body fat in pullets at sexual maturity and that feed restriction would result in targeted body size before birds start to lay.

Eitan and Soller (2001) indicated a gain in body weight of chickens that were feed restricted earlier and later shifted to *ad libitum* feeding. This is in line with the findings of the present study that revealed that Koekoek chickens that were in the RA treatment had better mean body weight gains. This can further be argued in terms of the compensatory growth principle. Birds in the AR treatment lost body weight from the age of 28 weeks and this could be because the limited feeds they were getting were not satisfying their growing demands since it is assumed that chickens would require more feed as they age. The same argument could justifiably be correct as the daily feed requirement for the layers is between 104 to 118g per bird in a complete diet (Douglas and Quart, 1992). Tolkamp *et al*. (2005) indicated that restricted fed birds normally loose weight during the peak laying period because the nutrients intake of birds fails to meet their metabolic requirement, which is believed to be the case in this study.

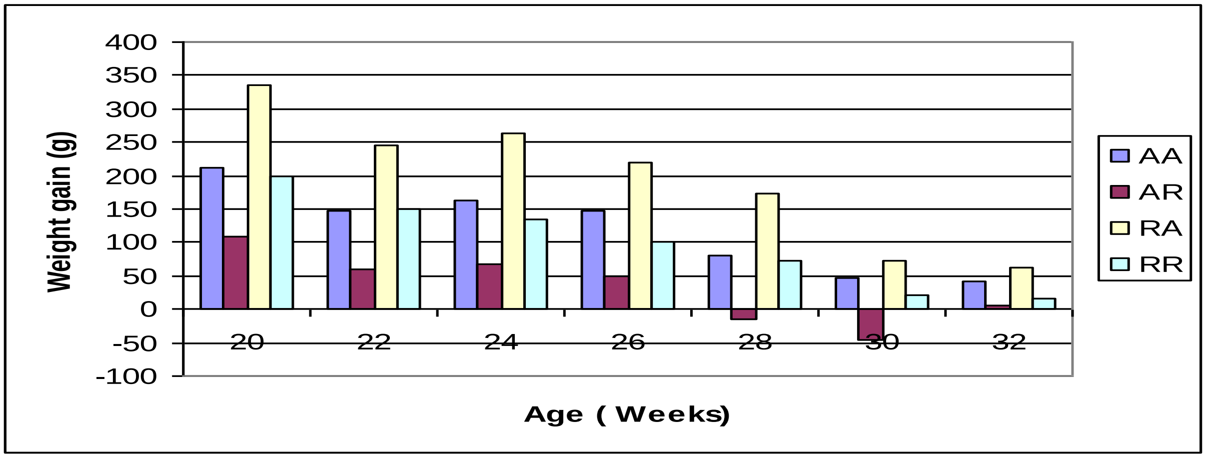

Figure 2.3: Body weight gain of Koekoek chickens subjected to different feeding levels from 20 to 32 weeks
Footnote:
AA-full feeding during rearing and laying. AR-full feeding during rearing and restricted during laying, RA-restricted feeding during rearing and full feeding during laying, RR-restricted during rearing and laying, S.E-standard error.

The results for the influence of season on the weight gain of Koekoek chickens are demonstrated on Table 3.9. These results show that season had an effect on the weight gain of Koekoek chickens. Koekoek chickens gained more ($p<0.05$) body weight in summer than in winter. At the age of 10 weeks, the weight gain difference was 116.3g between chickens that were kept in summer and winter. At puberty (18 weeks) the mean weight gain for Koekoek chickens that were kept in summer was 7% less ($p<0.05$) than in winter.

The differences in the weight gains of birds can be attributed to the seasonal temperature effect. Koekoek chickens that were raised in summer were performing better ($p<0.05$) than those in winter for the first four weeks of the experiment (week 10 to week 14). The assumption for the significant differences at the beginning of the study could be attributed to the fact that at young age the chickens were more exposed to coldness because of less feather coverage hence the other feed portion was used for body heat generation instead of body weight gain.

Table 2.10: Body weight gain (g/d) of Koekoek chickens that were reared either in summer or winter during both rearing and laying phases

	Season		
Age (wks)	**Summer**	**Winter**	**S.E**
Rearing phase (10 - 18 weeks)			
(Weights, g)			
10	185.6^{a}	69.3^{b}	7.07
12	278.0^{a}	115.6^{b}	5.69
14	158.5^{a}	108.7^{b}	2.60
16	172.6	149.9	3.06
18	144.4	134.3	3.04
Overall (10-18)	889.4^{a}	565.3^{b}	0.05
Laying phase (20 - 32 weeks)			
(Weights, g)			
20	178.6^{a}	148.1^{b}	4.08
22	155.4	146.1	2.56
24	190.7^{a}	123.3^{b}	2.37
26	148.8	111.2	5.66
28	91.4	64.4	3.32
30	32.2	15.2	2.64
32	34.0	29.0	2.55
Overall (19-32)	651.5^{a}	605.6^{b}	13.07
Overall (10-32)	1716.0^{a}	1308.0^{b}	12.26

^{ab} Means within a row with no common superscript differ significantly ($p<0.05$).

During the laying phase Koekoek chickens that were kept in summer registered more body weight gains compared to those kept in winter. At the beginning of the laying period (20 weeks) the weight gains for Koekoek chickens were reduced by 17.1% in winter ($p<0.05$). The overall weight gain in winter was 91.5% of the one in summer.

In support of the results of the present study, Akyuz (2009) showed that rearing birds in summer could result in higher body weight gains compared to birds kept in winter though the differences were not significant. In contradiction to the findings of this study, Yalcin *et al.* (1997b) stated that the body weight gain of chickens that are exposed to summer would be less by 23%. Deeb and Cahaner (2001a) also shared the same sentiments. The two studies explain that the reduced weight in summer was because birds had a low feed intake due to heat stress, which the same argument would not apply to the situation in Lesotho as the temperatures can hardly exceed 28^0C. The higher weight gain of Koekoek chickens in summer in this study can be explained by the fact that the majority of feeds consumed in summer contributed mainly to the growth of chickens while in winter the chickens would need some energy for warmth.

Filho *et al.* (2005) reported that higher temperatures normally stimulate hyperthermia and dehydration, which will lead to reduced feed intake and hence delayed growth. In a study done in turkeys Veldkamp *et al.* (2000) also shared the similar view that high temperature would result in significantly lower body weight gains of 22%. This inverse relationship between the environmental temperature and body weight gain of poultry was also reported by Mendes *et al.* (1997). On the other hand, the findings of this study partially confirm the experiment conducted by Blahova *et al.* (2007) who indicated that the effect of temperature on the body weight gain of chicken broilers was not significant. This can be proved by the fact that the insignificant weight gain scores were recorded most of the time except in week 20 and 24 where the significant values were observed between Koekoek chickens that were raised in two different seasons.

In the rearing phase, the results depicted the interaction between the feeding level and season during the first four weeks of the study (10-14 weeks of age). Koekoek chickens that were under the AA, AR, RA and RR in summer gained weight more ($p<0.05$) rapidly than in winter. In this period, the findings revealed that either restricted feeding or full feeding would produce better results in terms of weight gains as long as Koekoek chickens are reared in summer as illustrated in Table 3.9. This indicated that winter conditions hindered the weight gain of Koekoek chickens. The overall weight gain of Koekoek chickens clearly showed a significant interaction between the feeding level and the season. The results pointed that feeding Koekoek chickens unrestrictedly in summer (SAA and SAR) was more beneficial as chickens achieved more body weight as compared to birds that were subjected to other interactive combinations (WAA, WAR, SRA, WRA, SRR and WRR). The chickens that were fed restrictedly in winter (WRA and WRR) evidenced the least in terms of weight gain. This showed that feeding chickens restrictedly in winter possibly disadvantaged the chickens' potential to gain more weight.

During the laying phase (19-32weeks) an interaction ($p<0.05$) was only detected on the 24^{th} and 32^{nd} weeks of age in Koekoek chickens. At the 24^{th} week the results showed that chickens that were in the AA, AR, RA and RR treatments in summer gained 27.2%, 30.8%, 45.9% and 23.7% more body weight (343.3g) than in winter. The weight gain difference was more prominent in the RA treatment. The findings of these results clearly demonstrate that all ages birds that were kept in summer gained more ($p<0.05$) weight than those that were kept in winter irrespective of the treatment. At week 32, the results specify that chickens that were in the RA treatment in summer still gained more (79.02g) weight as compared to chickens in other treatments. These results indicated that chickens that were in the SAR and WAR treatments lost weight from week 28 up to the 30^{th} week with the weight loss extending to the 32^{nd} week in the SAR chickens. This implies that the feed requirements of Koekoek chickens that were in those treatments during laying were higher than what was offered to them. This clearly states that at peak laying chickens will normally lose weight if they are underfed irrespective of the time of the year since it is assumed that some of the energy is used in the development of an egg.

The total weight gain differences between chickens under the AA, AR, RA and RR treatments in summer and winter were 496, 225, 641 and 111.4g respectively. Birds kept in summer performed better in all treatments except in the RR treatment. This means that chickens that were fed more in summer had improved weight gain as compared to feeding chickens restrictedly in winter. This entails that it would be better to restrict Koekoek chickens in summer rather than in winter. In a case where a maximum weight gain is aimed in winter, a farmer should be prepared to use more feed in winter even though the weight gain of Koekoek chickens would still not match the one in summer .

Table 2.11: Effect of the interaction between feeding level and season on weight gain (g/d) of Koekoek chickens

	Treatment* Season															
Age	**SAA**	**S.E**	**WAA**	**S.E**	**SAR**	**S.E**	**WAR**	**S.E**	**SRA**	**S.E**	**WRA**	**S.E**	**SRR**	**S.E**	**WRR**	**S.E**
10	214.6^{a}	8.67	19.6^{b}	7.84	214.6^{a}	8.22	20.6^{b}	7.4	151.9^{a}	7.34	-7.6^{b}	8.24	161.3^{a}	7.42	-4.9^{b}	8.27
12	336.4^{a}	18.92	124.4^{b}	17.12	329.9^{a}	17.94	127.5^{b}	16.3	222.1^{a}	16.03	104.0^{b}	17.98	223.8^{a}	16.20	106.6^{b}	17.85
14	139.8 ^{a}	15.00	213.4^{b}	13.57	127.7^{a}	14.22	200.0^{b}	12.9	87.1^{a}	12.71	110.1^{b}	14.26	80.0^{a}	12.84	110.7^{b}	14.15
16	229.0	16.40	205.6	14.84	241.8	15.55	212.1	14.1	109.0	13.89	87.8	15.59	190.7	16.70	94.0	15.48
18	190.7	16.70	161.9	15.12	202.6	15.83	172.9	14.4	92.6	14.15	101.7	15.87	91.71	14.30	100.8	15.76
10-18	1111^{a}	25.18	724.9^{b}	22.78	1117^{a}	23.88	733.2^{b}	21.7	662.8^{a}	21.34	396.0^{b}	23.94	667.6^{a}	21.56	407.2^{b}	23.76
20	180.2	19.72	241.9	17.84	100.8	18.70	114.9	17.0	282.9	16.71	386.9	18.75	150.3	16.89	248.6	18.61
22	159.4	17.27	134.0	15.62	22.6	16.37	98.1	14.9	296.9	14.63	195.8	16.42	142.6	14.79	156.4	16.30
24	187.3^{a}	14.15	136.3^{b}	12.80	79.2^{a}	13.42	54.8^{b}	12.2	343.3^{a}	11.99	185.6^{b}	13.45	152.8^{a}	12.12	116.6^{b}	13.36
26	153.1	20.69	142.6	18.72	57.3	19.62	42.2	17.8	257.9	17.53	183.1	19.67	126.8	17.72	76.9	19.53
28	97.9	17.55	63.7	15.87	-26.1	16.63	-3.8	15.1	201.1	14.86	145.8	16.68	92.8	15.02	51.7	16.55
30	61.9	12.46	29.7	11.27	-55.1	11.82	-34.2	10.7	79.0	10.56	47.7	11.85	14.2	10.67	18.9	11.76
32	51.3^{a}	11.82	32.8^{b}	10.74	-28.0^{a}	10.56	36.6^{b}	11.9	21.6^{a}	10.67	22.6^{b}	11.76	14.2^{a}	31.82	18.9^{b}	28.70
20-32	795.7	41.64	646.3	37.67	140.7	39.48	187.2	35.9	122.3	35.28	103.10	39.58	446.8	35.6	558.2	39.29
10-32	2002^{a}	31.82	1506^{b}	28.78	1267^{a}	30.17	1042^{b}	27.4	2224^{a}	26.96	1583^{b}	30.24	1369^{a}	27.25	1099^{b}	30.02

^{ab} Means within a row with no common superscript differ significantly ($p<0.05$ and $p<0.01$).

Footnote:

SAA-full feeding during rearing and laying in summer season. SAR-full feeding during rearing and restricted during laying in summer season, SRA-restricted feeding during rearing and full feeding during laying in summer season, SRR-restricted during rearing and laying in summer season, WAA-full feeding during rearing and laying in winter season. WAR-full feeding during rearing and restricted during laying in winter season, WRA-restricted feeding during rearing and full-feeding during laying in winter season, WRR-restricted during rearing and laying in winter season, S.E-standard error

Table 2.12: Feed intake per day (g/d) of Koekoek chickens that were subjected to different levels of feeding

			Treatment		
Age (wks)	**AA**	**AR**	**RA**	**RR**	**S.E**
Rearing phase (10 - 18 weeks)					
(Weights, g)					
10	54.2^{a}	54.4^{a}	42.8^{b}	42.0^{b}	0.143
11	59.8^{a}	59.8^{a}	43.0^{b}	43.0^{b}	0.003
12	63.5^{a}	63.5^{a}	46.0^{b}	46.0^{b}	0.007
13	66.6^{a}	66.5^{a}	48.0^{b}	48.0^{b}	0.007
14	70.8^{a}	70.9^{a}	49.0^{b}	49.0^{b}	0.011
15	80.0^{a}	80.0^{a}	56.0^{b}	56.0^{b}	0.002
16	79.6^{a}	79.6^{a}	56.0^{b}	56.0^{b}	0.043
17	81.4^{a}	81.2^{a}	57.0^{b}	57.0^{b}	0.074
18	83.0^{a}	83.0^{a}	58.0^{b}	58.0^{b}	0.010
8-18	494^{a}	494^{a}	359^{b}	3585^{b}	1.500
Laying phase (19 - 32 weeks)					
(Weights, g)					
19	100.7^{a}	85.0^{b}	88.9^{c}	73.4^{d}	0.135
20	115.0^{a}	83.7^{b}	117.0^{c}	83.9^{b}	0.089
21	117.0^{a}	84.0^{b}	117.2^{a}	84.0^{b}	0.020
22	116.5^{a}	83.9^{b}	116.9^{a}	84.0^{b}	0.056
23	117.2^{a}	84.0^{b}	117.2^{a}	84.0^{b}	0.028
24	117.2^{a}	84.0^{b}	117.2^{a}	84.0^{b}	0.008
25	117.3^{a}	84.0^{b}	117.3^{a}	84.0^{b}	0.015
26	117.4^{a}	84.0^{b}	117.4^{a}	84.0^{b}	0.002
27	117.3^{a}	84.0^{b}	117.3^{a}	84.0^{b}	0.012
28	117.1^{a}	84.1^{b}	117.3^{a}	84.0^{b}	0.018
29	117.1^{a}	84.0^{b}	117.3^{a}	84.0^{b}	0.013
30	117.2^{a}	84.0^{b}	117.4^{a}	84.0^{b}	0.009
31	117.4^{a}	84.0^{b}	117.0^{a}	84.0^{b}	0.003
32	117.4^{a}	84.0^{b}	117.4^{a}	84.0^{b}	0.002
19-32	10530^{a}	7649^{b}	10470^{c}	7569^{d}	1.178
10-32	15480^{a}	12600^{b}	14060^{c}	11150^{d}	1.825

^{abcd} Means within a row with no common superscript differ significantly (p<0.05).
Footnote:
AA-full feeding during rearing and laying. AR-full feeding during rearing and restricted during laying, RA-restricted feeding during rearing and full feeding during laying, RR-restricted during rearing and laying, S.E-standard error.

Koekoek chickens that were not limited on feeding had higher (p<0.05) feed intakes compared to those that were feed restricted for the entire rearing period (Table 2.12). Koekoek chickens that were fed restrictedly were consuming all their feeds that is 70% of the feed supplied to full-fed chickens. At the beginning of the trial, the average feed intake for unrestricted fed Koekoek chickens was 21.9% higher than in the restricted fed chickens. During the final week of the rearing phase, the daily feed consumption was higher in the full-fed chickens than in the restricted fed chickens by 30.1%. The results obtained in this research project are in line with Ukachukwu and Akapan (2007a) who reported that feed restriction in pullets depressed feed intake. The average feed consumption of a Koekoek chicken from 8 to 18 weeks was 70.7g per day for chickens that were full-fed (AA and AR) while an average daily feed intake for restricted fed chickens amounted to 51.29g. Feed restriction programme in the rearing phase was able to save a total of 26.5% of feed per bird in comparison with *ad libitum* feeding.

The initial two weeks of the laying phase indicate that Koekoek chickens from different treatments consumed feeds significantly different from one another. As presented in Table 3.7 the results demonstrate that chickens that were under the AA treatment consumed 15.7, 11.8 and 27.2g/d more ($p<0.05$) feed than those in the AR, RA and RR treatments respectively at the age of 19 weeks. At the age of 20 weeks, the daily feed consumption of birds in the RA treatment was higher than in the AA, AR and RR treatments by 1.7%, 28.5% and 28.3% respectively. The difference was higher ($p<0.05$) in the feed intakes of chickens that were full-fed and those that were feed restricted. The difference between the feed intake of Koekoek chickens in the AR and RR treatments were insignificant. The results of this study clearly showed that from the age of 21 weeks to the end of the experiment chickens that were fed restrictedly had on average lower ($p<0.05$) daily feed intake of 28.2% less than the full-fed chickens.

The total feed intake of birds in the RR treatment differed by 3, 0.08 and 2.9kg per bird from those in the AA, AR and RA treatments respectively. When considering the total amount of feed intake per bird from 8 to 32 weeks it can be seen as presented in Table 4.7 that Koekoek chickens in the AA treatment ate 18.6%, 9.2% and 28% more than those in the AR, RA and RR treatments respectively. The results of this study are in agreement with Ukachukwu and Akpan (2007a) who stated that feed intake appears to be a reflection of the amount of feed made available to the various groups of birds based on the percentage of restriction imposed on each group.

The findings of the current study are in agreement with the previous research reports that reflected a reduced feed intake in early-restricted fed birds (Tumova *et al.*, 2002 and Mohebodini *et al.*, 2009). In support of the results of the current study, Sekoni *et al.* (2002) concluded that restricted fed chickens consumed 30% less feed compared to the *ad libitum* fed ones. Turkeys subjected to restricted feeding had a reduced feed intake in comparison with birds raised on *ad libitum* feeding (Crounch *et al.*, 2002a).

Even though birds that were under AA and RA received the same amount of feed, birds under RA treatment increased their feed intake by 59.06g in a period of two weeks from 18 to 20 weeks while feed intake of birds in the AA treatment increased their feed intake by 31.92g. These results are in agreement with the findings of Naraharl *et al*. (1975) who stated that birds that have been restricted during rearing and then allowed to feed *ad libitum* during laying display increased daily feed intake. The birds that were previously feed restricted and later shifted to *ad libitum* feeding tend to eat more due to an increased appetite (Eitan and Soller, 2001). In support of these results Hassanabadi and Moghaddam (2004) reported that birds that were restricted at an early stage of their development increased their feed intake rapidly in order to get into what the intake would have been if they were not restricted. CIWF (2003) indicated that feed restricted broiler breeders consume their feed in a very short period of time and are chronically hungry and this is demonstrated by the fact that they are strongly motivated to consume feed at all times.

The feed intake of Koekoek chickens that were transferred from full feeding to restricted feeding (AR) increased to 84g per day during the laying period that represent 70% of the full-fed amount that was availed to them. These results disagree with the findings of Krueger (1987) who indicated that birds that were transferred from *ad libitum* feeding to restricted feeding resulted in significantly reduced feed intake. The feed intake of Koekoek chickens in RR treatment agrees with Eitan and Soller (2001) as they suggested that feed intake of the restricted fed chickens' increases between 20-22 weeks of age in restricted fed birds and the same results were observed in the current study. Crounch *et al.* (2002a) made an observation that the feed intake of restricted fed birds resulted in a saving in terms of feed costs and this observation was confirmed by the present study.

The feeding pattern of Koekoek chickens was affected by time of the year (season) as outlined in Table 3.12. The results indicate that Koekoek chickens consumed more feeds in winter than in summer during the growing phase effective from the 11th week of age. The results demonstrate that chickens that were kept in winter had a greater ($p<0.05$) feed intake compared to those raised during the summer. The observations of this study suggested that a Koekoek chicken kept in winter consumed between 48.3g and 78g per day from 10 to 18 weeks of age while a chicken in summer ate between 48.4g and 63g per day. The summer conditions suppressed the overall feed consumption by 12.9% during the rearing phase.

In the laying phase the results indicated that Koekoek chickens that were reared during the winter season ate more ($p<0.05$) layer mash compared to chickens in summer throughout the entire experimental period (19 to 32 weeks). On average chickens that were kept in winter had a daily feed intake ranging from 100.6g to 102g while Koekoek chickens that were kept in summer were consuming between 99.2g and 99.5g daily basis from 19 to 32 weeks.

The findings of the current study are confirmed by previous researchers who stated that the feed intake would be depressed due to high temperature in chickens (Plavnik and Yahav, 1998; Veldkamp *et al.*, 2000; 2005 and Lu *et al.*, 2007). This was observed in Koekoek chickens that were kept in winter, which ate significantly more than those kept in summer from the age of 11 to 18 weeks. On the other hand, the results on the feed consumption for the initial period (10 weeks) of the study contradict the earlier findings. The reason for variation can be attributed to the behavior of chickens when responding to low temperature. The rationale would be that during the early age, birds took more time huddled as a way of generating heat instead of eating. Since the rearing of Koekoek chickens in summer started in September and other group of chickens in March, it might be possible that at the beginning of September the temperatures were still low compared to the ones in March hence why Koekoek chickens on the summer treatment ate significantly more than in winter.

Bonnet *et al.* (1997) also stated a reduction of 30% in feed consumption during the summer season. In a study conducted in turkeys, it was discovered that temperature affected the feed intake of the birds to the point that there was a decline of 1.6 % in feed intake per a one degree Celsius increase (Veldkamp *et al.,* 2000; Blahova *et al.*, 2007 and Akyuz, 2009). Since chickens live comfortably in a narrowly thermo neutral zone the extreme temperatures either being low or high would negatively affect the feed intake of chickens hence why it was noted from this study that birds in winter clearly showed an increased appetite. The increased appetite in winter is also due to fact that birds would eat more as some of the feed consumed will be used for the chickens' heat generation.

Table 2.13: Feed intake per day (g/d) of Koekoek chickens reared either in summer or winter season during both rearing and laying phases

	Seasons		
Age (wks)	**Summer**	**Winter**	**S.E**
Rearing phase (10 - 18 weeks)			
(Weights, g)			
10	48.4	48.3	0.29
11	51.7^{a}	52.2^{b}	0.05
12	54.0^{a}	55.5^{b}	0.01
13	56.5^{a}	58.0^{b}	0.01
14	57.8^{a}	62.1^{b}	0.02
15	58.0^{a}	78.0^{b}	0.00
16	57.6^{a}	78.0^{b}	0.09
17	60.4^{a}	77.93	0.15
18	63.0^{a}	78.0^{b}	0.02
Overall 10-18	3970^{a}	4558^{b}	3.00
Rearing phase (19 - 32 weeks)			
(Weights, g)			
20	99.2	100.6	0.18
21	99.2^{a}	101.9^{b}	0.04
22	99.5^{a}	101.1^{b}	0.11
23	99.5^{a}	101.8^{b}	0.06
24	99.2^{a}	102.0^{b}	0.02
25	99.2^{a}	102.1^{b}	0.03
26	99.4^{a}	102.0^{b}	0.00
27	99.2^{a}	102.0^{b}	0.02
28	99.3^{a}	101.9^{b}	0.04
29	99.2^{a}	101.9^{b}	0.03
30	99.4^{a}	102.0^{b}	0.02
31	99.4^{a}	102.0^{b}	0.01
32	99.4^{a}	102.0^{b}	0.00
Overall 19-32	905	9060	2.36
Overall 10-32	1303^{a}	13620^{b}	3.65

^{ab} Means within a row with no common superscript differ significantly p<0.05), S.E-standard error

The results indicate the interaction between the feeding level and the season of the year excluding the 10th week. The highest feed intakes were recorded in chickens that were in the AA and AR treatments in winter while the lowest feed intake was observed in chickens that were in the RA and RR treatments in summer. The accumulated daily feed consumption differences in the AA, AR, RA and RR treatments in winter and summer were 725, 713, 463 and 451g respectively during the rearing phase. The difference was much higher in the full-fed chickens than in the restricted fed groups.

At 20 weeks of age, it was observed that Koekoek chickens that were in the AA and RA treatments in winter ate more than those that were in other treatments. During the same period, the lowest feed intake was recorded in chickens that were in the AR and RR treatments regardless of the rearing season with the average feed intake ranging from 82.8g to 84g per day. This implies that chickens that were fed restrictedly were able to consume all the feed they were fed. The chickens that were fed *ad libitum* in summer had a daily average feed intake ranging from 114g to 115.9g. Similar results were noticed for the whole study period (19 to 32 weeks) of Koekoek chickens during the laying phase. The overall feed intakes for the period of 14 weeks show that the chickens in the AA and RA treatments in winter were higher than in winter by 1.7% and 0.5% respectively. In the AR and RR treatments, the feed intake was higher in summer with the difference of 0.2% and 2.3% between summer and winter. The reason for the feed intake differences in Koekoek chickens that were full fed but kept in different seasons could be due to a reduced amount of feed intake in chickens during the summer season because of the increased environmental temperature in a way to control their body temperatures.

In view of the total feed intake for the entire research study the findings portrayed that Koekoek chickens that were in the AA treatment had higher feed intake in spite of the season while those in the RR treatment ate the lowest amount regardless of the season. Koekoek chickens that were changed from either restricted feeding to full feeding (RA) or visa versa (AR) in winter consumed more than those in summer. In the AR and RA treatments the feed consumption in winter deviated by 5.3% and 3.6% from that in winter. These results also portray that Koekoek chickens will have lower daily feed intake when shifted from full feeding to restricted feeding during the laying phase as opposed to shifting from restricted feeding in the rearing phase to full feeding during the laying phase.

Table 2.14: Effect of the interaction between feeding level and season on feed intake per day (g/d) of Koekoek chickens

Treatment*Season																
Age (wks)	**SAA**	**S.E**	**WAA**	**S.E**	**SAR**	**S.E**	**WAR**	**S.E**	**SRA**	**S.E**	**WRA**	**S.E**	**SRR**	**S.E**	**WRR**	**S.E**
10	54.7	0.91	53.7	0.83	54.71	0.87	54.7	0.79	42.1	0.77	43.5	0.87	42.1	0.78	41.9	0.86
11	58.7^{a}	0.24	61.0^{b}	0.22	58.68^{a}	0.23	60.9^{b}	0.21	42.6^{a}	0.20	43.4^{b}	0.23	42.6^{a}	0.20	43.4^{b}	0.23
12	62.0^{a}	0.04	65.0^{b}	0.03	62.0^{a}	0.04	65.0^{b}	0.04	46.0^{a}	0.36	46.0^{b}	0.04	46.0^{a}	0.04	46.0^{b}	0.04
13	65.1^{a}	0.04	68.0^{b}	0.04	65.1^{a}	0.04	68.0^{b}	0.04	48.0^{a}	0.04	48.0$_{b}$	0.04	48.0^{a}	0.04	48.0^{b}	0.04
14	66.6^{a}	0.07	75.1^{b}	0.07	66.6^{a}	0.07	75.1^{b}	0.06	48.9^{a}	0.06	49.2^{b}	0.07	48.9^{a}	0.06	49.1^{b}	0.07
15	67.0^{a}	0.01	93.0^{b}	0.01	67.0^{a}	0.01	93.0^{b}	0.01	49.0^{a}	0.01	63.0^{b}	0.01	49.0^{a}	0.01	63.0^{b}	0.01
16	66.48^{a}	0.28	92.9^{b}	0.25	66.4^{a}	0.26	92.7^{b}	0.23	48.8^{a}	0.23	63.3^{b}	0.26	48.8^{a}	0.24	63.3^{b}	0.26
17	70.11^{a}	0.47	92.6^{b}	0.42	70.4^{a}	0.44	92.0^{b}	0.40	10.5^{a}	0.40	63.6^{b}	0.45	50.5^{a}	0.40	63.6^{b}	0.44
18	72.96^{a}	0.06	93.0^{b}	0.06	73.0^{a}	0.06	93.0^{b}	0.05	53.0^{a}	0.05	63.0^{b}	0.06	53.0^{a}	0.05	63.0^{b}	0.06
10-18	4579^{a}	9.55	5304^{b}	8.64	4584^{a}	9.06	5297^{b}	8.23	3359^{a}	8.09	3822^{b}	9.08	3359^{a}	8.18	3810^{b}	9.01
19	114.7^{a}	0.86	8664.5^{b}	0.78	84.1^{a}	0.82	85.9^{b}	0.75	114.9^{a}	0.73	62.9^{b}	0.82	84.1^{a}	0.74	62.9^{b}	0.82
20	116.1^{a}	0.56	113.8^{b}	0.50	85.2^{a}	0.53	82.2^{b}	0.48	115.9^{a}	0.47	118.1^{b}	0.53	85.0^{a}	0.48	82.8^{b}	0.52
21	114.4^{a}	0.13	119.6^{b}	012	84.0^{a}	0.12	84.0^{b}	0.11	114.4^{a}	0.11	120.0^{b}	0.12	84.0^{a}	0.11	84.0^{b}	0.12
22	114.8^{a}	0.35	118.1^{b}	0.32	84.3^{a}	0.34	83.6^{b}	0.31	114.6^{a}	0.30	119.1^{b}	0.34	84.2^{a}	0.30	83.7^{b}	0.33
23	114.7^{a}	0.18	119.8^{b}	0.16	84.2^{a}	0.17	83.8^{b}	0.15	114.7^{a}	0.15	119.8^{b}	0.17	84.2^{a}	0.15	83.8^{b}	0.17
24	114.4^{a}	0.05	120.0^{b}	0.04	84.0^{a}	0.05	84.0^{b}	0.04	114.3^{a}	0.04	120.0^{b}	0.05	84.0^{a}	0.04	84.0^{b}	0.09
26	114.8^{a}	0.01	120.0^{b}	0.01	84.0^{a}	0.01	84.0^{b}	0.01	114.8^{a}	0.01	120.0^{b}	0.01	84.0^{a}	0.01	84.0^{b}	0.01
27	114.7^{a}	0.07	120.0^{b}	0.07	84.1^{a}	0.07	84.0^{b}	0.06	114.7^{a}	0.06	120.0^{b}	0.07	84.0^{a}	0.06	83.9^{b}	0.07
28	114.3^{a}	0.11	119.9^{b}	0.10	84.1^{a}	0.10	83.9^{b}	0.01	114.7^{a}	0.09	119.9^{b}	0.10	84.1^{a}	0.09	83.9^{b}	0.10
29	114.2^{a}	0.08	119.9^{b}	0.07	84.1^{a}	0.08	83.9^{b}	0.07	114.6^{a}	0.07	119.9^{b}	0.08	84.1^{a}	0.07	83.9^{b}	0.08
30	114.5^{a}	0.05	120.0^{b}	0.05	84.1^{a}	0.05	84.0^{b}	0.05	114.8^{a}	0.05	120.0^{b}	0.05	84.0^{a}	0.05	84.0^{b}	0.05
31	114.8^{a}	0.02	120.0^{b}	0.02	84.0^{a}	0.02	84.0^{b}	0.02	114.8^{a}	0.02	120.0^{b}	0.02	84.0^{a}	0.02	84.0^{b}	0.02
32	114.8^{a}	0.01	120.0^{b}	0.01	84.0^{a}	0.01	84.0^{b}	0.01	114.8^{a}	0.01	120.0^{b}	0.01	84.0^{a}	0.01	84.0^{b}	0.01
19-32	1044^{a}	7.40	1062.^{b}	6.70	765.9^{a}	7.01	763.9^{b}	6.37	1045^{a}	6.27	1050^{b}	7.03	765.7^{a}	6.33	748.2^{b}	6.98
10-32	1503a	11.65	1593^{b}	10.54	1226^{a}	11.05	1294^{b}	10.04	1380^{a}	9.87	1432^{b}	11.08	1102^{a}	9.98	1129^{b}	11.00

^{ab} Means within a row with no common superscript differ significantly ($p<0.05$ and $p<0.05$).

Footnote:

SAA-full feeding during rearing and laying in summer season. SAR-full feeding during rearing and restricted during laying in summer season, SRA-restricted feeding during rearing and full feeding during laying in summer season, SRR-restricted during rearing and laying in summer season, WAA-full feeding during rearing and laying in winter season. WAR-full feeding during rearing and restricted during laying in winter season, WRA-restricted feeding during rearing and full-feeding during laying in winter season, WRR-restricted during rearing and laying in winter season, S.E-standard error.

Table 2.15: Feed conversion ratio of Koekoek chickens that were subjected to different feeding level treatments

			Treatment		
Age (weeks)	**AA**	**AR**	**RA**	**RR**	**S.E**
Rearing Phase (10 -18weeks)					
10	3.5^{a}	3.5^{a}	4.2^{b}	4.0^{b}	0.05
12	3.7	3.7	3.9	4.0	0.05
14	5.4^{a}	6.5^{a}	7.3^{b}	7.4^{b}	0.20
16	5.4^{a}	5.1^{a}	8.0^{b}	7.8^{b}	0.09
18	5.0^{a}	4.7^{a}	6.3^{b}	6.3^{b}	0.10
10-18	5.5^{a}	5.4^{a}	6.8^{b}	6.7^{b}	0.60
Laying Phase (20-32weeks)					
20	7.4^{a}	11.8^{b}	4.4^{c}	6.2^{d}	0.17
22	9.9	-6.1	11.4	12.0	5.10
24	10.8^{a}	21.3^{b}	6.7^{c}	8.9^{a}	0.35
26	11.8^{ab}	27.2^{c}	9.5^{a}	12.4^{b}	0.46
28	22.3	15.7	7.3	14.8	3.63
30	47.8^{a}	-60.0^{b}	34.5^{a}	55.3^{a}	4.59
32	65.3	-6.6	8.4	-2.01	17.09
20-32	15.0^{a}	46.3^{b}	9.4^{a}	15.8^{a}	3.47
10-32	8.9^{a}	11.0^{b}	7.5^{c}	9.1^{a}	0.03

^{abcd} Means within a row with no common superscript differ significantly ($p<0.05$).

Footnote:

AA-full feeding during rearing and laying. AR-full feeding during rearing and restricted during laying, RA-restricted feeding during rearing and full feeding during laying, RR-restricted during rearing and laying, S.E-standard error.

Results shown in Table 3.14 indicate the significant difference in FCR between Koekoek chickens that were full-fed and those that were feed restricted during the growing phase. Koekoek chickens that were in the AA and AR treatments were more efficient in feed conversion than those in the RA and RR treatments by 14.6% at the age of 10 weeks. The same trend of the results was observed throughout the growing phase and the only exception was at the 12th week of which the FCR difference between the different feeding levels was not significant. The overall FCR scores for full-fed and restricted fed chickens were 5.5 and 6.8 respectively during the rearing phase. The results of this study suggest that full-fed chickens converted feeds into body weight better than feed restricted chickens.

During the laying phase Koekoek chickens that were in the RA treatment had better ($p<0.05$) feed conversion ratio from the first oviposition up to the end of the experiment (32 weeks) than chickens that were in other treatments (AA, AR and RR). When looking at the overall FCR for the laying period (20-32 weeks) it was seen that chickens that were subjected to the RA treatment were more efficient in feed coversion than chickens that were in the AA, AR and RR treatments by 37.3%, 79.7% and 40.5%

respectively. The FCR of the chickens in the RA treatment improved by 18.7%, 46.7% and 21.3% more than in the AA, AR and RR treatments respectively for the entire study (10 to 32 weeks).

The findings of this study are not in line with Farhat *et al.* (1986) who reported that restricted feeding resulted in slower feed passage rate (FPR) through the digestive system hence an increase in the utilization of feed. Farhat *et al.* (1986) further argued that feed restriction lengthens the time in which the feeds are in contact with the enterocytes and as a result, the nutrient absorption will improve. The fact that chickens that were subjected to the RA treatment were able to convert more feed into weight is supported by the findings of Farhat *et al.* (1986) who stated an increase in FCR when restricted feeding is followed by *ad libitum* feeding in chickens. Farhat *et al.* (1986) also mentioned that a feed restriction of 25% in layers would yield better results in terms of compensatory growth and feed conversion ratio.

The findings of this study indicate a significant difference between the seasons of summer and winter in feed conversion efficiency of Koekoek chickens (Table 3.15). The results indicate that chickens that were raised in summer were more efficient in conversion of feeds into body development as compared to chickens that were raised in winter. It was observed that the feed conversion ratio was better ($p<0.05$) in chickens reared in summer compared to those kept in winter and the same pattern of results was observed throughout the rearing period (10-18 weeks). The summer conditions improved ($p<0.05$) the overall FCR for the rearing phase by 43.6%.

During the laying period (20 to 32 weeks) the results show that Koekoek chickens that were kept in summer were not different ($p>0.05$) from chickens that were kept in winter for the entire laying period except during the 32nd week of age. However, even though the FCR values were not statistically different, one would recognize that Koekoek chickens that were subjected to warm environment conditions had lower FCR for the entire laying period of the study as compared to chickens that were reared in winter. At the age of 32 weeks Koekoek chickens that were under summer treatment had better (224.1) FCR as compared to the ones that were subjected to winter conditions (-191.00) at 0.05 siginficant level. When looking at an average feed conversion ratio from 10 to 32 weeks, the results show the difference ($p<0.05$) of 30% between the chickens reared in summer and winter with the latter having a higher FCR.

Table 2.16: Feed conversion ratio (FCR) of Koekoek chickens reared in either summer or winter during both rearing and laying phases

	Season		
Age (wks)	**Summer**	**Winter**	**S.E**
Rearing phase (10 - 18 weeks)			
10	0.4^{a}	7.1^{b}	0.24
12	2.4^{a}	5.2^{b}	0.44
14	6.8	6.5	0.23
16	5.3^{a}	7.9^{b}	0.15
18	6.5^{a}	7.8^{b}	0.07
10-18 weeks	4.4^{a}	7.8^{b}	0.15
Laying phase (20 - 32weeks)			
20	8.8	6.1	0.56
22	-41.7	55.3	0.23
24	10.1	13.7	0.49
26	13.1	16.5	1.10
28	32.7	-2.5	1.95
30	5.3	33.5	13.39
32	224.1^{a}	-191.0^{b}	34.51
Overall 20-32	31.5	23.9	6.67
Overall 10-32	7.9^{a}	10.5^{b}	0.07

^{ab} Means within a row with no common superscript differ significantly ($p<0.05$), S.E-standard error.

These results are confirmed by the findings of Akyuz (2009) who reported a better-feed conversion ratio of chickens raised in summer than those kept in winter. According to Faria *et al.* (2005), chickens raised under high temperature would perform better than those exposed to cold temperature but lower than the ones kept under a thermo-neutral environment. The results of the present study indicate that exposure of chickens to cold environment greatly affected their feed conversion ratio (FCR) and this is in accordance with Blahova *et al*. (2007) who conducted their study in a more or less similar environmental condition to Lesotho. In their study, the low temperature was between 4 and 13^{o}C while the thermo-neutral environment would be from 21 to 24^{o}C. Mendes *et al.* (1997) also concluded that chickens that were under either cold or hot temperature had high feed conversion ratio as compared with those under thermo-neutral conditions. In another study, which was done on turkeys, Veldkamp *et al*. (2000) indicated that the feed conversion ratio was better in turkeys that were kept under high temperature as opposed to their counterparts. However, the findings of Bonnet *et al.* (1997), Veldkamp *et al.* (2005) and Lu *et al.* (2007) reported an improved feed conversion ratio in birds kept in low temperatures as opposed to those kept in high temperatures. The insignificant differences between chickens that were kept in summer and winter can be because chickens had fully developed their feathers at this stage hence the feeds given to chickens in winter were converted to body weight rather than keeping birds warm as in growing chicks.

The results indicated that there was an interaction between the feeding level and the season at the 10th, 12th and 18th weeks of age (Table 3.16). The overall performance in the rearing phase also reveals that the chickens in summer were efficient in feed conversion. The performance of the chickens in the AA, AR, RA and RR treatments in summer were more efficient than in winter by 50.5%, 50.3%, 37.8% and 37.4% respectively. The difference between the chickens raised in summer and winter was higher in the AA and AR treatments in comparison with those in the RA and RR treatments. In general, these results signified the efficiency of chickens kept in summer in converting feed into muscles more than in winter.

At the age of 32 weeks, the results indicate that Koekoek chickens ate more to gain body weight in all treatments as compared to the time when chickens were still young. The best ($p<0.05$) FCR (172.3) was seen in chickens that were in the AR treatment in summer while those that were in the RR treatment in winter had the negative FCR (-230). Chickens in the AA, RA and RR treatments in summer had the FCRs of 277.6, 220.2 and 226 respectively. This indicates that chickens in those treatments were growing very slowly during the last two weeks of this study. This can be supported by the fact that at peak laying period chickens have a tendeny to gain less weight as a characteristic of laying chicken. A negative FCR in the AA (-147), AR (-185), RA (-203) and RR (-230) treatments in winter is alleged to have been contributed by the impact of low temperature and high laying percentage of chickens at this period. It is contemplated that during the laying period a lot of feed is converted into egg laying instead of weight gain hence a negative feed conversion.

The total FCR still reflects that chickens that were in the AA, AR, RA and RR treatments in summer were 32.1%, 15.1% and 19% more efficient in converting feeds than in winter. The findings of the present study suggest that the better FCR results were obtained when feed restricting chickens in summer as compared to feeding chickens unlimitedly in winter. As reflected in these results the highest FCR was observed in chickens that were in the AR treatment in winter and this means that shifting chickens from full feeding to restricted feeding (AR) compromised their efficiency in converting feed into body weight as opposed to shifting from restricted feeding to full feeding (RA). The results of this study also revealed that Koekoek chickens that were feed restricted for the entire study (RR) in winter ate less feed to gain weight in comparison to those that were only feed restricted during the laying phase (AR) irrespective of being raised in either winter or summer.

Table 2.17: Effect of the interaction between feeding level and season on feed conversion ration of Koekoek chickens

	Treatment*season															
Age (wks)	**SAA**	**S.E**	**WAA**	**S.E**	**SAR**	**S.E**	**WAR**	**S.E**	**SRA**	**S.E**	**WRA**	**S.E**	**SRR**	**S.E**	**WRR**	**S.E**
10	- 0.1^{a}	0.32	7.0^{b}	0.29	0.1^{a}	0.31	6.9^{b}	0.28	1.0^{a}	0.27	7.4^{b}	0.31	0.7^{a}	0.28	7.2^{b}	0.30
12	1.9^{a}	0.35	5.4^{b}	0.31	2.0^{a}	0.33	5.4^{b}	0.30	2.8^{a}	0.29	3.0^{b}	0.30	5.0^{a}	0.33	3.0^{b}	0.30
14	5.8	1.28	5.1	1.16	7.4	1.21	5.6	1.10	6.9	1.08	7.6	1.22	7.2	1.09	7.7	1.21
16	-4.2	0.58	6.6	0.52	3.6	0.55	6.6	0.50	6.7	0.49	9.4	0.55	6.6	0.49	9.4	0.55
18	5.7	0.63	4.3	0.57	5.3	0.59	4.1	0.54	7.4	0.53	5.1	0.59	7.4	0.54	5.2	0.59
10-18	3.6^{a}	0.18	7.3^{b}	0.16	3.6^{a}	0.17	7.2^{b}	0.16	5.2^{a}	0.15	8.4^{b}	0.17	5.1^{a}	0.15	8.2^{b}	0.17
20	9.1	1.07	5.7	1.01	11.5	1.01	12.2	0.96	6.2	0.90	2.8	1.06	8.5	0.91	3.8	1.06
22	-37.5	31.47	57.3	29.60	-66.6	29.80	54.3	28.32	-33.2	26.57	56.0	31.09	-29.4	26.86	53.4	31.21
24	8.4	2.17	13.2	2.04	20.9	2.06	21.7	1.95	3.7	1.83	9.8	2.15	7.6	1.85	10.20	2.15
26	11.8	2.83	11.8	2.67	26.5	2.68	27.8	2.55	7.2	2.39	11.8	2.80	10.3	2.42	14.4	2.81
28	47.7	22.39	-3.0	21.06	14.5	21.21	16.9	20.15	31.2	18.91	-16.5	22.12	37.4	19.11	-7.7	22.21
30	17.4	28.34	78.3	26.66	-44.1	26.84	-75.9	35.50	9.9	23.93	59.2	28.00	38.3	24.19	72.2	28.11
32	277.6	105.50	-147.0	99.24	172.3	99.92	-185.0	94.93	220.2	89.07	-203.0	104.24	226.1	90.05	-230.0	104.64
20-32	10.2	21.40	19.5	20.13	94.0	20.27	46.2	19.26	6.2	18.07	13.3	21.14	15.5	18.27	16.5	21.22
10-32	7.2	0.19	10.6	0.18	10.1	0.18	11.9	0.18	5.8	0.16	9.3	0.19	8.1	0.17	10.0	0.19

^{ab} Means within a row with no common superscript differ significantly ($p<0.05$)

Footnote:

SAA-full feeding during rearing and laying in summer season. SAR-full feeding during rearing and restricted during laying in summer season, SRA-restricted feeding during rearing and full feeding during laying in summer season, SRR-restricted during rearing and laying in summer season, WAA-full feeding during rearing and laying in winter season. WAR-full feeding during rearing and restricted during laying in winter season, WRA-restricted feeding during rearing and full-feeding during laying in winter season, WRR-restricted during rearing and laying in winter season, S.E-standard error.

The results on mortality are non-significant between Koekoek chickens that were under different feeding regimes (Table 2.17). During the growing phase (10 to 18 weeks) the total mortality in birds that were full-fed (AA and AR) was 3.7% while the mortality of restricted fed Koekoek chickens (RA and RR) was 2%. Even though the results obtained from the present study reflect insignificant mortality rate of full-fed chickens compared to those that were allotted to restricted feeding it was noticed that full-fed chickens had 1.7% more death incidents than restricted fed ones.

During the laying phase, the death rate in Koekoek chickens was 2.5%, 1.6% , 1.6% and 1.9% for birds in treatments AA, AR, RA and RR respectively. As observed in Table 3.17 Koekoek chickens that were full-fed for the entire study (AA) had an insignificantly higher number of dead chickens compared to those that were in other treatments (p>0.05).

Table 2.18: Mortality (%) of Koekoek chickens that were subjected to different feeding level treatments

	Treatments				
Age	**AA**	**AR**	**RA**	**RR**	**S.E**
10 – 18 weeks **(**rearing phase**)**	2.98	4.29	1.43	2.50	0.73
20 -32 weeks (laying phase)	2.51	1.59	1.59	1.85	0.57

Food note:
AA-full feeding during rearing and laying. AR-full feeding during rearing and restricted during laying, RA-restricted feeding during rearing and full feeding during laying, RR-restricted during rearing and laying, S.E-standard error.

The results obtained from this study on the rearing phase are in agreement with Tottori *et al.* (1997); Lippens *et al*. (2000) and Robert (2009) who indicated that feed restriction is effective in controlling mortality. Balnave (1984) also demonstrated that a feed restriction of 25 to 50% could reduce mortality in birds. The results of the present study suggest that a 30 percent feed restriction slightly lowered the mortality rate in Koekoek chickens. This slight decrease in the death rate of chickens that were under restricted feeding cannot be underestimated as this would a mean a lot to a subsistence farmer in the rural village in Lesotho.

During the laying phase, the results of this study contradict previous findings that stated that the higher percentage of mortality in the full-fed chickens could possibly result from high body weight that is associated with pathological conditions and metabolic disorders such as ascites (Farhat *et al.*, 1986; Tolkamp *et al*., 2005 and Mahmood *et al*., 2007). CIWF (2003) stated that *ad libitum* fed breeding chickens are more prone to obesity, thermal discomfort, lameness as well as skeletal disorders, heart failure and excessive body weight that are all associated with reduced disease resistance. Naraharl *et al*. (1975) stated that mortality is reduced from 19.3 to 10.5% in crossbred strains when restricted feeding follows *ad libitum* feeding. Lippens *et al*. (2000) suggested that a mild feed restriction might offer economic advantage by decreasing mortality, and better feed conversion efficiency. The reason for the results of the present study differing from the previous ones could be attached to the different types of chicken breeds studied. Koekoek chickens can survive even under adverse management as opposed to exotic commercial breeds, which are more vulnarable.

During the growing phase, which is from 10 to 18 weeks the results clearly showed that Koekoek chickens that were allocated to winter treatment increased mortality by 3% (3.18). During the laying phase (19 to 32 weeks), the results show the insignificant differences in the mortality rates of Koekoek chickens that were subjected to different seasons. However, Koekoek chickens that were subjected to winter conditions had a higher percentage (2.8 %) of dead chickens compared to the mortality rate of less than 1% (0.9%) in chickens that were reared in summer. The reason behind the insignificant mortality rate differences could likely be attributed to the feather coverage of chickens at this production stage.

Table 2.19: Mortality percentage of Koekoek chickens that were reared in either summer or winter during both rearing and laying phases

	Season		
AGE	**Summer**	**Winter**	**S.E**
8-18	1.13^{a}	4.46^{b}	0.71
19-32	0.93	2.84	0.59

^{ab} Means within a row without a common superscript differ significantly (p<0.05) , S.E- Standard Error

In support of these results, Cooper and Washburn (1998) reported the low mortality of chickens that were either kept in high or moderate temperature. The other factor for the lower mortality can also be attributed to the fact that Koekoek chickens are believed to be hardy and adaptable to the local environmental conditions as reported by Joubert (1996). However, the previous findings of Petracci *et* *al.* (2006) recorded a higher number of deaths in summer as compared to winter in both turkeys and broilers, which could be explained by the high environmental temperature and hence the occurrence of heat stress. The explanation for Koekoek chickens in winter to die more than those in summer could possibly be attached to the type of the housing chickens were kept in. This can further be argued by the fact that the corrugated iron sheets are extremely cold in winter especially at night bearing in mind that the temperatures in Lesotho can drop below $0^{o}C$. It was also observed that at the age of 8 weeks, the chickens' feathers were still developing and hence why chickens were more susceptible to coldness.

The results of the present study show an insignificant effect of the interaction between feeding level and season on the mortality rate of Koekoek chickens during both rearing and laying phases (Table 3.19). However, the records demonstrate that Koekoek chickens that were reared in winter irrespective of whether they were full fed or restricted fed had insignificantly highest mortality rate ($p>0.05$). This implies that the effects of chickens' mortality rate in the present study can be linked more to the low winter temperatures while the feeding level seems to have contributed very little.

Table 2.20: Effect of the interaction between feeding level and season on mortality (%) of Koekoek chickens

	Treatment* season															
Age	**SAA**	**S.E**	**WAA**	**S.E**	**SAR**	**S.E**	**WAR**	**S.E**	**SRA**	**S.E**	**WRA**	**S.E**	**SRR**	**S.E**	**WRR**	**S.E**
8-18	1.67	2.06	4.29	1.91	1.42	1.91	8.57	1.91	1.42	1.91	1.42	1.91	0.00	2.06	5.00	2.06
19-32	1.85	1.76	3.17	1.63	0.00	1.63	3.17	1.63	0.00	1.63	3.17	1.63	1.85	1.76	1.85	1.76

Footnote:

SAA-full feeding during rearing and laying in summer season. SAR-full feeding during rearing and restricted during laying in summer season, SRA-restricted feeding during rearing and full feeding during laying in summer season, SRR-restricted during rearing and laying in summer season, WAA-full feeding during rearing and laying in winter season. WAR-full feeding during rearing and restricted during laying in winter season, WRA-restricted feeding during rearing and full-feeding during laying in winter season, WRR-restricted during rearing and laying in winter season, S.E-standard error.

2.4 Conclusion

- Full feeding during the rearing phase improved ($p<0.05$) body weight, weight gain, feed intake and FCR compared to restricted feeding.
- Early feed restriction followed by full feeding (RA) resulted in higher body weights, weight gain and FCR compared to the other treatments tested in this experiment.
- The feeding level did not have any effect on the mortality rate of Koekoek chickens.
- Rearing Koekoek chickens in winter is more risky in terms of mortality rate.
- Summer conditions resulted in better body weights, weight gain, FCR and less feed intake.
- 70 percent feed restriction during the rearing phase followed by full feeding in the laying phase (RA) in summer is the most profitable strategy.

2.5 Recommendations

- It is recommended that farmers who intend to keep Koekoek chickens beyond 18 weeks of age to feed them restrictedly during the rearing and shift to full feeding during the laying phase (RA).
- In the case where chickens are reared exclusively for the purpose of meat consumption and with the intention of slaughtering the birds at an earlier age, full feeding (AA and AR) in the rearing phase would be the best feeding management option.
- In order to capitalize on body weight, FCR and to lower mortality rates it is best to raise Koekoek chickens in summer.

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CHAPTER 3

Effect of restricted feeding and season on the carcass characteristics of Koekoek chickens

Abstract

This experiment was conducted to evaluate the impact of feed restriction and season on carcass characteristics of Koekoek chickens. Two hundred and seventy hens and twenty-seven cocks were randomly allocated to four treatments in a completely factorial randomized design being AA, AR RA and RR. The trial was done in summer and winter. Each treatment had seven replicates (10 animals per replicate) with the exception of the RR treatment that had six replicates (10 animals per replicate). Collected data was subjected to SPSS (17.00) package and analyzed by using multifactorial analysis of variance (ANOVA). Feed restriction resulted in reduced slaughter weight, defeathered weight, dressing weight, skin weight, breast muscle weight, shank width, chest width and heart girth in the rearing phase. Intestine weight, liver weight and abdominal fat weight were higher in chickens that were full-fed. Chickens that were allocated to summer treatment had higher shank width, slaughter weight, defeathered weight, chest width, heart girth, breast muscle weight, skin weight and the relative skin percentage. Shank length, dressing percentage and the muscle dressing percentage were higher in chickens that were reared in winter. Chickens that were reared in summer had higher abdominal fat weight, abdominal fat percentage, intestine weight and liver weight. Chickens that were raised in winter registered higher absolute and relative gizzards weights. Abdominal fat weight, abdominal percentage, intestine percentage, liver weight, gizzard weight and gizzard percentage were higher in *ad libitum* fed chickens. The season demonstrated a role on the performance of internal organs of chickens.

Key words: Koekoek chickens, full-fed, feed restriction, carcass characteristics, abdominal fat, organs, season and temperature.

3.1 Introduction

For many years, indigenous poultry production has been a major supplier of poultry meat at village level in Lesotho though this is difficult to quantify, given the unavailability of statistics. Nutritionally, people eat poultry meat for its high quality protein and its low fat content. Animal protein sources like mutton are very expensive, whereas beef has a limited use due to its high cholesterol content. Therefore, chicken production may help in reducing the gap between supply and demand of animal protein. Higher amount of fat has become a major concern in poultry industry due to its health hazards and this has forced a significant number of people to shift to lean poultry meat (Attia *et al.,* 1998; Novele *et al.*, 2008).

Restricted feeding is one of the management strategies in reducing carcass fat in chickens. The study of Melnychuk *et al*. (2004) reported a higher fat content in full fed broiler breeder hens as opposed to restricted fed ones at sexual maturity. Broiler chickens raised on restricted feeding during the rearing period and later shifted to normal feeding programme usually have reduced carcass fat and low incidences of leg disorders (McGovern *et al.*, 2000). Some studies showed that feed restriction improves the relative breast muscle percentage of broiler breeder chickens (Renema *et al.,* 1999a; Crounch *et al.*, 2002c and Melnychuk *et al.*, 2004). In a study done on Large White turkey hens Crounch *et al.* (2000c) stated feed restriction as a course of decrease in the breast muscles, shank lengh and width. Feed restriction lowered the intestine weight of the broiler chickens as explained by Novele *et al.* (2008) and Yagoub and Babiker (2008). The greater liver and gizzard weights were reported in *ad libitum* fed broiler chickens (Renema *et al.*, 1999a; Pishnamazi *et al.*, 2008).

The season in which chickens are reared has a significant role in the carcass characteristics of birds. Broiler chickens reared in summer result in accumulted abdominal fat pad (Blahova *et al*., 2007). The increased temperature reduces the breast muscle, liver and gizzard and intestine weights of broiler chickens (Aksit *et al.,* 2006; Rosa *et al.*, 2007 and Rajini *et al.,* 2009).

Therefore, in the interest of reducing the carcass fat and improving the quality of carcass characteristics in Koekoek chickens this study was focused mainly on the level of feeding management of Koekoek chickens at different seasons of the year.. The information on the carcass characteristics of Koekoek chickens will assist poultry farmers in rural communities to sustainable produce quality and desirable chicken at affordable feeding costs at different seasons of the year.

3.2 Materials and Methods

Two hundred and seventy (270) hens and twenty- seven (27) cocks of Koekoek chickens were bought at eight weeks of age. The chickens were housed in twenty- seven (27) pens. Ten hens and one cock were randomly selected and placed in each pen. The chickens were given a stress pack in water to combat traveling stress and lasoda vaccine in water to prevent Newcastle disease. They were fed pullet grower mash from arrival day up to 18 weeks of age, and then fed laying mash from 19 to 32 weeks. Koekoek chickens under restricted feeding were fed 70% feeds of the full-fed. Chickens were offered fresh water without restriction and fed the same commercial feeds but at different quantities per day. The experiment was designed as a four feeding levels × two seasons (summer and winter) factorial arrangement in a completely randomized design.

Table 3.1 Description of different feeding levels in Koekoek chickens during the rearing and laying phases

Treatments	**Description of feeding treatments**
AA	Chickens were full-fed during rearing (8-18 weeks) and laying phases (19-32 weeks).
AR	Chickens were full-fed in the rearing phase (8-18 weeks) and shifted to restricted feeding during the laying phase (19-32 weeks).
RA	Chickens were fed restricted feeding during rearing phase (8-18 weeks) and shifted to full feeding in the laying phase (19-32 weeks).
RR	Chickens were fed restricted feeding in the rearing (8-18 weeks) and laying phases (19-32 weeks).

Treatment AA, AR and RA were replicated seven (7) times except treatment RR that was replicated six (6) times. Therefore, there were twenty-seven (27) experimental units.

At 18 and 32 weeks of age, one Koekoek chicken (hen) per replicate was slaughtered from chickens that were allocated to AA, AR, RA and RR treatments. Birds were starved for 12 hours before slaughtering. The slaughtering procedure was followed as outlined by Jones (1984). The slaughter weights (body weights) for chickens were determined just before slaughtering. Post slaughter weights (weight after bleeding) were taken. Birds were weighed again after plucking (defeathered weight). Then birds were eviscerated and dissected. The dead birds were weighed individually. Carcass dressing weight, liver weight, gizzard weight, skin weight, intestinal weight and abdominal fat weight were taken using a digital weighing scale. Fat surrounding the gizzard and intestine extending within the ischium and surrounding the bursa of fabricus was considered as abdominal fat. The shank length and heart girth were measured by measuring tape while shank width as well as chest width were measured using Vernier Caliper. Chest width was measured by placing a caliper under the wings, 2.5 cm posterior to the cranial. The chest (heart girth) girth was measured using a tape at the widest point on the breast positioned under the wings and this measurement was taken during exhalation (Renema *et al.,* 2007). Chest and shank measurements are considered to be growth and development monitoring parameters in chickens. The pectoralis major muscle and pectoralis minor muscle (breast muscles) were removed and weighed. The relative weight percentage of all the carcass components was based on the slaughter weight.

The collected data was entered on to a computer Excel Spread Sheet. Data was transformed and then subjected to SPSS (17.00) package and analyzed with the use of multifactorial analysis of variance (ANOVA). The arrival weights of birds were used as covariates. The significant levels were based on $p<0.05$ unless otherwise stated. The experiment was done in summer and winter seasons.

3.3 Results and Discussion

3.3.1 Effect of restricted feeding and season on carcass characteristics of Koekoek chickens at 18 and 32 weeks of age

The results on the carcass characteristics of Koekoek chickens are presented in Tables 3.2 and 3.3. These results indicate a significant effect of restricted feeding and season on a number of carcass traits of Koekoek chickens at 18 and 32 weeks of age. A significant difference was recorded between the two groups of birds that were under different feeding levels namely the full-fed and restricted feeding. Birds that were full-fed (AA and AR) weighed 370g higher than those that were reared under feed restriction (RA and RR). The relative percentage of the defeathered weight suggests that apart from accelerating body weight of chickens full feeding also had a significant effect in the development of feathers. The results of the present study indicate that in the full-fed chickens 13.5% of the body weight was contributed by feathers while in restricted fed chickens, feathers contributed 17.2 to 19.1 % of the slaughter weight. This suggests that chickens that were exposed to restricted feeding either had faster feather development compared to those that had free access to feeding or they were not losing their feathers as fast as the ones that were full-fed. The results from this study also indicated a positive ($p<0.01$) correlation ($r=0.953$) between the slaughter weight and defeathered weight.

Table 3.2: Carcass characteristics of Koekoek chickens that were subjected to different feeding level treatments

			Treatments			
Parameters	**AA**	**AR**	**RA**	**RR**		**S.E**
Rearing phase (18 weeks)						
Shank length (mm)	66.6	65.3	65.9	65.7		0.25
Shank width (mm)	8.9^{a}	8.7^{a}	8.1^{ab}	8.0^{b}		0.10
Slaughter weight (g)	1743^{a}	1697^{a}	1339^{b}	1361^{b}		2.52
Post slaughter wt (g)	1677^{a}	1647^{a}	1292^{b}	1293^{b}		12.62
Defeathered wt (g)	1502^{a}	1471^{a}	1100^{b}	1103^{b}		4.04
Defeathered %	86.2^{a}	86.7^{a}	82.6^{b}	80.9^{b}		0.49
Chest width (mm)	53.5^{a}	50.3^{a}	45.8^{b}	44.2^{b}		0.59
Chest girth (mm)	266.0^{a}	263.5^{a}	249.4^{b}	239.6^{b}		1.95
Dressing weight (g)	1229^{a}	1168^{ab}	948.5^{b}	940.4^{b}		9.60
Dressing. %	70.6	69.1	71.0	69.1		0.44
Muscle breast wt (g)	107.7^{a}	99.1^{a}	87.1^{b}	81.2^{b}		2.03
Muscle breast %	4.1^{a}	4.1^{a}	5.4^{b}	5.2^{b}		0.05
Skin wt (g)	120.4^{a}	114.1^{a}	83.4^{b}	83.5^{b}		0.81
Skin %	6.9^{a}	6.7^{a}	6.2^{b}	6.1^{b}		0.08
Laying phase (32 weeks)						
Shank length (mm)	69.6^{a}	68.6^{ab}	69.6^{a}	67.3^{b}		0.38
Shank width (mm)	12.1^{a}	10.9^{b}	11.3^{b}	$11.^{ab}$		0.13
Slaughter weight (g)	2372^{a}	1888^{b}	2351^{a}	1824^{b}		19.6
Defeathered wt (g)	2221^{a}	1732^{b}	2210^{a}	1533^{b}		35.2
Defeathered %	93.9	92.0	94.2	84.8		1.80
Chest width (mm)	65.2^{a}	61.4^{ab}	63.9^{a}	59.3^{b}		0.34
Chest girth (mm)	293.3^{a}	271.9^{b}	290.9^{a}	267.8^{b}	1	0.65
Dressing weight (g)	1723^{a}	1369^{b}	1707^{a}	1264^{b}		1.42
Dressing %	72.2	72.7	72.0	69.2		0.92
Muscle breast wt (g)	124.6^{a}	91.9^{b}	127.5^{a}	102.8^{b}		3.12
Muscle breast %	5.2	4.8	5.5	5.6		0.14
Skin wt (g)	175.1^{a}	125.6^{b}	159.6^{c}	122.0^{b}		2.7 7
Skin %	7.5^{a}	6.7^{b}	6.8^{ab}	6.7^{b}		0.12

^{ab} Means within a row without a common superscript differ significantly ($p<0.05$).
Foot note:
AA-full feeding during rearing and laying. AR-full feeding during rearing and restricted during laying, RA-restricted feeding during rearing and full feeding during laying, RR-restricted during rearing and laying, S.E-standard error.

During the laying phase, birds that were full-fed (AA and RA treatments) had heavier ($p<0.05$) slaughter weights and defeathered weights than those that were fed restrictedly (AR and RR treatments). The slaughter weights of chickens that were under the AA treatment were 484, 21 and 548g heavier than those under the AR, RA and RR treatments respectively. The observed defeathered weight measurements were 2221g, 1732g, 2210g and 1533g for birds that were in the AA, AR, RA and RR treatments respectively. The non-significant difference between Koekoek chickens that were in the AA and RA treatments signify the compensatory growth pattern shown by birds that were feed restricted earlier and later shifted to full feeding (RA). The fact that the slaughter weights of birds that were feed restricted for the entire study (RR) were not insignificantly different (p>0.05) from birds that were in the AR treatment suggests that birds in the RR group grew at the constant rate from rearing to laying phase which might be because of their bodies being acclimatized to the lower level of feeding. The results also demonstrated a good relationship between the feed intake and weight gain on both slaughter and defeathered weights.

Table 3.3: Carcass characteristics of Koekoek chickens reared in either summer or winter

	Season		
Parameters	**Summer**	**Winter**	**S.E**
Rearing phase (18 weeks)			
Shank length (mm)	64.4^{a}	67.41^{b}	0.51
Shank width (mm)	9.8^{a}	7.1^{b}	0.20
Slaughter weight (g)	1673^{a}	1397^{b}	25.03
Weight after slaughter (g)	1617^{a}	1337^{b}	25.24
Defeathered weight (g)	1383^{a}	1205^{b}	28.05
Defeathered %	82.3^{a}	86.0^{b}	0.98
Chest width (mm)	60.4^{a}	36.7^{b}	1.19
Chest girth (mm)	260.2^{a}	249.0^{b}	0.91
Dressing weight (g)	1141^{a}	1002^{b}	19.2
Dressing %	68.4^{a}	71.6^{b}	0.88
Muscle breast %	4.1^{a}	5.3^{b}	0.12
Muscle breast wt (g)	108.4^{a}	79.2^{b}	4.07
Skin wt (g)	114.6^{a}	86.1^{b}	1.63
Skin %	6.8^{a}	6.2^{b}	1.15
Laying phase (32 weeks)			
Shank length (mm)	66.9^{a}	70.6^{b}	0.75
Shank width (mm)	10.8^{a}	12.1^{b}	0.26
Slaughter weight (g)	2332^{a}	1885^{b}	39.29
Defeathered weight (g)	2115^{a}	1733^{b}	70.40
Defeathered %	90.4	92.0	3.40
Chest width (mm)	70.2^{a}	54.8^{b}	0.69
Chest girth (mm)	294.5^{a}	267.4^{b}	3.31
Dressing weight (g)	1715^{a}	1317^{b}	42.84
Dressing %	73.1	69.9	1.83
Muscle breast wt (g)	23.7	99.6	6.54
Muscle breast w %	5.3	5.3	0.28
Skin wt (g)	152.6^{a}	138.6^{b}	5.55
Skin %	6.5^{a}	7.1^{b}	0.24

^{ab} Means within a row without a common superscript differ significantly (p<0.05), S.E=Standard Error.

The results of this study indicate that the mean slaughter weight of Koekoek chickens that were shifted from restricted feeding to full feeding (RA) at 32 weeks of age was mainly contributed by the carcass weight rather than the feathers even though it was not different from chickens that were full-fed for the entire study (AA). The relative feather weight percentage of chickens that were in the RA treatment was lower than in the AA, AR and RR treatments by 0.3%, 2.2% and 10.1% respectively. The slaughter weight was highly ($p<0.01$) positively correlated ($r=0.813$) with the defeathered weight. This positive relationship suggests that the differences in the slaughter weights of Koekoek chickens were not because of the weights of the feathers.

The results of the current study are in agreement with the findings of Richards *et al.* (2003) who pointed out that birds that were on restricted feeding had significantly lower body weights compared to the *ad libitum* fed chickens. Vakali *et al.* (2000) and Bochno *et al* (2007) shared the same sentiments in demonstrating higher body weights of broilers that were fed on a daily basis compared to those that were under the skip a day treatment.

It was not possible to relate the effect of restricted feeding on defeathered weight in chickens because this subject has not been dealt with in previous studies and therefore the findings of this study should be regarded as the reference to the studies that would follow.

Table 3.3 illustrated that chickens that were reared in summer had a higher slaughter weight compared to those that were subjected to winter conditions at 18 and 32 weeks of age. The chickens that were raised in summer were 16.5% and 19.2% higher than in winter at 18 and 32 weeks of age respectively. Despite the absolute defeathered weights being higher in chickens that were reared in summer it was revealed that an average relative defeathered percentage of chickens that were kept in winter was higher than the defeathered percentage of those that were exposed to warm summer conditions. These results clearly show that the featherweight contributed to dissimilar slaughter weights of chickens that were kept in different seasons. The featherweight contributed 17.7% of total slaughter weight in Koekoek chickens that were reared in summer while featherweight contribution in those that were under winter treatment was only 13% at the age 18 weeks. Fourteen weeks later (32 weeks) chickens that were on summer treatment had a higher ($p<0.05$) absolute defeathered weight (2115g) in comparison with chickens that were raised under winter conditions (1733g). These results indicate that chickens that were raised under warm conditions had more feather coverage than the ones that were raised under cool conditions. Therefore, the present results suggest that birds in summer treatment were more efficient in converting feeds into both meat and feathers than those that were raised in winter. It is assumed that more protein was used for energy in winter and less was left for feathering.

The results show no interaction ($p>0.05$) between the effect of restricted feeding and season on the slaughter weight and defeathered weight of Koekoek chickens (Table 4.6). The findings of the present results show the interactive effect ($p<0.01$) of feeding level and season on the defeathered percentage of chickens at the age of 18 weeks. The results indicate that chickens that were in the AA and AR treatments in winter had a higher ($p>0.01$) defeathered percentage than those that were in the AA and AR during the summer by approximately 2.18%. This implies that Koekoek chickens that were reared in winter had a lower ($p<0.05$) feather percentage than chickens that were kept in summer regardless of the feeding level. The differences in the feather performance of chickens could be possibly because chickens were using some of the energy to generate heat in winter as opposed to feather development. The other scenario that might have contributed to less feather coverage in winter could be the stress effect, which could have prompted moulting in chickens.

During the laying phase (32 weeks), feeding level and season interaction ($p<0.01$) affected the slaughter weight of chickens. The highest slaughter weight (2724g) was obtained in chickens that were in the AA treatment in summer (SAA) followed by chickens that were full-fed only during the laying phase (RA) in summer (SRA) with slaughter weight of 2677g. The lowest slaughter weights were recorded in chickens that were under feed restriction (RR and AR) in winter with the slaughter weights of 1713g and 1784g respectively. The results on an effect of the feeding level and season interaction on defeathered weight as shown in Table 4.6 reflect the same pattern as in slaughter weight performance.

The defeathered weight performance of chickens in the AA, AR, RA and RR treatments in summer were 22.7%, 2.6%, 21.4% and 22.6% higher than in winter. In terms of defeathered percentage, the results reflected the non-significant differences between chickens that were subjected to various feeding level treatments. These results imply that the differences in the defeathered weights of chickens that were subjected to different interactive treatments were mainly due to the differences in the slaughter weights of chickens.

The results of the present study suggest that the summer conditions in Lesotho do not influence negatively the growth parameters of Koekoek chickens. This shows that Lesotho temperatures are only a problem in winter for the production traits that are related to growth. Therefore, these results cannot be compared with previous studies, which stated that high temperature would negatively affect the final body weights of chickens because of the reduced appetite caused by increased environmental conditions (Yalcin *et al.*, 1997a; Deeb and Cahaner, 1999; Aksit *et al.*, 2006; Plavnik and Yahav, 1998). The reason for being incomparable is attached to the fact that summer conditions in Lesotho cannot go as high as the 32°C that was observed in the previous studies.

The chickens that were full-fed had heavier absolute dressing weights than those in the restricted feeding with the difference of 254g. The similar carcass dressing percentages between the different treatments signify that the differences in the dressing weights were because of the different slaughter weights. This can be verified by a higher ($p<0.01$) correlation ($r = 0.939$) between slaughter weight and dressing weight of Koekoek chickens. The slaughter weight and the relative carcass dressing percentage were inversely correlated ($r = -0.312$, $p<0.05$) at the age of 18 weeks (Table 3.3).

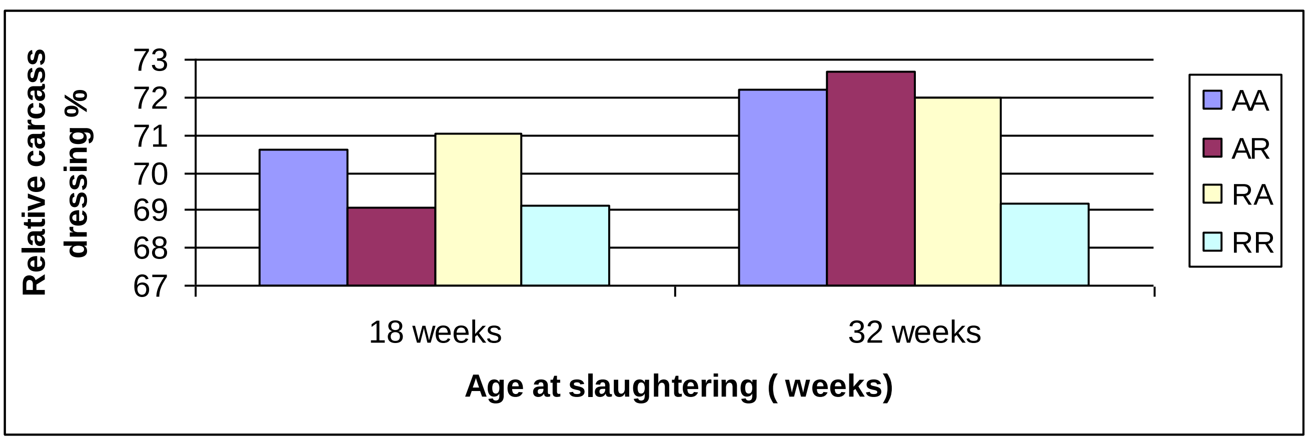

Figure 3.1: The carcass dressing percentage of Koekoek chickens subjected to different feeding levels

Footnote:
AA-full feeding during rearing and laying. AR-full feeding during rearing and restricted during laying, RA-restricted feeding during rearing and full feeding during laying, RR-restricted during rearing and laying..

Koekoek chickens that were full-fed (AA and RA) in the laying phase had heavier ($p<0.05$) carcass dressing weights than those that were under restricted feeding. The insignificant differences in carcass dressing weights between chickens that were in the AA and RA treatments illustrate that birds that were in the RA treatment had a compensatory growth. This can be verified by the fact that chickens that were in the RA treatment had carcass dressing weight increase of 758.5g as opposed to those in the AA, AR and RR treatment with the carcass dressing increments of 429g, 201g and 323.6g respectively. The fact that chickens that were in the AR treatment gained the lowest dressing weight between 18 and 32 weeks of age proved the point that they took some time to acclimatize to restricted feeding unlike those that were fed restrictedly for the entire study (RR). The similar dressing percentages between the four feeding level treatments imply that the differences ($p<0.05$) in the dressing weights could simply be attached to slaughter weights differences of chickens subjected to different treatments. The results of this study demonstrated a relationship ($p<0.01$; $r = 0.936$) between the slaughter weight and the carcass dressing weight while the correlation between slaughter weight and the carcass dressing percentage was 0.279 (Table 3.3).

In support of these results, Saleh *et al.* (2005) demonstrated that male broilers that were in the *ad libitum* feeding significantly had higher carcass dressing weight compared with the feed restricted chickens. The study by Yagoub and Babiker (2008) also indicated a similar carcass dressing performance of broiler chickens that were subjected to either *ad libitum* or restricted feeding which is in line with the findings of the present study.

Contrary to the findings of the present study, Mahmood *et al*. (2007) observed non-significant differences on the dressing weight between broiler chicken groups that were kept on feed restriction programmes of various durations. Novele *et al*. (2008) also reported that chickens that were on 50% *ad libitum* feeding had a lower dressing percentage than those on *ad libitum.* This partially contradicts the findings of the present study that clearly showed that the carcass dressing percentage of Koekoek chickens that were in the RR treatment was 2.8% less than the dressing percentages of those that were at one time during the course of the study exposed to full feeding. The results show an insignificant increase in carcass dressing percentage between chickens that were slaughtered at 18 and 32 weeks of age across the four feeding level treatments (Figure 3.1). This tells us that the carcass dressing percentage does not increase or decrease with age in Koekoek chickens.

The average carcass weights in summer were 12.2% and 23.2% higher than in winter at 18 and 32 weeks of age respectively. However, the relative dressing percentage was higher ($p<0.05$) in chickens that were allocated to cold winter conditions (71.6%) than the ones of birds that were exposed to warm summer condition (68.4%). The relative dressing percentage of chickens exposed to different seasons was not significant at 32 weeks of age. The results also portrayed an interaction ($p<0.01$) between feeding level and season on the carcass dressing performance of Koekoek chickens (Table 4.6). At the age of 18 weeks, an average carcass dressing weight of chickens that were full-fed in summer was 5.1% higher than in winter. The results on the carcass dressing weight demonstrated that chickens that were reared in summer always performed better than their counterparts reared in winter. With reference to the carcass dressing percentage the difference between chickens that were subjected to the AA and AR treatments in winter and summer was 1.9%. These results indicate that chickens that were reared in winter out-competed those that were kept in summer regardless of whether they were full-fed or feed restricted.

During the laying phase (32 weeks) the dressing weights in Koekoek chickens that were in the AA and RA treatments in summer were 650 and 660g respectively higher than those in winter. The differences in the dressing weights of chickens in the AR and RR treatments in summer and winter were 100 and 190g respectively. This means that the difference between the chickens that were reared in summer and winter was much better in the full feeding regime than in the restricted feeding regime during the laying phase. In spite of the differences in the carcass dressing weights of chickens it was revealed that there was no interaction ($p>0.05$) between the feeding level and season on the carcass dressing percentage. This implies that the differences in the carcass dressing weights were due to the different slaughter weights between the different interactive treatments of Koekoek chickens at 32 weeks of age.

It was not possible to compare this study on the effect of season on dressing weight of chickens with previous studies due to the unavailability of literature on this subject and therefore the findings of this study could probably be used as the basis for the future studies. However, the carcasses dressing performance of chickens followed the same pattern as the slaughter weight and in that way the same arguments that were used on slaughter weight would still apply on an effect of season on the dressing weight.

There were significant differences observed on the skin weights between Koekoek chickens that were full-fed and restricted fed. During the growing phase (18 weeks), birds that were full-fed were 33.8g and 8.8% heavier ($p<0.05$) than the feed restricted chickens in terms of absolute and relative skin weight. The differences ($p<0.05$) in the relative skin percentages between the full-fed and restricted fed chickens imply that the differences in the skin weights were not primarily due to the differences that were observed in the slaughter weights of chickens. These results suggested that the absolute and relative skin weights were positively correlated with slaughter weights of chickens. These results disclosed that heavier chickens had higher skin weights. The slaughter weight had a positive ($p<0.01$) correlation with the absolute skin weight ($r =0.881$) and relative skin percentage ($r = 0.357$). During the laying phase (32 weeks), the skin weight of birds that were in the RR treatment was only different from the one in the AA treatment with a difference of 30.3%. Chickens that were slaughtered at 18 and 32 weeks of age had almost similar relative skin percentages.

In this study, it was established that there was a positive relationship (($p<0.01$; $r =0.743$) between slaughter weight and skin weight because the more the bird had access to feed intake, the more the skin weight gained. Relative skin percentage did not correlate significantly ($r=-0.106$) with slaughter weight (Table 3.4). No information is available in the literature on the effect of restricted feeding on relative skin percentage in chickens. The present data probably provide a good estimate of the effects of restricted feeding on the relative skin percentage in Koekoek chickens and could probably be used as a base line study.

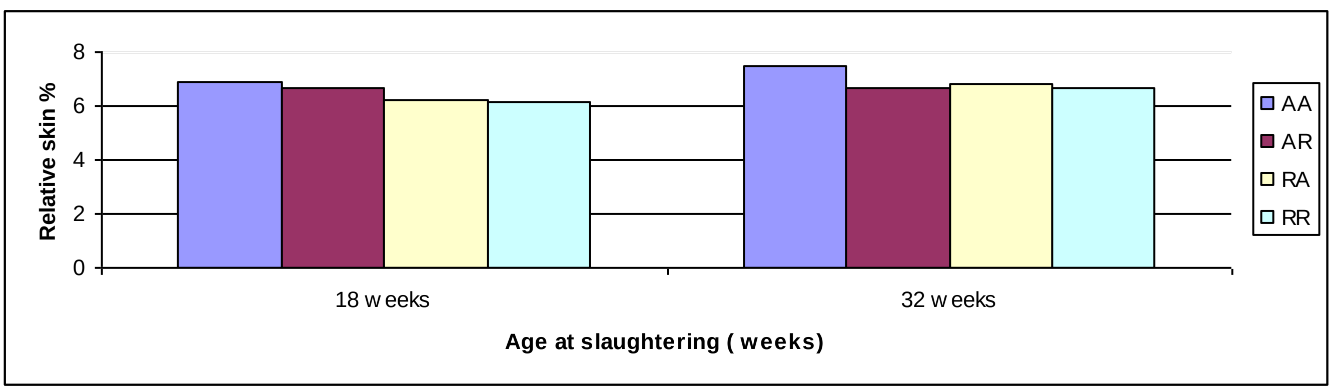

Figure 3.2: The relative skin weights of Koekoek chickens that were subjected to different feeding levels
Footnote:
AA-full feeding during rearing and laying. AR-full feeding during rearing and restricted during laying, RA-restricted feeding during rearing and full feeding during laying, RR-restricted during rearing and laying, S.E-standard error.

The results illustrate that the average, the absolute and relative skin weights of chickens were higher in summer than in winter by 24.9% and 8.2% respectively at 18 weeks of age (Table 3.5). The skin weights of chickens that were kept in summer corresponded positively with the body weights of chickens. During the laying phase, chickens that were reared in summer had heavier skin weight by 14g but the relative skin percentage was lower by 8.5% than in winter. The reason why the skin weight was relatively higher in chickens that were kept in winter could possibly be attached to their low laying performance as well as an increased feed intake in winter. Chickens in winter were consuming comparatively more than in summer and at the same time their laying performance was significantly reduced which might have been due to the reduced number of sunlight hours chickens were receiving per day. In that way it is possible that chickens were storing a lot of fat, hence they had fatty skins in winter, which influenced the skin weight.

As demonstrated in Table 3.6 the results pointed out an effect of feeding level and season interaction ($p<0.01$) on the skin performance of Koekoek chickens. In the rearing phase (18 weeks), birds that were full-fed and restricted fed in summer were on average 26.7% and 7.4% respectively heavier than in winter. The results on how the interaction between feeding level and season affected the relative skin percentage of Koekoek chickens showed that the differences in the skin weights were not because of the differences in the slaughter weights but were due to interactive treatment effects.

During the laying phase the results indicate that the skin weights of chickens in the AA, AR and RA treatments in summer were higher ($p<0.05$) than in winter by 30, 4.3 and 30g respectively. On the RR treatment the skin weight was lower ($p<0.05$) in summer (118g) compared to winter (126g). On the other hand, the relative skin percentage of chickens that were full-fed in winter (WAA) was higher in summer by 1.9%. The results of the present study demonstrate that chickens that had higher ($p<0.05$) relative skin percentages were those were reared in winter as opposed to those kept in summer.

There was no difference ($p>0.05$) on shank length observed between the full-fed and restricted fed chickens during the rearing phase (Table 3.1). The findings also portrayed an insignificant correlation between the slaughter weights and the shank lengths of Koekoek chickens. These results imply that the growth of shank lengths was statistically similar ($p>0.05$) regardless of the significant differences in the slaughter weights of chickens. During the laying phase (32 weeks) it was observed that Koekoek chickens that were in the AA (69.6mm) and RA (69.6mm) treatments had the longer ($p<0.05$) shanks than those in the AR (68.6mm) and RR(67.3mm) treatments. These results indicate a non-significant correlation (r= -0.2) between chickens' slaughter weight and shank length. This reveals that shank lengths of chickens did not positively correspond with the slaughter weights. These results imply that the shank length cannot be used as an estimate for either the slaughter weight or carcass dressing weight in Koekoek chickens.

The results of this study are in agreement with the findings of Pishnamazi *et al*. (2008) who observed no difference in the shank lengths of the broiler breeders aged 12 or 16 weeks. In addition, Ingram *et al*. (2001) reported that shank length was less sensitive to feed restriction as well as keel length and head width. Renema *et al*. (1999a) and Yu *et al.* (1992) indicated that restricted fed birds had significantly shorter shank lengths in comparison with those in the *ad libitum* feeding. They also showed that restricted fed birds had shank length of 9.2 cm with 1.9kg body weight in comparison to *ad libitum* fed chickens that had 10.8cm with body weight of 4.2kg.

The shanks of chickens that were raised in winter were 5.5% longer than in summer. During the laying phase it was discovered that Koekoek chickens that were subjected to summer conditions had shorter ($p<0.05$) shanks compared to those that were exposed to lower winter temperatures. Birds that were reared in winter had an average shank length of 70.6 mm which was longer ($p>0.05$) than those of chickens that were exposed to summer conditions (66.92 mm). This showed that Koekoek chickens that were subjected to cold winter conditions had longer ($p<0.05$) shanks from rearing up to laying phase. The results depicted non-significant interaction between restricted feeding and season on the shank length at the age of 18 and 32 weeks.

These results imply that the heavier chickens in summer had reduced shank lengths while the small body weights of chickens that were kept in winter resulted in longer shanks. The longer shanks in chickens that were raised in winter suggest that the reduced body weight was not suppressing the vertical growth of the shanks. It is also possible that the reduced egg production in winter contributed to the accumulation of calcium in bones hence the shank development.

The results of this study are in agreement with the findings of Bruno *et al.* (2007) who emphasized that chickens that were kept at low temperature had increased leg yield compared to those that were kept in high temperature. Leeson and Caston (1993) also reported an increased leg weights of chickens that were exposed to low temperature and in that fashion one would suppose that the longer the shank the heavier it is, so in that way the results of Lesson and Caston (1993) are in agreement with the findings of the present study. Contrary to the results of the present study, N'dri *et al*. (2006) observed an increased leg yield in chickens that were subjected to hot environmental conditions. The results obtained by Mcgovern *et al.* (2000) neither support the findings of neither the present study nor other previous studies since they stated that temperature fluctuations did not affect the lengths of chickens' shanks.

The results for the effect of restricted feeding on shank width indicate that Koekoek chickens that were full-fed had thicker ($p<0.05$) shanks as compared to those that were exposed to feed restriction. The average shank width of full-fed chickens was thicker than the restricted fed ones by 8% at 18 weeks of age. At the age of 32 weeks, the shank widths of Koekoek chickens that were allotted to the AR treatment were 90%, 96.5% and 96.6% of the ones in the AA, RA and RR treatments respectively. A positive ($p<0.05$) correlation of 0.324 and 0.550 at the age of 18 and 32 weeks respectively was noted between the shank length and shank width of Koekoek chickens. This means that chickens that had longer shanks also attained higher circumferences of shanks. When looking at the relationship between slaughter weight and shank circumference, the results revealed a positive correlation ($p<0.001$; $r=0.716$) at 18 weeks of age, which means that 51.3% ($r^2 = 0.513$) of the variation in shank circumference is explained by slaughter weight. On the other hand, a non-significant negative correlation ($r= -0.158$) was noticed between the slaughter weight and shank width at the age of 32 weeks. The results of the present study suggest that at a young age the shank circumferences of Koekoek chickens grew proportionally to body weight. The inverse relationships at the age of 32 weeks though insignificant imply that it does not automatically guarantee that a chicken with a higher body weight and carcass dressing weight would have thicker shank circumference.

The results of this study are in agreement with the findings of Crounch *et al.* (2002c) who indicated that the shank circumference was reduced in feed restricted turkey hen breeders more especially in the rearing stage since turkeys that were *ad libitum* fed had higher shank circumferences. This was confirmed by Robinson *et al.* (2007) who explained that the body frame of broiler breeders was hindered when feed restricted.

The findings at the age of 32 weeks disagree with the results of Crounch *et al.* (2002c) and Robinson *et al.* (2007) who stipulated that the shank circumferences were reduced in hens that were restricted fed for a longer period of time.

The shank widths of chickens that were exposed to summer and winter conditions were 9.8 and 7.1mm respectively. These measurements were different ($p<0.05$) from one another during the rearing phase (18 weeks) by 27.6%. During the laying phase, the results indicate that the shanks widths of chickens that were kept in summer were 10.7% less than in winter. It is assumed that the possible reason for Koekoek chickens that were reared in winter to have thicker shanks compared to those in summer could be due to the different laying patterns of chickens. Since birds that were kept in summer had a higher laying percentage at 32 weeks of age, it is possible that they withdrew a lot of calcium from the bones hence why they did not have thicker shank circumferences as compared to those that were reared in winter. The laying performance of chickens was lower in winter meaning that the calcium from the bones was not over-drawn hence the thicker shanks.

The findings of the present study as presented in Table 4.6 demonstrate that feeding level and season interaction had no effect ($p>0.05$) on the circumferences of the shanks at the age of 18 weeks. At 32 weeks of age it was established that chickens that were reared in winter and either full-fed or restricted fed had higher ($p<0.05$) shank widths compared to those that were kept in summer.

There were differences ($p<0.05$) observed between the full-fed and restricted fed birds during the rearing phase (18 weeks). The breast muscles of the chickens in the full-fed treatment were 19.2g heavier than restricted fed chickens. Nonetheless, chickens that were feed restricted had a higher ($p<0.05$) relative breast muscle weight expressed as a percentage of the body weight by 22.2%. This explains that restricted fed chickens significantly had more breast muscles in proportion to their body weight compared to chickens that were fed unrestrictedly.

During the laying phase (32 weeks) the breast muscles of Koekoek chickens that were in the RA were 2.3%, 27.9% and 19.4% higher than those in the AA, AR and RR treatments respectively. This indicates that birds that were in the RA treatment had the benefit of compensatory growth since they were able to accumulate more weight than others were during the laying phase. The observation from these results is that the breast muscle weights of chickens in the AR treatments developed at a lower rate compared to those that were fed restrictedly during both rearing and laying phases (RR). This can be verified by the fact that chickens in the RR treatment were 10.9g heavier than those in the AR treatment regardless of the fact that the breast muscle weights of chickens in the AR treatment were already heavier than the ones of the chickens in the RR treatment at the age 18 weeks by almost 18.2%. The results of this study indicated a positive relationship between body weights at which chickens were slaughtered and breast muscle weights. The results demonstrate that breast muscle weights responded positively to the body weights of chickens during both rearing and laying phases. The correlation ($p<0.01$) between slaughter weight and breast muscle weight during the rearing ($r=0.730$) and laying ($r=0.717$) phases was significant.

In terms of absolute breast muscle weights, these results are in conformity with the findings of Renema *et al*. (1999a) who reported that feed restriction resulted in a reduction in breast muscle weight because of reduced weight gain. These results were further supported by Robinson *et al.* (2007a) who gave an evidence of variability in the breast weight percentage due to diverse feed allocations. Melnychuk *et al*. (2004), Saleh *et al*. (2005) and Renema *et al*. (1999a) also observed that full-fed birds had significantly heavier breast weights than feed restricted birds. Contrary to the results of the present study, Crounch *et al.* (2002c) indicated that restricted fed turkey hens would have high breast muscle weights at 30 and 32 weeks. With respect to compensatory growth displayed by chickens that were in the RA treatment these results are not in harmony with the findings of Crounch *et al.* (2002c) who pointed out that turkeys would have the lower breast muscle weights if they are feed restricted early in their lives.

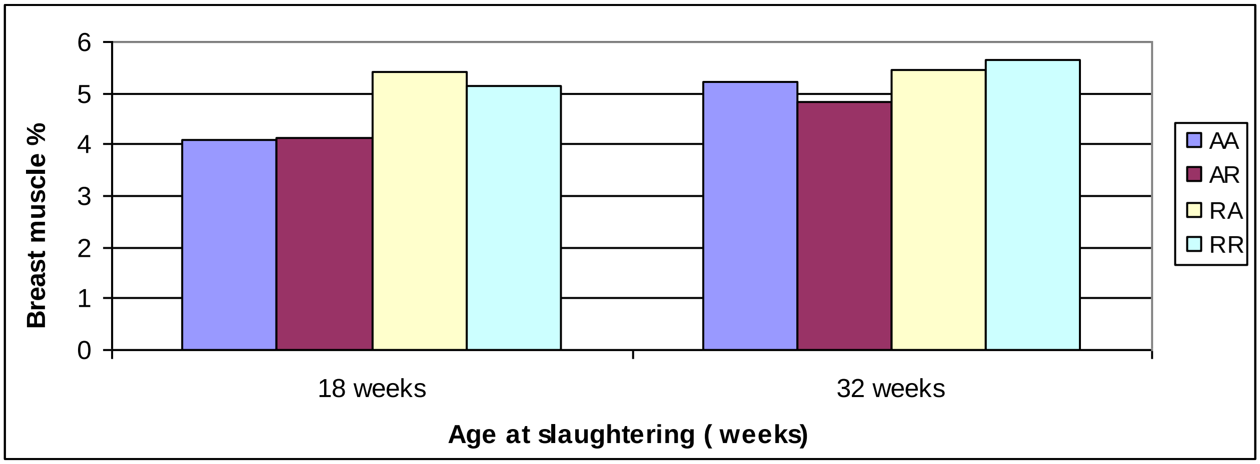

Figure 3.3: The relative breast muscle percentages of Koekoek chickens subjected to different feeding levels

Footnote:

AA-full feeding during rearing and laying. AR-full feeding during rearing and restricted during laying, RA-restricted feeding during rearing and full feeding during laying, RR-restricted during rearing and laying, S.E-standard error.

Season played an important role on the breast muscle weights of Koekoek chickens. At the age of 18 weeks, the cold winter conditions slowed down the development of chicken breast muscles by almost 26.9%. With regard to the relative percentage of breast muscle it was discovered that chickens that were reared in winter performed better ($p<0.05$) than chickens reared in summer by 22.6%. During the laying phase (32 weeks), chickens that were in the summer and winter treatments had similar absolute and relative breast muscle weight performance. This means that at 32 weeks of age the breast muscle of Koekoek chickens were not affected ($p<0.05$) by cold winter conditions as compared to when they were 18 weeks of age. This tells us that the chicks are more prone to unfavourable winter conditions than the grown up chickens hence heat supply is important to chicks.

Koekoek chickens that were subjected to the full and restricted feeding in summer had higher ($p<0.05$) breast muscle weights than in winter by 43.4 and 14.9g respectively. The highest difference was observed in chickens that were full-fed in the rearing phase. The findings of the present study reflect that chickens that were raised in summer outperformed the ones that were kept in winter irrespective of the quantity of feeds they were offered. The breast muscle weights of Koekoek chickens that were fed without restriction in winter were 10.8% less than those feed restricted in summer and 34.71% less than those that were full-fed in summer. Regardless of the breast muscle weights, chickens that were in the restricted feeding (RA and RR) during the summer had a higher (6%) breast muscle percentage while those that were full-fed had the lowest (3.7%) relative breast muscle percentage. The breast muscle percentage of the chickens that were full-fed in winter was 4.5% on average. An average breast muscle percentage of chickens that were under the RA and RR treatments in summer was 4.6%. These results indicate that chickens that were kept in winter but fed restrictedly had higher breast muscle percentage compared to chickens that were reared in summer and either full-fed or restricted fed. The differences in the breast muscle weights of chickens that were subjected to different interactive treatments were due to the differences in the slaughter weights of chickens rather than an effect of the feeding level and season.

During the laying phase (32 weeks), it was discovered that there were significant differences caused by feeding level and season interaction on the breast muscle weights of Koekoek chickens. The breast muscle weights of the chickens in the AA, AR, RA and RR treatments in summer differed from those in winter by 52.1, 19.7, 23 and 1.5g respectively. Despite the significant differences in the breast muscle weights it was revealed that feeding level and season interaction had no effect ($p>0.05$) on the breast muscle percentages of Koekoek chickens. This proves the point that the differences in the breast weights were mainly due to the differences that existed in the slaughter weights of chickens not necessarily because of the influence of the treatments effects.

The results obtained by Chen *et al.* (2007) are in agreement with the findings of the present study as they stated that the breast weight corresponds with the number of sunlight hours chickens are exposed to in a day. In that way, it would be expected that chickens that were reared in summer would have higher breast muscle weights, as it was the case in this study. This study cannot be compared with the findings of Aksit *et al.* (2006), Alleman and Leclercg (1997) who argued that broiler chickens that are exposed to high temperature had decreased breast weights. The reason being that the current research was conducted in a lower temperature than were previous studies.

Koekoek chickens that were full-fed (AA and AR) had wider ($p<0.05$) chest girths as compared to those that were subjected to restricted feeding. These results indicated that an average heart girth of restricted fed chickens was 7.7% less than on the full-fed diet. Therefore, there was a good relationship observed between feed consumption efficiency and chest girth because, the more feed consumed, the wider the chest (heart) girth attained. The heart girth was highly ($p<0.01$) correlated with the slaughter weight (r=0.723), carcass dressing weight (r=0.669) breast muscle weight (r=0.696), abdominal fat weight (r=0.633) and liver weight (r=0.404).

During the laying phase, heart girth measurements were 293.286mm, 271.857mm, 290.857mm and 267.75mm for birds in the treatments AA, AR, RA and RR respectively. Birds raised under full feeding (AA and RA) had wider chest girths than those raised under restricted feeding (AR and RR). These results imply that chickens with heavy body weights will finally have wider chest girths. The chickens that were in the AR treatment had their chest girths developing at a decreasing rate, which might be because of the shortage of feed intake. Koekoek chickens that were under feed restriction (RR) gave an impression that their chests have been constantly developing with age hence why chickens in AR and RR were insignificantly different during the laying phase which was not the case in the rearing phase.

A positive correlation (r=0.844) between the body weight and the heart girth of Koekoek chickens was highly significant ($p<0.01$). These results suggest that heavy chickens had wider chest girths and a positive relationship between body weight and heart girth was more pronounced, as chickens were ageing. The heart girth also had a positive correlation with defeathered weight (r=0.668), chest width (r=0.767), carcass dressing weight (r=0.765), breast muscle % (r=0.694), gizzard weight (r=0.564) and the skin weight (r=0.661). The heart girth was negatively correlated with intestine percentage (r= -0.490), liver percentage (r=-0.413) and gizzard percentage (r=0.391). This reflects that the heart girth can possibly be used as an indicator of performance in a number of carcass traits of Koekoek chickens.

These results are comparable to the results of Pishnamazi *et al*. (2008) who noted that the heavier breast muscle weight might contribute to the wider chest girth in *ad libitum* fed broiler chickens. Pishnamazi *et al*. (2008) also stated that broiler chickens that were offered *ad libitum* feeds had larger chest girths than those that were fed restrictedly. Furthermore, birds that were in the RA treatment had wider chest girth than other treatments because of compensatory growth.

The heart girths of chickens that were allocated to winter conditions were 4.3% less than those of chickens that were subjected to summer conditions at the age of 18 weeks. At 32 weeks of age the results indicate that the chest girths of chickens that were exposed to summer conditions were 9.22% higher than those that were subjected to winter conditions.

These results depict that the gap between the chest girths of chickens that were subjected to different season's narrows with the ageing of chickens. The reason for the difference between the chest girths of chickens that were raised in summer and winter to be wide at early age could be attached to the fact that chickens were using a considerable portion of energy to keep themselves warm instead of developing the chest muscles in winter. This could possibly be true as it is well known that at young age chickens' feathers are not yet fully developed, so that would mean chickens would need more feeds to generate their body heat. The results of the present study revealed that the heart girth was not affected ($p<0.05$) by the feeding level and season interaction during both rearing and laying phases.

During the rearing, the chest widths of Koekoek chickens that were full-fed were 7.2mm higher than those on the feed restriction. These results portray that the chest widths responded positively to the body weights of chickens. This can be attested to by the fact that the chest width was highly correlated ($p<0.01$) with slaughter weight ($r=0.776$), defeathered weight ($r=0.639$) and the carcass dressing weight ($r=0.665$). The chest widths of Koekoek chickens also had a positive correlation ($p<0.01$) with other carcass components such as shank width ($r=0.886$), heart girth ($r=0.615$) breast muscle weight ($r=0.751$), abdominal fat ($r=0.555$), abdominal fat % ($r=0.445$), intestine weight ($r=0.461$), liver weight ($r=0.542$) and skin weight ($r=0.773$). The chest width had an inverse relationship ($p<0.01$) with the shank length ($r= -0.500$), carcass dressing % ($r= -0.407$), breast muscle percentage ($r= -0.773$) as well as gizzard % ($r= -0.746$).

During the laying phase, chest width measurements were 65.2mm and 63.9mm for the AA and RA groups respectively which were higher ($p<0.05$) than those obtained in groups AR and RR being 61.4mm and 59.3mm respectively. The results showed that there were differences ($p<0.05$) between full-fed and restricted fed birds. It can be revealed from the findings of this study that in spite of chickens in the AA treatment having the highest chest widths, chickens in the RA treatment had highest (18.1mm) development of the chest widths from the 18^{th} to 32^{nd} week with chickens on the RR treatment (15.2mm) being second in chest development performance. Koekoek chickens on the AR treatment were lowest in chest widths growth as they managed to increase their chest widths by only 10.6mm for the period of 14 weeks while those that were on the AA treatment had an increase of 11.7mm for the same period of time.

It was observed that the chest widths were in proportion to the slaughter weights of Koekoek chickens. This means that the higher the chest width the higher the slaughter weight, defeathered weight and the carcass dressing weight as well the carcass dressing percentage. The results from the present study demonstrated a positive correlation ($p<0.01$) between the chest width and slaughter weight ($r=0.761$), defeathered weight ($r=0.615$), chest girth ($r=0.765$), carcass dressing weight ($r=0.765$), breast muscle % ($r=0.553$), gizzard weight ($r=0.556$) and the skin weight($r=0.438$). The results for correlations suggest that chicken carcass traits are dependent on each other in such a manner that selecting for broader chest widths would automatically go along with a number of improved carcass traits.

These results are in line with the results by Pishnamazi *et al*. (2008) who stated that broiler chickens fed *ad libitum* had greater chest widths than birds fed restrictedly.

The results for the chest widths of Koekoek chickens that were allotted to different seasons are presented in Table 3.6. The findings of the present study portray the chest width difference of 39.2% between chickens that were raised in summer and winter ($p<0.05$). The results clearly indicate that the cold conditions hindered the chest width development of chickens in the growing phase (18 weeks). During the laying phase (32 weeks), the results specified that the chest widths of Koekoek chickens that were subjected to summer conditions were 15.4mm higher than chickens that were subjected to winter conditions. Despite the average chest widths of chickens that were allotted to summer treatment being higher ($p<0.05$) than in winter at both 18 and 32 weeks of age, the results show that the older the chickens the lesser the difference in the chest widths between chickens that were kept in summer and winter seasons. This can be proved by the fact that the chest width difference between chickens that were kept in summer and the ones kept in winter was reduced by 17.6% from 18 to 32 weeks of age. This is authenticating that the chest width growth of Koekoek chickens is less affected by coldness in winter once their feathers are fully-grown.

The results of the present study show a non-significant interaction between feeding level and season on the chest width of chickens at the age of 18 weeks. An interaction ($p<0.01$) on the chest width was only observed at 32 weeks of age. The chest widths of Koekoek chickens in the AA, AR, RA and RR treatments in summer deviated from those in winter by 27.4%, 15.5%, 23.1% and 20.7% respectively. The chickens reared in summer had higher performance between all feeding regimes. The pattern of the chest width results seemed to tally with the ones portrayed by interaction between the feeding level and season on the slaughter weights of Koekoek chickens. This can be confirmed by a higher correlation ($p<0.01$) between the slaughter weight and the chest width ($r= 0.776$) as reflected in Table 4.4. This suggests that 60.2% ($r^2=0.602$) of the chest width could possibly be explained by the slaughter weigh

Table 3.4: Correlations between carcass characteristics of Koekoek chickens at the age of 18 weeks

Carcass traits	Shank length (mm)	Shank width (mm)	Slaughter weight (g)	Defeathered weight (g)	Defeathered %	Carcass dressing weight (g)	Carcass dressing %	Chest width (mm)	Heart girth (mm)	Breast muscle weight (g)	Breast muscle %	Skin %	Skin weight (g)
Shank length (mm)	1	-0.550**	-0.279*	-0.217	0.105	-0.163	0.334*	-0.500**	-0.172	-0.303	0.314*	-.0329*	-0.351**
Shank width (mm)	-550**	1	0.716**	-0.217	-0.184	0.607**	-0.390**	0.886**	0.436**	0.730**	-0.737**	0.407**	0.607**
Slaughter weight (g)	-0.279*	0.716**	1	-0.217	0.105	-0.163	0.334*	-0.500**	-0.172	.730*	-0.956**	0.357**	0.881**
Defeathered weight (g)	-0.217	0.594**	0.953**	1	0.424**	0.888**	-0.311*	0.639**	0.738**	0.673**	-0.900**	0.349**	0.884**
Defeathered %	0.105	-0.184	0.132	0.424	1	0.106	-0.067	-0.212	0.263	-0.083	0.033	0.089	0.133
Carcass dressing weight (g)	-0.163	0.607**	0.939**	0.888**	0.106	1	0.031	0.665**	0.669**	0.645**	-0.825**	0.275*	0.792**
Carcass dressing %	0.334*	-0.390**	-0.312*	-0.311*	-0.067	0.031	1	-0.407	-0.231	-0.316*	0.514**	-0.247	-0.358**
Chest width (mm)	-0.500**	0.886**	0.776**	0.639**	-0.212	0.665**	-0.407**	1	0.615**	0.751**	-0.773**	0.449**	0,773**
Heart girth (mm)	-0.172	0.436**	0.723**	0.738**	0.263	0.669**	-0.231	0.615**	1	-0.638**	0.696**	0.225	0.617**
Breast muscle weight (g)	-0.303	0.574**	0.730**	0.673**	0.033	0.645	-.316*	0.751**	0.696**	1	-0.642**	0.338*	0.692**
Breast muscle %	-0.303*	0.574**	-0.956**	-0.900**	-0.083	-.0825**	0.514**	-.0773**	-0.638**	-.0642**	1	-0.323*	-0.838**
Skin %	-0.329*	-0.407**	0.357**	0.349**	0.089	0.275*	-0.247	0.449**	0.225	0.338*	-0.323*	1	0.751**
Skin weight (g)	-0.351**	0.716**	0.881**	0.884**	0.133	0.792**	-0.358**	0,773**	0.617**	0.692**	-0.838**	0.751**	1
Abdominal Fat weight (g)	-0.182	0.495**	0.870**	0.887**	0.310**	0.833**	-0.223	0.555**	0.633**	0.615**	-0.802**	0.862**	0.405**
Abdominal fat %	-0.144	0.401**	0.784**	0.346*	0.768**	0.820**	-0.159	0.445**	0.550**	0.493**	-0.725**	0.795**	0.483**
Intestines	-0.352**	0.508**	0.471**	0.417**	-0.061	0.412**	-0.217	0.461**	0.214	0.418**	-0.477**	0.439**	0.213

weight (g)													
Intestines %	-0.103	-0.146	-0.446**	-0.461**	-0.192	-0.450**	0.074	-0.241	-0.432**	-0.214	0.415**	-0.361**	-0.098
Liver weight (g)	-0.199	0.543**	0.737**	0.739**	0.203	0.688**	-0.236	0.542**	0.404**	0.537**	-0.718	0.653**	0.260
Liver %	0.085	-0.181	-0.276*	-0.210	0.130	-0.264	0.087	-0.256	-0.377**	-0.171	0.262	-0.243	-0.110
Gizzard weight (g)	0.240	-0.140	0.104	0.158	0.207	0.245	0.369**	-0.171	0.056	0.048	-0.002	-0.067	-0.259
Gizzard %	0.379**	-0.690**	-0.765**	-0.678**	0.069	-0.636**	0.474**	-0.746**	-0.521**	-0.521**	0.816**	-0.752**	-0.419**

Table 3.4: continued

Carcass traits	**Abdominal Fat weight (g)**	**Abdominal fat %**	**Intestines weight (g)**	**Intestines %**	**Liver weight (g)**	**Liver %**	**Gizzard weight (g)**	**Gizzard %**
Abdominal Fat weight (g)	1	0.982**	0.315*	-0.479**	0.633**	-0.248	0.135	-0.561**
Abdominal fat %	0.982**	1	0.257	-0.466**	0.579**	-0.218	0.144	-.0561**
Intestines weight (g)	0.315*	0.257	1	0.570**	0.483**	0.078	0.090	-0.341
Intestines %	-0.479**	-0.466**	0.570**	1	-0.187	0.352**	-0.002	0.377**
Liver weight (g)	0.633**	0.579**	0.483**	-0.187	1	0.436**	0.080	-0.556**
Liver %	-0.248	-0.218	0.078	0.352**	0.436**	1	0.014	0.258
Gizzard weight (g)	0.135	0.144	0.090	-0.002	0.080	0.014	1	0.537**
Gizzard %	-0.625**	-0.561**	-0.341*	0.377**	-0.556**	0.258	0.537**	1

** Correlation is significant at the 0.01 level (2 tailed)

* Correlation is significant at the 0.05 level (2 tailed)

Table 3.5: Correlations between carcass characteristics of Koekoek chickens at the age of 32 weeks

Carcass traits	Shank length (mm)	Shank width (mm)	Slaughter weight (g)	Defeathered weight (g)	Defeathered %	Carcass dressing weight (g)	Carcass dressing %	Chest width (mm)	Heart girth (mm)	Breast muscle weight (g)	Breast muscle %	Skin weight (g)	Skin %
Shank length (mm)	1	0.324*	-0.155	-0.079	0.080	-0.106	-0.125	-0.460**	-0.252	-0.025	-0.125	0.089	0.351**
Shank width (mm)	0.324*	1	-0.158	-0.028	0.173	-0.136	-0.004	-0.347*	-0.181	0.008	-0.093	0.083	0.301*
Slaughter weight (g)	-0.155	-0.158	1	0.813**	0.000	0.936**	0.276*	0.761**	0.844**	0.067	0.717**	0.743**	-0.106
Defeathered weight (g)	-0.079	-0.028	0.813**	1	0.581**	0.760**	0.222	0.615**	0.668**	-0.211	0.409**	0.519**	-0.230
Defeathered %	0.080	0.173	0.000	0.581**	1	-0.001	-0.008	0.001	-0.033	-0.459**	-0.301*	0.519**	-0.230
Carcass dressing weight (g)	-0.106	-0.136	0.936**	0.760**	-0.001	1	0.597**	0.765**	0.767**	0.075	0.682**	0.681**	-0.127
Carcass dressing %	0.083	-0.004	0.279	0.222	-0.008	0.597*	1	0.341*	0.171	0.075	0.682**	0.169	-0.127
Chest width (mm)	-0.460**	-0.347*	0.761**	0.615**	0.001	0.765	0.341	1	0.765	0.062	0.553**	0.438**	-0.059
Heart girth (mm)	-0.252	-0.181	0.844**	0.688**	-0.033	0.767**	0.179	0.765**	1	0.185	0.694**	0.438**	-0.305*
Breast muscle weight (g)	-0.25	0.008	0.067	-0.221	-0.459**	0.075	0.046	0.062	0.185	1	0.737	0.228	0.285
Breast muscle %	-0.125	-0.093	0.717**	0.409**	-0.301*	0.682**	0.224	0.553**	0.694**	0.737**	1	0.648**	0.116
Skin weight (g)	0.089	0.083	0.743**	0.519**	-0.152	0.681**	0.169	0.438**	0.661**	0.228	0.648**	1	0.580**
Skin %	0.351**	0.301*	-0.106	-0.230	-0.257	-0.127	-0.103	-0.305*	-0.059	0.285*	0.116	0.580**	1
Abdominal Fat weight (g)	0.237	0.229	0.534**	0.422	-0.027	0.418**	-0.051	0.115	0.476**	0.049	0.384**	0.632**	0.304*
Abdominal fat %	0.358**	0.362**	0.103	0.063	-0.042	-0.005	-0.224	-0.280*	0.117	0.33	0.084	0.355**	0.423**
Intestines	0.164	0.037	-0.019	0.108	0.209	-0.048	0.065	-0.035	0.066	-0.013	-0.006	0.120	0.187

weight (g)													
Intestines %	0.205	0.119	-0.627**	-0.399**	0.190	-0.603**	-0.462**	-0.493**	-0.490**	-0.077	-0.462**	-0.386**	0.175
Liver weight (g)	0.311*	0.075	0.287*	0.298*	0.103	0.186	-0.108	0.024	0.286*	0.062	0.241	0.401**	0.241
Liver %	0.407**	0.185	-0.504**	-0.343*	0.109	-0.547**	-0.319*	-0.570**	-0.413**	-0.009	-0.339*	-0.218	0.283
Gizzard weight (g)	-0.296*	-0.155	0.592**	0.508**	0.039	0.564**	0.200	0.556**	0.531**	0.183	0.553**	0.327*	-0.235
Gizzard %	-0.142	-0.019	-0.487**	-0.361**	0.055	-0.435**	-0.075	-0.234	-0.391**	0.096	-0.234	-0.507**	-173

Table 3.5: Continued

Carcass traits	**Abdominal fat weight (g)**	**Abdominal fat %**	**Intestines weight (g)**	**Intestines %**	**Liver weight (g)**	**Liver %**	**Gizzard weight (g)**	**Gizzard %**
Abdominal Fat weight (g)	1	0.890**	0.033	-0.331*	0.364**	-0.120	0.120	0.107
Abdominal fat %	0.890**	1	0.037	-0.067	0.238	0.089	-0.169	-0.328*
Intestines weight (g)	0.033	0.037	1	0.776**	0.510**	0.468**	-0.169	-0.328
Intestines %	-0.331*	-0.067	0.776**	1	0.185	0.652**	-0.393**	0.276*
Liver weight (g)	0.364**	0.238*	0.510**	0.185	1	0.670**	0.027	-0.333
Liver %	-0.120	0.089	0.468**	0.652**	0.670**	1	-0.436**	0.063
Gizzard weight (g)	0.107	-0.169	-0.042	-0.393**	0.027	-0.0436**	1	0.402**
Gizzard %	-0.509**	-0.328*	-0.036	0.276*	-0.333*	-0.063	0.402**	1

** Correlation is significant at the 0.01 level (2 tailed)

* Correlation is significant at the 0.05 level (2 tailed)

Table 3.6: The effect of the interaction between feeding level and season on carcass characteristics of Koekoek chickens

Carcass traits	SAA	S.E	WAA	S.E	SAR	S.E	WAR	S.E	SRA	S.E	WRA	S.E	SRR	S.E	WRR	S.E
Rearing phase (18 weeks)																
Shank length (mm)	64. 8	0.70	68.4	0.70	64.1	0.70	66.4	0.70	65.43	0.70	66.4	0.70	63.0	0.76	68.33	0.76
Shank width (mm)	9.9	0.28	7.9	0.28	10.2	0.28	7.1	0.28	9.44	0.28	6.8	0.28	9.5	0.30	6.50	0.30
Slaughter weight(g)	1851	34.68	1636	34.68	1816	34.63	1578	34.68	1521	34.68	1158	34.68	1504	37.46	1219	37.46
Post Slaughter wt (g)	1770	34.98	1584	34.98	1771	34.98	1524	34.98	1471	34.98	1112	34.98	1458	37.78	1129	37.78
Defeathered weight(g)	1557	38.91	1428	38.9	1557	38.91	1385	38.91	1185	38.91	1015	38.91	1214	42.23	991.8	42.03
Defeathered %	85.1^a	1.35	87.4^b	1.35	85.7^a	1.35	87.8^b	1.35	77.77^a	1.35	87.7^b	1.35	80.6^a	1.46	81.3^b	1.46
Chest width (mm)	66.3	1.65	40.7	1.65	62.3	1.65	39.4	1.65	59.00	1.65	32.6	1.65	54.2	1.78	34.2	1.78
Chest Girth(mm)	277.4	5.42	254.6	5.41	267.4	5.41	259.6	5.41	255.0	5.41	243.9	5.41	241.0	5.85	238.2	5.85
Dressing weight(g)	1270^a	26.61	1188^b	26.61	1191^a	26.61	1145^b	26.61	1062^a	26.61	834.8^b	26.61	1041^a	28.74	839.7^b	28.74
Carcass dressing%	68.6^a	1.21	72.7^b	1.21	65.6^a	1.21	72.6^b	1.21	69.9^a	1.21	72.2^b	1.21	69.3^a	1.31	68.9^b	1.31
Breast Muscle wt(g)	136.7^a	5.64	78.7^b	5.64	113.6^a	5.64	84.7^b	5.64	93.6^a	5.64	80.7^b	5.64	89.7^a	6.09	72.7^b	6.09
Breast muscle %	3.7^a	0.15	4.5^b	0.15	3.6^a	0.15	4.7^b	0.15	4.6^a	1.15	6.3^b	0.15	4.6^b	0.16	5.7^b	0.16
Skin weight (g)	136.0^a	2.26	104.9^b	2.26	134.6^a	2.26	93.6^b	2.26	95.0^a	2.26	71.7^b	2.26	92.8^a	2.44	74.2^b	2.44
Skin %	7.4^a	0.21	6.4^b	0.21	7.4^b	0.21	5.9^a	0.21	6.3^b	0.21	6.2^a	0.21	6.2^b	0.23	6.1^a	0.23
Laying phase (32 weeks)																
Shank length (mm)	67.1	1.04	2.1	1.04	68.4	1.04	68.9	1.04	68.4	1.04	70.7	1.04	63.7	1.12	70.8	1.12
Shank width(mm)	12.1^a	0.36	12.1^b	0.36	10.3^a	0.36	11.4^b	0.36	10.4^a	0.36	12.3^b	0.36	10.2^a	0.36	12.5^b	0 .36
Slaughter weight(g)	2724^a	54.43	2020^b	54.43	1993^a	54.43	1784^b	54.43	2677^a	54.43	2025^b	54.43	1936^a	58.79	171^b	58.79
Defeathered wt(g)	2503^a	97.55	1936^b	97.55	1755^a	97.55	1709^b	97.55	2474^a	97.55	1945^b	97.55	1728^a	105.37	1338^b	105.33
Defeathered %	9188	4.98	95.9	4.98	88.2	4.98	95.8	4.98	92.40	4.98	96.0	4.98	89.3	5.38	80.3	5.38
Chest Width(mm)	75.6^a	0.96	54.9^b	0.96	66.6^a	0.96	56.3^b	0.96	72.3^a	0.96	55.6^b	0.96	66.2^a	1.03	52.5^b	1.03
Heart Girth(mm)	310.7	4.58	275.9	4.56	284.3	4.58	259.4	4.58	304.7	4.58	277.0	4.58	278.3	4.95	257.2	4.95
Dressing Weight(g)	2050^a	59.37	1400^b	59.37	1410^a	59.37	1320^b	59.37	2040^a	59.37	1380^b	59.37	1360^a	64.12	1170^b	64.12
Carcass dressing %	75.1	2.53	69.2	2.53	71.06	2.53	74.3	2.53	76.06	2.53	68.0	2.53	70.4	2.74	68.0	2.74

Breast muscle wt(g)	150.7^{a}	8.64	98.6^{b}	8.64	101.7^{a}	8.64	82.0^{b}	8.64	139.0^{a}	8.64	116.0^{b}	8.64	103.5^{a}	9.33	102.0^{b}	9.33
Breast muscle %	5.5	0.39	4.9	0.3	5.11	0.3	4.6	0.39	5.2	0.39	5.7	0.39	5.4	0.42	5.9	0.42
Skin weight (g)	190.0^{a}	7.69	160.0^{b}	7.69	127.7^{a}	7.69	123.4^{b}	7.69	174.6^{a}	7.69	144.6^{b}	7.69	118^{a}	8.30	126.0^{b}	8.30
Skin %	7.0^{a}	0.34	7.9^{b}	0.34	6.4^{a}	0.3	6.9^{b}	0.34	6.5^{a}	0.34	7.2^{b}	0.34	6.1^{a}	0.36	7.3^{b}	0.36

^{ab} Means within a row with no common superscript differ significantly ($p>0.05$ and $p<0.01$)

Footnote:

SAA-full feeding during rearing and laying in summer season. SAR- full feeding during rearing and restricted during laying in summer season, SRA-restricted feeding during rearing and full feeding during laying in summer season, SRR-restricted during rearing and laying in summer season, WAA- full feeding during rearing and laying in winter season. WAR- full feeding during rearing and restricted during laying in winter season, WRA-restricted feeding during rearing and full feeding during laying in winter season, WRR-restricted during rearing and laying in winter season, S.E-standard error, sig- Significance level, wt- weight, the weight is in grams (g) while the length, width and girth are in millimeters (mm).

3.3.2 Effect of restricted feeding and season on organs and abdominal fat in Koekoek chickens at 18 and 32 weeks of age

The results on abdominal fat and organs characteristics of Koekoek chickens are presented in Tables 3.7 and 3.8. These results are for both rearing and laying phases of Koekoek chickens.

Table 3.7 Organs and abdominal fat characteristics of Koekoek chickens that were subjected to different feeding level treatments

	Treatments				
Parameters	**AA**	**AR**	**RA**	**RR**	**S.E**
Rearing phase (18 weeks)					
Abdominal Fat (g)	63.1^a	66.1^a	21.9^b	22.8^b	0.88
Abdominal Fat %	3.6^a	3.9^a	1.6^b	1.6^b	0.05
Intestine wt (g)	56.4	60.5	53.6	54.8	1.26
Intestine %	3.2^a	3.6^a	4.0^b	4.0^b	0.08
Liver wt (g)	32.0^a	31.4^a	26.0^b	26.3^b	0.52
Liver %	1.8	1.9	2.0	1.9	0.03
Gizzard wt (g)	38.7	37.4	35.6	36.0	0.66
Gizzard %	2.2^a	2.2^a	2.7^b	2.7^b	0.04
Laying phase (32 weeks)					
Abdominal fat (g)	125.1^a	71.1^b	104.2^a	73.8^b	4.07
Abdominal Fat %	5.3^a	3.8^b	4.5^{ab}	4.1^b	0.18
Intestine wt	74.1	70.1	68.6	63.3	1.88
Intestine %	3.2^{ab}	3.7^a	3.0^b	3.5^{ab}	0.09
Liver wt	40.9^a	33.9^b	41.1^a	31.8^b	0.85
Liver %	1.8	1.8	1.8	1.8	0.04
Gizzard wt	37.4^a	34.4^b	38.1^a	35.9^b	0.72
Gizzard %	1.6^a	1.8^b	1.7^{ab} +	2.0^b	0.03

^{ab} Means within a row without a common superscript differ significantly (*p*<0.05).
Foot note:
AA-full feeding during rearing and laying. AR-full feeding during rearing and restricted during laying, RA-restricted feeding during rearing and full feeding during laying, RR-restricted during rearing and laying, S.E-standard error.

Koekoek chickens that were exposed to restricted feeding were not different (p>0.05) from those that were full-fed as far as the intestine weights are concerned. In spite of insignificant differences between chickens that were subjected to either full-fed or restricted fed it was noted that the intestine weights of chickens that were under full-fed treatment were 7.3% higher than the ones of chickens that were subjected to restricted feeding during the rearing phase (18 weeks). It was detected that chickens that were fed without restrictions had an average relative intestine percentage of 3.4% while an average relative intestine percentage of chickens that were feed restricted was 4%. The negative relationship between slaughter weight and relative percentage of the intestines demonstrate that the significant

($p<0.05$) differences in the intestinal weights were inherited from the chickens slaughter weights rather than being brought about by the effect of restricted feeding.

During the laying phase (32 weeks), the results indicate that Koekoek chickens had intestine weights of 74.1, 70.1, 68.6 and 63.3g for chickens that were in the AA, AR, RA and RR treatments respectively. The results on intestine weight performance were not significantly different ($p>0.05$) between the four feeding level treatments. The results show that Koekoek chickens that had heavier intestine weights at early age continued to surpass chickens that were on restricted feeding at the initial phase of the study. This suggests that the development of intestines was not affected by the amount of the feeds given to chickens during the laying phase. Regarding the relative percentage of the intestines, the results portrayed the non-significant differences between chickens that were subjected to different feeding levels (Figure 4.4). Koekoek chickens that were full-fed during rearing and later shifted to restricted feeding in the laying phase (AR) had a higher relative intestine percentage (3.8%) followed by chickens that were in feed restriction for the entire study (RR) with the relative intestine percentage of 3.5%. The proportion of the intestine weights relative to the body weight of chickens that were fed without any restriction during the laying phase (AA and RA) was 3.2% and 3% respectively. It can be seen from these results in both rearing and laying phases that chickens that were on 70% full feeding had a higher relative percentage of intestines hence a higher negative correlation ($r=-0.776$) between an intestine weight and the relative intestine percentage ($p<0.01$). The results indicate an insignificant correlation ($r=-0.019$) between the slaughter weight and intestine weight of Koekoek chickens at 32 weeks of age. On the other hand, an inverse relationship was seen between the slaughter weight and intestine percentage of the chickens. The findings of this study suggest that Koekoek chickens with small bodies at slaughter age (32 weeks) will proportionally have heavier intestinal weights.

The results of this study are not in accordance with the findings of Yagoub *et al*. (2008) who observed a difference ($p<0.05$) in the intestine weight of birds that were exposed to *ad libitum* and restricted feeding. The findings of Novele *et al.* (2008) stated that broiler chickens that were initially on restricted feeding and later shifted to *ad libitum* feeding had more intestine weight compared to birds that were either feed restricted or given feeds unlimitedly for the whole study.

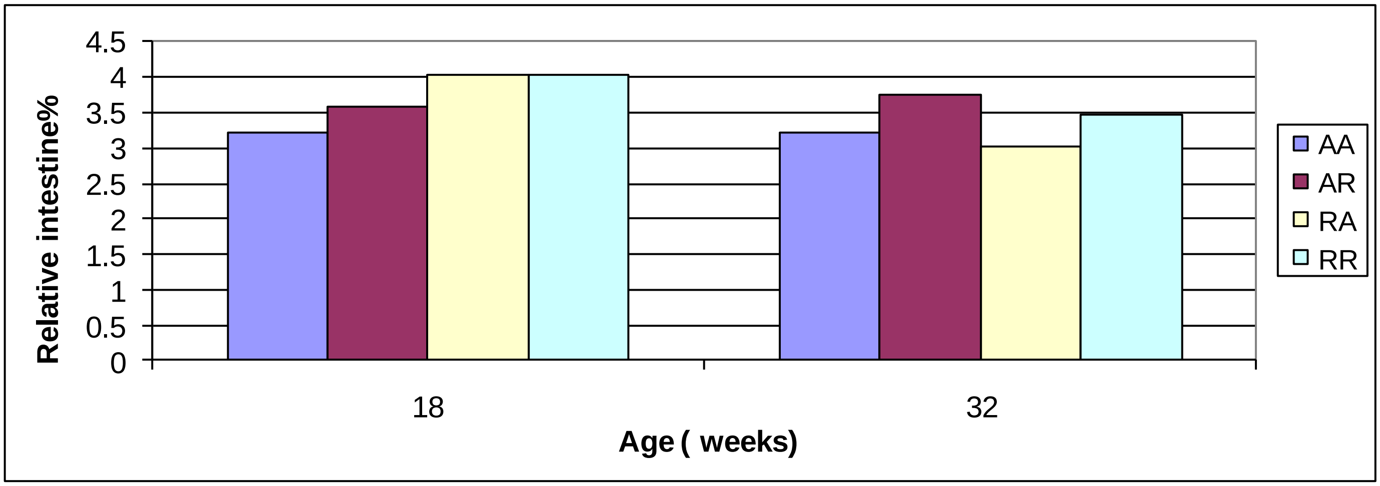

Figure 3.4: The relative intestine percentage in Koekoek chickens subjected to different feeding levels
Footnote:
AA-full feeding during rearing and laying. AR-full feeding during rearing and restricted during laying, RA-restricted feeding during rearing and full feeding during laying, RR-restricted during rearing and laying.

The reason for the results of the present study to vary from the previous ones could be due to the different types of chickens used as well as the age difference. The previous studies were conducted on broiler chickens that were slaughtered before the age of 18 weeks whilst that was not the case in this study.

The intestine weights of chickens were 61.5g and 51.1g for chickens that were under summer and winter treatments respectively. This indicates that an average intestine weight of chickens that were raised in summer was 10.3g higher than in winter. Seasonal effect reflected no significant ($p>0.05$) differences in the weight (3.7%) of the intestines as a percentage of slaughter weight. The results imply that the weight difference in chicken intestines was mainly because of the differences in the slaughter weights of chickens. The findings of the present study established a negative relationship ($r=-0.446$) between the intestine weight as a percentage of the body weight and the body weight of Koekoek chickens at 18 weeks of age.

At 32 weeks of age, the results illustrate that the intestine weights of chickens that were reared in summer were not significantly different from the intestine weights of those that were reared during the winter. Despite the non-significant differences in absolute intestine weights between chickens that were subjected to different seasons, there was an effect ($p<0.05$) of season on the relative intestine weight as the percentage of the body slaughter weight. The relative intestine percentages were 16.2% higher in winter than in summer.

The findings of the present study show that the effect of feeding level and season interaction was only observed in the relative intestine percentage of Koekoek chickens at 32 weeks of age (Table 3.9). The results reveal that the chickens that were under the AA and AR treatments in winter were higher than in summer by 27.8% and 7.7% respectively. On the RR treatment, the intestine percentage of birds in summer was 0.8% higher than those under winter treatment. It was observed from the present study that the intestine weights as the percentage of the slaughter weights were mostly higher in the full-fed chickens during the rearing phase in winter.

The results of this study for chickens at the age of 32 weeks seemed to tally with the findings of Rajini *et al*. (2009) who reported a longer intestine length of chickens in winter in comparison to an intestine length of chickens that were reared in summer. In support of these results, Keshavarz (1998) discovered that the length of the intestines was longer under a short light day regimen compared to a step-down light regimen.

The liver weights of chickens on full-fed treatment during the rearing phase (18 weeks) were 35g higher than those that were feed restricted. Regardless of the differences in the liver weights of Koekoek chickens that were subjected to different feeding levels the relative liver percentages were not different ($p>0.05$). These results suggest that the results pattern of the liver weights can be compared to the ones of the slaughter weights, hence there was a high correlation ($r=0.737$) between the two ($p<0.01$).

During the second phase (32 weeks) of the study, it was discovered that RA treatment improved the liver weight by 0.5%, 17.5% and 22.6% compared to the AA, AR and RR treatments respectively. The results indicate that Koekoek chickens that were fed without any restriction during their laying period had higher ($p<0.05$) liver weights compared to chickens that were in feed restriction during the same time. A compensatory growth of the liver weights was observed in chickens that were in the RA treatment. The non-significant differences were seen in Koekoek chickens that were either full-fed or restricted fed in terms of the relative liver percentages. The liver weight was positively related (r=0.670) to the liver percentage in Koekoek chickens that were subjected to different feeding levels ($p<0.05$). The results show that the liver weight corresponded positively ($p<0.05$) with the body weight of chickens hence the positive correlation (r=0.287) between the liver weight and the slaughter weight. It was also discovered that the relative liver percentage had an inverse association with the slaughter weight ($p<0.01$). This negative relationship explains that the different feeding level treatments failed to affect the liver weight as the percentage of the body weight.

The findings of this study are similar to those of Renema *et al*. (1999a) who reported that feed restriction resulted in decreased liver weights compared to the liver weights of broiler chickens that were fed *ad libitum*. Contrary to the findings of the present study Melnychuk *et al*. (2004) and Yagoub and Babiker (2008) stated no differences on liver weights between the chickens that were subjected to *ad libitum* feeding and restricted feeding. The findings of Pishnamazi *et al*. (2008) also discovered that the liver weights were higher in broiler chickens that were fed *ad libitum* as a percentage of body weight due to the generous feed allowance that is in conflict with the findings of the present study. In support of other research findings which are in conflict with the results of the present study Mahmood *et al.* (2007) concluded that the liver weights between *ad libitum* fed and restricted fed broiler chickens were not significantly different.

The results pointed out that an average liver weight of chickens that were exposed to summer conditions was 31.2g as opposed to 26.6g of chickens that were exposed to winter conditions at the age of 18 weeks. The results indicated that cold winter conditions hindered the liver weight performance by 4.6g. In terms of the liver weight as the percentage of slaughter weight it was discovered that chicken's performance was statistically similar ($p>0.05$). The findings of this study imply that the differences ($p<0.05$) in the liver weights were mainly because of the body weights.

During the laying phase (32 weeks), the differences in the liver weights were not significant. Despite the similarities in the weights of chickens that were subjected to different seasonal treatments it was observed that an average liver weight as a percentage of the slaughter weight differed significantly between chickens that were raised in summer and winter ($p<0.05$). The relative liver percentage of Koekoek chickens that were in winter treatment was 19.3% lower than in summer. Koekoek chickens in winter had an average liver weight as a percentage of slaughter weight the relative liver percentage of chickens that were reared in summer was 20% higher than in winter. The findings of this study portray an inverse relationship (($p<0.01$; $r=-0.504$) between the slaughter weight and the relative liver percentage of chickens. When comparing the liver weights of chickens at different ages it was recognized that the liver weights of chickens that were in winter treatment increased by 10.8g while the ones of chickens that were under summer treatment increased by 5.3g. This implies that the liver weights of chickens that were reared in winter grew twice more than the ones that were exposed to warm summer conditions.

Chickens that were in the RA and AA treatments in winter performed better. The lowest relative liver percentages were observed in Koekoek chickens that were allocated to the AA treatment in summer. The differences in liver percentages in the AA, AR, RA and RR treatments in summer and winter were 0.6%, 0.1%, 0.6% and 0.1% respectively. The difference between those that were in the AA and RA treatments during the laying phase was much greater compared to those in the AR and RR treatments. The results demonstrate that the relative liver percentages of chickens that were kept in winter outperformed their counterparts when subjected to equivalent feeding level treatments.

The results obtained in a study that was conducted by Rosa *et al*. (2007) are in accord with the finding of the present study who stated the decreased liver weights in chickens as the result of the high temperature. In support of these results, Blahova *et al*. (2007) added that liver weights of chickens were noticeably increased in low temperatures. Rajini *et al*. (2009) established that the liver weights of chickens were higher in winter.

In contradiction with the results of the present study, Chen *et al.* (2007) reported that the liver weights of chickens were not different regardless of the number of light light hours chickens were exposed to in a day.

Despite the insignificant differences between the gizzard weights of chickens that were full-fed and restricted fed, the findings of this study revealed a significant ($p<0.05$) difference between Koekoek chickens that were full-fed and those that were feed restricted as far as the relative gizzard percentages were concerned. The relative gizzard percentages of chickens that were under full (AA and AR) feeding was 2.2% while those that were subjected to restricted feeding (RA and RR) had the relative gizzard percentage of 2.7% (Figure 4.5). The slaughter weight had no relationship with the gizzard weight in chickens. A positive correlation (r=0.537) between the gizzard weight and the relative gizzard percentage ($p<0.01$) was noticed.

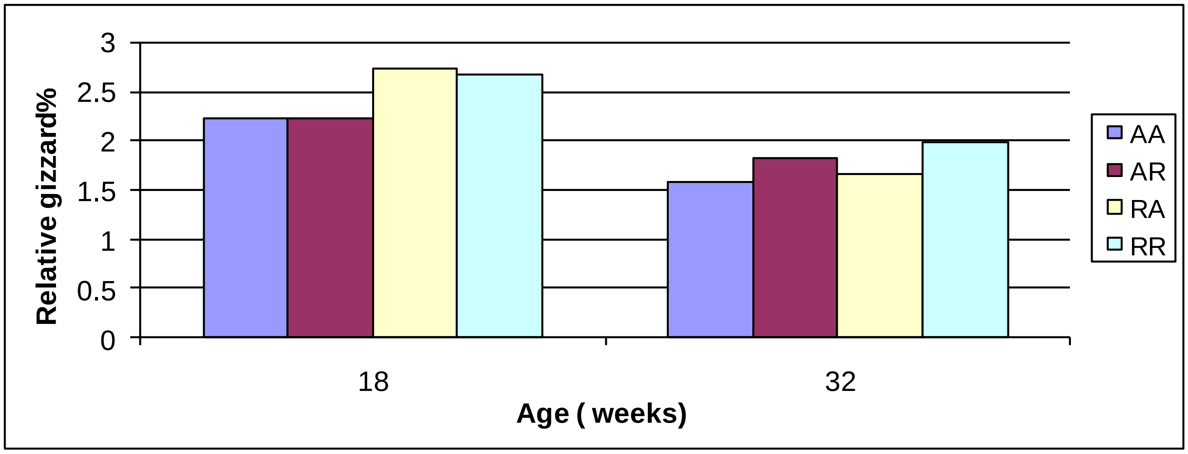

Figure 3.5: The relative gizzard percentage of Koekoek chickens subjected to different feeding levels

Footnote: AA-full feeding during rearing and laying. AR-full feeding during rearing and restricted during laying, RA-restricted feeding during rearing and full feeding during laying, RR-restricted during rearing and laying.

In the laying phase (32 weeks), the results demonstrate that Koekoek chickens that were subjected to the RA treatment were higher than those in the AA, AR and RR treatments by 1.8%, 9.7% and 5.5% respectively in terms of gizzard weights. These results clearly demonstrate that Koekoek chickens that were full-fed were on average 6.8% better than restricted fed chickens. With reference to the relative gizzard percentages at the age of 32 weeks Koekoek chickens that were under the AA, AR, RA and RR treatments had 1.6%, 1.8%, 1.7% and 2% respectively. Koekoek chickens that were full-fed only during the rearing phase (AR) had higher relative gizzard percentages in comparison with chickens that were in other treatment though they were not different ($p>0.05$) from chickens that were in the RA and RR treatments. The other observation was that chickens that were in the AA treatment had lower ($p<0.05$) relative gizzard percentages than the relative gizzard percentages of chickens that were in other treatments excluding chickens that were in the RA treatment. The findings of this study undoubtedly illustrate that the relative gizzard percentages of Koekoek chickens that were once introduced to restricted feeding at any stage of the study (AR, RA and RR) were statistically similar ($p>0.05$). Generally it was noticed that on average Koekoek chickens that were feed restricted during the laying period (AR and RR) had a higher relative gizzard percentage than chickens that had free access to feed (AA and RA). These results show that the gizzard weights were positively correlated ($p>0.01$) with the relative gizzard percentages ($r=0.402$) and slaughter weights ($r=0.592$).

The findings of the present study correspond with the results of Yagoub and Babiker (2008) who explained that the similarities between the gizzards weights of broiler chickens that were exposed to either restricted or *ad libitum* feeding were because of the muscular nature of the gizzard. Mahmood *et al.* (2007) also found no significant differences in gizzard weights between broiler chickens that were fed *ad libitum* and those that were feed restricted.

The results indicate the gizzard weights difference of 7.3% between Koekoek chickens that were reared in summer and winter with the latter having a higher ($p<0.05$) gizzard weight at 18 weeks of age. The relative gizzard weights as the percentage of the slaughter weight showed a similar pattern to the results as in absolute weights. This explains that the differences in the gizzards weights were not only related to the body weights of chickens but were mainly due to the treatment effects.

At the age of 32 weeks it was discovered that chickens that were exposed to warm summer conditions improved ($p<0.05$) the gizzard weights by 17.2% than in winter. With reference to the relative weight of the gizzards as a percentage of the slaughter weight it was detected that chickens that were in summer and winter treatments had statistically ($p>0.05$) similar relative gizzard percentages (1.8%). The insignificant differences in the relative gizzard weights as a percentage of the slaughter weight suggest that the differences of the absolute gizzard weights were mainly because of the slaughter weights rather than the seasonal effect. There were no effects ($p>0.05$) of feeding level and season interaction on the performance of the gizzards in absolute and relative terms at 18 and 32 weeks. The results obtained from the present study are in agreement with the findings of Rosa *et al.* (2007) who concluded that chickens that were exposed to heat had reduced gizzard weights.

The findings of the present study stated the differences ($p<0.05$) between Koekoek chickens that were full-fed and those that were under feed restriction at 18 weeks of age. The mean abdominal fat contents of chickens that were full-fed and restricted fed were 64.7 and 22.4g respectively. This implies that the abdominal fat of full-fed chickens was 65.4% higher ($p<0.05$) than the abdominal fat of those that were fed restrictedly. When considering abdominal fat as a percentage of body weight it was noted that full-fed chickens performed higher (p<0.05) than restricted fed chickens by 56.5% (Figure 4.6). The relative abdominal fat percentage of Koekoek chickens that were full-fed was different (p<0.05) from the relative fat percentage of chickens that were under restricted feeding. At this phase (18 weeks) of production it was discovered that the abdominal fat content was correlated (p<0.01) with the abdominal fat percentage (r=0.982) and the slaughter weight (r=0.870). This means that the differences in the abdominal fat content were primarily because of the effect of feeding level. It was also revealed from these results that 75.7% of the abdominal fat weight could be explained by the slaughter weight in Koekoek chickens. In this study, it was established that there was a positive relationship (p<0.01; r =0.743) between slaughter weight and skin weight because the more the birds had access to feed intake, the more the skin weight gained (Table 3.3).

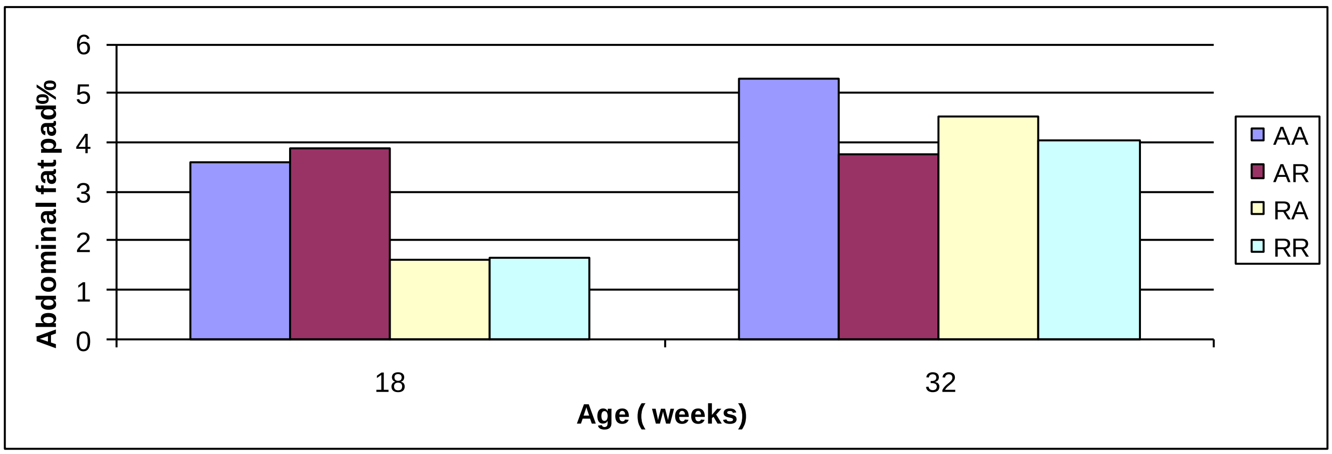

Figure 3.6: The relative abdominal fat percentage of Koekoek chickens that were subjected to different feeding levels
Footnote:
AA-full feeding during rearing and laying. AR-full feeding during rearing and restricted during laying, RA-restricted feeding during rearing and full feeding during laying, RR-restricted during rearing and laying, S.E-standard error.

During the laying phase (32 weeks) an average abdominal fat content of Koekoek chickens that were in the AA was higher than in the AR, RA and RR treatments by 54, 20.9 and 51.3g respectively. It was also observed that Koekoek chickens that were in the RA treatment gained more abdominal fat (82.4g) from the age of 18 to 32 weeks in comparison with chickens that were subjected to the AA, AR and RR treatments with the abdominal fat gains of 62g, 5.1g and 51g respectively. This implies that the fat accumulation process in the full-fed chickens was more rapid than in the feed restricted chickens. The amount of abdominal fat as a percentage of body weight followed a similar trend as the absolute abdominal fat content, hence a higher ($p<0.01$) correlation ($r=0.890$) between the abdominal fat content and the relative abdominal fat percentage. The relative abdominal fat of chickens that were allocated to the RA treatment was statistically ($p>0.05$) similar to all other treatments. The results for how different feeding management practices affected the abdominal fat pad demonstrate that differences in the fat content were primarily because of the feeding treatments rather than simply because of the different slaughter weights of Koekoek chickens. This can be confirmed by a high correlation between the slaughter weight and the abdominal fat content ($r=0.534$). This means that the slaughter weight contributed only 28.5% in the abdominal fat weight.

The results of the present study are in agreement with the findings of Novele *et al*. (2008) who stated that full-fed broiler chickens had excessive abdominal fat content than restricted fed ones. In addition, Mahmood *et al*. (2007) reported that restricted broilers had lower abdominal fat content at market age than those fed *ad libitum.* The same results were reported by Crounch *et al.* (2002c) and Richards *et al*. (2002). Renema *et al.* (1999a) confirmed a large difference in the relative fat pad with *ad libitum* fed broiler chickens representing a higher level of fat pad percent of body weight compared to restricted fed chickens. Nikoloval *et al*. (2007) stated that abdominal fat weight in broilers fed *ad libitum* increased significantly with age. This is in harmony with the results of the present study as it was noticed that the abdominal fat of *ad libitum* fed chickens was higher at 32 weeks age compared to when they were at 18 weeks of age. Attia *et al*. (1998) also reiterated that late feed restriction reduces the deposition of fat in broiler chickens as opposed to early feed restriction. Contrary to the findings of the present study, Saleh *et al*. (2005) reported that either abdominal fat content expressed as absolute or percentage of carcass weight was not affected by feed restriction.

Chickens that were subjected to summer treatment had an abdominal fat pad of 51.3g while those were in winter had 35.6g. The results indicate that an abdominal fat weight in chickens that were reared in summer was higher by 30.5% than the one of chickens that were kept in winter. The results suggest that an abdominal fat weight was positively associated ($r=0.87$) with the slaughter weight of chickens. This explains that 75.7% of an abdominal fat pad weight can be attached to the body weight of Koekoek chickens at slaughter age. The results on abdominal fat weight as the percentage of the slaughter weight indicate that chickens that were kept during the summer obtained heavier abdominal fat pad weight than those that were kept in winter. Koekoek chickens that were in summer treatment achieved the relative abdominal fat percentage of 3% compared to 2.4% of those that were reared in winter. The fact that the relative abdominal fat of chickens that were in summer treatment was higher ($p<0.05$) than the one for chickens that were subjected to cold environmental conditions suggests that the differences in the absolute abdominal fat were not mainly due to the different body weights but the different seasons contributed to the different abdominal fat performance. There were no feeding level and season interaction effects on abdominal fat pad characteristics in terms of abdominal fat weight and relative abdominal fat percentage on Koekoek chickens.

In support of the results of the present study, Wabeck *et al.* (1994) discovered that chickens that were reared in summer accumulated a higher amount of fat compared to the ones that were kept in winter. In an experimental study conducted by Rosa *et al.* (2007), a lower environmental temperature resulted in lower abdominal fat pad weight. Blahova *et al.* (2007) and Chen *et al.* (2007) also concluded that broilers that were kept under higher temperatures accumulated increased fat pad.

Table 3.8: Organs and abdominal fat characteristics in Koekoek chickens that were reared either in summer or winter

	Season		
Parameters	**Summer**	**Winter**	**S.E**
Rearing phase (18 weeks)			
Abdominal Fat wt (g)	51.3^{a}	35.6^{b}	1.77
Abdominal Fat %	3.0^{a}	2.4^{b}	0.11
Intestine wt (g)	61.5^{a}	51.1^{b}	2.53
Intestine %	3.7	3.7	0.16
Liver wt (g)	31.2^{a}	26.6^{b}	1.04
Liver %	1.9	1.9	0.06
Gizzard wt (g)	35.5^{a}	38.3^{b}	1.31
Gizzard %	2.2^{a}	2.8^{b}	0.08
Laying phase (32 weeks)			
Abdominal Fat wt (g)	91.3^{a}	95.8^{b}	8.14
Abdominal Fat %	3.8^{a}	5.0^{b}	0.37
Intestine wt (g)	69.0^{a}	69.1^{b}	3.77
Intestine %	3.1^{a}	3.7^{b}	0.20
Liver wt (g)	36.5	37.4	1.70
Liver %	1.6^{a}	2.0^{b}	0.08
Gizzard wt (g)	40.1^{a}	33.2^{b}	1.44
Gizzard %	1.8	1.8	0.06

[ab] Means within a row without a common superscript differ significantly ($p<0.05$), S.E=Standard Error

Table 3.9: The effect of the interaction between feeding level and season on organs and abdominal fat characteristics of Koekoek chickens

Carcass traits	SAA	S.E	WAA	S.E	SAR	S.E	WAR	S.E	SRA	S.E	WRA	S.E	SRR	S.E	WRR	S.E
Rearing phase (18 weeks)																
Abdominal fat wt(g)	73.0	2.45	53.1	2.45	75.6	2.45	56.6	2.45	26.7	2.45	17.0	2.45	29.8	2.65	15.8	2.65
Abdominal Fat %	4.0	0.15	3.3	0.15	4.2	0.15	3.6	0.15	1.8	0.15	1.5	0.15	2.0	0.16	0.3	0.16
Intestine wt (g)	60.7	3.50	52.0	3.50	64.4	3.50	56.6	3.50	59.3	3.50	48.0	3.50	61.5	3.79	48.0	3.79
Intestine %	3.9	0.22	3.2	0.22	3.6	0.22	3.6	0.22	3.9	0.22	4.2	0.22	4.1	0.24	3.9	0.24
Liver weight(g)	33.7	1.44	30.2	1.44	32.7	1.44	30.0	1.44	28.9	1.44	23.3	1.44	29.5	1.55	23.0	1.55
Liver %	1.8	0.09	1.9	0.09	1.8	0.09	1.9	0.09	1.9	0.09	2.0	0.09	2.0	0.09	1.9	0.09
Gizzard weight(g)	37.9	1.82	39.6	1.82	33.7	1.82	41.0	1.82	45.7	1.82	36.7	1.82	36.0	1.96	36.0	1.96
Gizzard %	2.1	0.11	2.4	0.11	1.9	0.11	2.6	0.11	2.9	0.11	3.2	0.11	2.4	0.12	2.9	0.12
Laying phase (32 weeks)																
Abdominal Fat wt(g)	132.1	11.28	118.0	11.28	66.7	11.28	75.4	11.28	107.0	11.28	101.4	11.28	59.3	12.19	88.3	12.19
Abdominal Fat %	4.9	0.51	5.7	0.51	3.3	0.51	4.2	0.51	4.0	0.51	5.0	0.58	3.1	0.55	5.0	0.55
Intestine wt(g(	69.9	5.22	71.1	5.22	71.1	5.22	69.1	5.22	64.7	5.22	72.6	5.22	70.2	5.64	56.3	5.64
Intestine %	2.6^a	0.27	3.6^b	0.27	3.6^a	0.27	3.9^b	0.27	2.4^a	0.27	3.6^b	0.27	3.6^a	0.29	3.3^b	0.29
Liver Weight(g)	39.1	2.36	42.6	2.36	35.0	2.36	32.7	2.36	39.1	2.36	43.1	2.36	32.8	2.55	31.0	2.55
Liver %	1.5^a	0.11	2.1^b	0.11	1.8^a	0.11	1.9^b	0.11	1.5^a	0.11	2.1^b	0.11	1.7^a	0.12	1.8^b	0.12
Gizzard Weight(g)	42.4	1.99	32.3	1.99	36.6	1.99	32.1	1.99	41.7	1.99	36.0	1.99	39.5	2.15	32.3	2.15
Gizzard %	1.6	0.08	1.6	0.08	1.8	0.08	1.8	0.08	1.6	0.08	1.8	0.08	2.0	0.09	1.9	0.09

^{ab} Means within a row with no common superscript differ significantly (p<0.05 and p<0.01).

Footnote:

SAA-full feeding during rearing and laying in summer season. SAR- full feeding during rearing and restricted during laying in summer season, SRA-restricted feeding during rearing and full feeding during laying in summer season, SRR-restricted during rearing and laying in summer season, WAA- full feeding during rearing and laying in winter season. WAR- full feeding during rearing and restricted during laying in winter season, WRA-restricted feeding during rearing and full feeding during laying in winter season, WRR-restricted during rearing and laying in winter season, S.E-standard error, sig- Significance level, wt- weight, the weight is in grams (g).

4.4 Conclusion

- Full feeding in the rearing phase improved the carcass characteristics of Koekoek chickens except for the breast muscle weight, intestine weight, liver weight and gizzard weight when expressed as percentage of the body weight as compared to restricted feeding.
- Warm summer conditions during the rearing phase increased the carcass characteristics except the dressing percentage, defeathered percentage, gizzard weight and shank length.
- Feeding chickens without restriction in summer proved to be the best option in terms of improved carcass dressing weight, carcass-dressing percentage, breast muscle weight and skin weight and percentage.
- Early feed restriction followed by full feeding improved the carcass characteristics during the laying phase.
- Rearing chickens in summer during the laying phase resulted in improved carcass characteristics with the exception of the shank length, shank width and the relative skin percentage.
- The cold winter conditions increased the abdominal fat weight and the percentage of the internal organs in Koekoek chickens during the laying phase.

4.5 Recommendations

- Based on the results of this research project it is recommended that Koekoek chicken be full-fed for the purpose of producing chicken meat in order to raise them to reasonable slaughter weight at 18 weeks of age.
- With reference to farmers who are keeping Koekoek chickens for laying purpose and also targeting meat production at the end of the laying period it is recommended that they should feed their birds unrestrictedly only during the laying phase since this will make them save some feed in the rearing stage.
- It is also recommended that birds should be raised under restricted feeding (RR) for purpose of producing lean meat at the end of the laying cycle. In order to have better results in terms of the majority of the carcass traits it would be more profitable if Koekoek chickens are reared in summer.

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CHAPTER 4

Effect of restricted feeding level and season on the carcass chemical composition of Koekoek chickens

Abstract

The main objective of this study was to determine the effect of restricted feeding and season on carcass chemical composition of Koekoek chickens. Two hundred and seventy hens and 27 cocks were used. An experiment was designed as a factorial of two seasons and four feeding regime treatments. The four treatments were AA, AR, RA and RR. Each treatment had seven replicates (10 birds per replicate) with an exception of RR treatment that was replicated six times (10 birds per replicate). Data was collected at 18 and 32 weeks of age. Data collected was subjected to SPSS (17.00) statistical package and analyzed by using multi- factorial analysis of variance (ANOVA). At the age of 18 weeks, feed restriction had an impact on dry matter, fat and crude protein percentage. At 32 weeks of age, birds that were fed restrictedly had reduced fat content and increased crude protein. The lowest crude protein percentage was recorded in chickens that were full-fed for the entire study (AA). Chickens that were allotted to summer treatment had a higher dry matter and crude protein content than chickens that were in winter treatment at 18 weeks of age. Koekoek chickens that were in summer and winter treatments performed differently in terms of dry matter, ash, crude fat and crude protein percentages at the age of 32 weeks. It is therefore, concluded that restricted feeding coupled with rearing chickens in winter resulted in lean carcass with more protein.

Key words: Koekoek chickens, feed restriction, full-fed, temperature, season, chemical composition.

4.1 Introduction

Increase in population in developing countries has not been marked by growth in agricultural productivity in the area of animal production, which leads to hunger and serious malnutrition among the people (Ukachukwu and Akpan, 2007). Basotho consume an average of 15g of animal protein per day as compared to 54g per capita per day in America and Europe. This is grossly inadequate and poses a threat of serious malnutrition (Jennings, 1974). Currently the high cost of poultry products makes it impossible for an average family in the country to consume an adequate quantity of animal protein.

These price increases are a reflection of corresponding high costs of feeds that result in low production and short supply of poultry.

The ash content was reported to be similar in the *ad libitum* and restricted fed chickens (Renema *et al.*, 1999a). Renema *et al.* (2007) explained that the percentage of crude fat in poultry meat is dependent on the severity of early feed restriction. In a study conducted by Crounch *et al*. (2002c) it was observed that carcass fat was reduced in restricted fed turkeys.

Higher moisture content was reported in chickens' meat produced in summer (Bianchi *et al.,* 2007). However, the results of Aksit *et al.* (2006) pointed to lower moisture content in chickens' thighs that were reared under increased environmental temperature while Barbour *et al.,* (2010) reported non-significant differences between the two groups of chickens. Summer conditions retarded the protein level in chickens (Aksit *et al.*, 2006 and Bianchi *et al.,* 2007). Bianchi *et al.* (2007) reported a lower ash percentage in summer reared chickens than in winter. The carcass fat was higher in chickens that were exposed to higher temperatures or summer conditions (Bogosavljevic- Boskovic *et al.*, 2006; Bianchi *et al.*, 2007; Rosa *et al.*, 2007 and Barbour *et al.,* 2010).

In order maintain meaningful and sustainable poultry production, it is necessary to find out the means of producing the acceptable quality of chicken meat at reduced costs in different seasons. An alternative feed management practice that would address this issue becomes imperative hence why this research project was focused on the effects of feed restriction and season on carcass chemical composition of Koekoek chickens. With the information obtained from this study, the farmers would be in a position to choose the appropriate feeding level and season so as to reduce the feeding costs without compromising the quality of meat from Koekoek chickens.

4.2 Materials and Methods

Two hundred and seventy (270) hens and twenty-seven (27) cocks of Koekoek chickens were bought at eight weeks of age. The chickens were housed in twenty-seven (27) pens. Ten hens and one cock were randomly selected and placed in each pen. The chickens were given a stress pack in water to combat travelling stress and lasoda vaccine in water to prevent Newcastle disease they might incur from travelling. They were fed pullet grower mash from arrival day up to 18 weeks of age, and then fed laying mash from 19 to 32 weeks. Koekoek chickens under restricted feeding were fed 70% of the full-fed diet. Koekoek chickens were offered fresh water without restriction and fed the same commercial feeds but at different quantities per day. The experiment was designed as a 4 feeding levels × 2 seasons (summer and winter) factorial arrangement in a completely randomized design. Treatments comprised: AA (Chickens were full-fed during both rearing and laying phases), AR (Chickens were full-fed during the rearing phase and shifted to restricted feeding during the laying phase), RA (Chickens fed restrictedly during the rearing phase and shifted to full feeding during the laying phase) and RR (Chickens fed restrictedly during both rearing and laying phases). Treatments AA, AR and RA were replicated seven (7) times except treatment RR, which was replicated six (6) times. Therefore, there were twenty-seven (27) experimental units.

At 18 and 32 weeks of age, one Koekoek chicken (hen) per replicate was slaughtered from chickens that were allocated to AA, AR, RA and RR treatments. Birds were starved for 12 hours before slaughtering. The slaughtering procedure was followed as outlined by Jones (1984). Following the weighing and measuring of organs and tissues, they were returned to their respective individual carcasses and stored at -40^{o}C. The carcass composition was carried out on birds without feathers with all carcass components. Thawed carcasses were dissected and then emptied into the blender (mincer) to be homogenized. The duplicate sample (200g) of each homogenate was freeze dried and then ground. The ground sample was then chemically analyzed for dry matter, protein, fat and ash (Van Marle Koster and Webb, 2000). The procedure for the chemical analysis of ground carcasses was as follows:

i) Dry Matter Chemical Analysis

Crucibles were cleaned and dried in a 105^{o}C oven for two hours. They were then placed in a deciccator for about 20 minutes in order to cool them to a room temperature. Two (2) grams of the grounded homogenous meat sample was weighed into the crucibles and each sample treatment was duplicated. The meat samples were placed in an oven for five (5) hours. The crucibles with meat samples were then removed from an oven and were placed again in a desiccator to cool to room temperature. The samples together with crucibles were then weighed back. The following formula was used to calculate the percentage of dry matter.

$$\% \text{ Dry Matter} = \frac{\text{(crucible weight + weight of the oven dried sample)}}{\text{Weight of sample before oven dried}} * 100$$

ii) Ash chemical analysis

The crucibles were placed in a muffle furnace of 350^{0}C for an hour. The temperature of the muffle furnace was then increased to 600^0 C for five hours. The crucibles were left in the muffle furnace over-night to cool down. They were then transferred to the desiccator to cool to room temperature. The following formula was used to calculate the ash percentage as dry basis:

$$\%\text{Ash as dry basis} = \frac{\text{Weight of ash}}{\text{Weight sample} * \%\text{DM}} *100$$

iii) Determining crude protein percentage using Leco FP-428

The leco FP- 428 is a microprocessor based using software controlled instrument that determines the nitrogen in variety of materials (Leco instruction manual). The ground meat sample weighing 0.2g was measured into the foil cup. The analysis cycle was composed of three (3) phases. During the drop purge phase, the encapsulated sample was placed in the loading head, sealed and purged of any atmospheric gases.

During the burning phase, the sample was dropped into a hot furnace of about 950^{o}C. It was then flushed with pure oxygen for very rapid combustion. The main products of combustion namely CO_2, H_2O, NOx and N_2 were passed through the thermo-electric cooler to remove most of the water then collected in the ballast volume. The products in the ballast were allowed to become a homogenous mixture at a pressure of approximately 975mm and at a constant temperature. In the third phase, the piston was forced down and a 10cc aliquot of the sample mixture was collected. The sample aliquot was swept through hot copper to remove oxygen and change NOx to N_2, then through lecosorb and anhydrone to remove carbon dioxide and water respectively. Finally, the remaining combustion product being nitrogen was measured using a thermal conductivity cell. The final product was then displayed as percent protein.

v) Determination of fat content

The crude fat percentage was determined with reference to Fat (Crude) or Ether Extract in Animal Feed (Method no 920.29, AOAC,, 1990). Two (2) grams of duplicated homogenous ground meat sample were weighed into tarred filter papers. The filter papers were folded and inserted into pre-numbered thimbles. The numbered fat cups (beakers) were dried in a 105^{o}C oven and then cooled in a desiccator.

The fat cups were lined up in front of the extractor to match the thimbles with their corresponding fat cups. The thimbles were slipped into the thimble holder that was clipped into position on an extractor. The fat cups were filled with petroleum ether (b.p. 40-60^{o}C) to the three quarter level. The beakers were clamped into an extractor. The heater switch, main power switch and condenser water were turned on. It was ensured that the ether did not leak. Extraction was allowed for four (4) hours. Rinsing was then allowed for an hour. The cups were detached from the extractor to allow for ether distillation. The distillation was done until a thin layer of ether remained at the bottom of the cups. The fat cups were then taken to the oven for 30 minutes. Finally, the cups were placed in a desiccator for cooling and then weighed again. The formula used to determine the percentage of crude fat was as follows:

$$\% \text{ crude fat} = \frac{\text{cup + extracted fat – cup weight}}{\text{Sample weight}} * 100$$

Data obtained and collected were stored in the computer under Microsoft excel and then finally analyzed using multi-factorial analysis of variance with the aid of SPSS (17.00) statistical package. Analyses were done on the transformed data. The same study was done in summer and winter.

4.3 Results and Discussion

The results for the chemical composition of the meat from chickens that were subjected to different feeding treatments at different slaughter ages are presented in Table 4.1. The results indicate that chickens that were subjected to different feeding levels performed differently in some of the nutrients. Koekoek chickens that were full-fed during the rearing phase (18 weeks) had a dry matter content of 96.7% and 96.9% for chickens that were in the AA and AR treatments respectively. Chickens that were subjected to restricted feeding had a dry matter content of 89.1% and 90.1% for those in the RA and RR treatments respectively. The dry matter content of chickens that were full-fed was higher ($p<0.05$) than the one in the feed restricted chickens by 7.4%.

At the age of 32 weeks, the dry matter content of chicken meat in the AA treatment was 0.7%, 0.8 and 0.8% lower ($p<0.05$) than in the AR, RA and RR treatments respectively. The findings of this study clearly indicate that the dry matter content failed to respond positively to body weight in chickens that were in the AA treatment at 32 weeks of age. It was also observed that the dry matter content of chickens that were full-fed in the rearing phase (AA and AR) declined during the laying phase while the dry matter of chickens that were feed restricted during the rearing phase (RA and RR) increased during the laying phase.

Table 4.1: Dry matter, ash, crude fat and crude protein percentages of meat from Koekoek chickens that were subjected to different feeding level treatments

		Treatments				
Age wks	**Nutrient (%)**	**AA**	**AR**	**RA**	**RR**	**S.E**
18	DM	96.7[a]	96.9[a]	89.1[b]	90.1[b]	0.24
	Ash	8.7	8.6	8.6	8.2	0.11
	Fat	43.4[a]	41.5[a]	33.5[b]	32.7[b]	0.47
	CP	37.9[a]	40.8[a]	50.0[b]	50.8[b]	0.57
32	DM	95.2[a]	95.9[b]	96.0[b]	96.0[b]	0.10
	Ash	6.1	6.2	6.1	6.3	0.15
	Fat	51.9[a]	45.3[b]	50.2[a]	40.0[c]	0.69
	CP	39.7[a]	41.9[ab]	41.8[ab]	45.1[b]	0.67

[ab] Means within a row with no common superscript differ significantly ($p<0.05$).
Footnote:
AA-full feeding during rearing and laying. AR-full feeding during rearing and restricted during laying, RA-restricted feeding during rearing and full feeding during laying, RR-restricted during rearing and laying, S.E-standard error. DM=Dry matter, CP=Crude protein

These results are in agreement with the results of Robinson *et al.* (1991b) who reported a significantly higher dry matter percentage in the full-fed chickens than in restricted fed chickens. Contrary to the results of the present study in the laying phase, Sobina *et al*. (1999) showed that chickens that are subjected to restricted feeding over a long period of time would show a significant decrease in the percentage of dry matter and fat.

Chickens that were kept in summer during the rearing phase (18 weeks) had a higher ($p<0.05$) dry matter percentage (94.1%) than those that were allocated to winter conditions (92.2%). This shows that the dry matter content of chickens that were reared in summer was 2% higher than in winter. During the laying phase (32 weeks), there was a significant difference in the percentage of dry matter observed between Koekoek chickens that were reared in summer and winter. Birds in summer improved the dry matter percentage by 1%. It was also observed that the dry matter content increased with the increase in the age of chickens. This can be confirmed by the fact that the dry matter content increased by 2.2% and 3.2% in chickens that were exposed to summer and winter condition respectively between 18 and

32 weeks of age. This indicates that a higher dry matter content in chickens that were kept in summer was possibly due to the higher weights that chickens experienced in summer.

The results of the present study are in accordance with the findings of Aksit *et al.* (2006) who noted that chickens that were raised under a higher temperature had a lower moisture content compared to those that were raised under a lower temperature. Contrary to the results of the present study, Chen *et al.* (2007) found no differences between the moisture content of chickens that were subjected to different sunlight hours in a day. Barbour *et al.* (2010) also reported non-significant differences in the moisture content of chickens that were exposed to different temperatures. Contrary to the findings of the present study, Bianchi *et al.* (2007) concluded that chicken meat produced in summer had higher moisture content.

The results portray that the dry matter percentage in chickens that were subjected to the restricted feeding in winter was 4.1% less than ($p<0.01$) in summer (Table 4.3). The feeding level and season interaction results clearly show that the differences in the dry matter were mainly due to the different slaughter weights that were noticed to be higher in summer at the age of 18 weeks.

The feeding level failed to affect the carcass ash contents in Koekoek chickens. The insignificant differences show that the carcass ash content was not related to the slaughter weight, hence there is a non-significant correlation ($r= 0.076$) between the ash content and slaughter weight. The ash percentage had an insignificant negative correlation ($r= -0.11$) with the slaughter weight. The carcass ash content had no significant correlation with crude protein, fat and dry matter percentages. This means that the ash content cannot be estimated by relating it either to body weight or to any of the nutrients. The results also show a decline of 27.5% in ash content across all treatments from 18 to 32 weeks of age meaning that that the older the chickens the lesser the ash content. The results of the present study are in agreement with the findings of Renema *et al.* (1999a) who reported similar ash content between full fed and restricted fed chickens.

At the age of 18 weeks as shown in Table 4.2, chickens that were kept in summer and winter obtained a similar (8.5%; $p>0.05$) meat ash contents. During the laying phase (32 weeks), the results indicate that the cold winter conditions improved the content of ash by 4.4%. This clearly shows that the ash content was negatively associated with the slaughter weight of chickens in a manner that meat from chickens with heavier body weights had a lower ash content.

It was also observed that the meat ash content decreased with an increase in age. The ash content from chicken meat produced in summer and winter treatments deteriorated by 29.1% and 26% respectively. This shows that the meat ash quality was negatively affected by high temperatures in summer rather than by low temperatures in winter. This means that low temperatures in winter were able to preserve the mineral and the vitamin components in chicken meat.

The results of the present study are in line with the findings of Aksit *et al.* (2006) who reported that the ash content seemed to decrease with an increase in age. The results by Bianchi *et al.* (2007) also stated that chicken meat produced in winter had a higher ash content compared to that produced in summer. Persia *et al.* (2003) found that the tibia ash percentage in chickens' meat was not affected by high temperature and this was not in agreement with the finding of the present study. Contrary to the results of the present study, Chen *et al.* (2007) disclosed that the relative ash percentage is not influenced by the different photoperiods.

An average crude fat percentage of chickens that were full-fed (AA and AR) was higher ($p<0.05$; 42.5%) than the one of Koekoek chickens that were feed restricted (RA and RR) with an average fat content of 33.1% at the age of 18 weeks. The findings imply that heavier chickens at slaughter age had higher crude fat percentage. This can be confirmed by a positive ($p<0.01$) correlation ($r=0.635$) between the slaughter weight and crude fat percentage. The crude fat percentage also had a positive correlation ($r=0.682$) with the dry matter percentage while the opposite was true with the crude protein percentage ($r= -0.627$; $p<0.01$).

At the age of 32 weeks, birds that were in the AA treatment had a higher fat content than those in the AR, RA and RR treatments by 6.6, 1.7 and 11.9% respectively. These results suggest a small difference between the crude fat percentage from AA and RA treatments as opposed to the AR and RR treatments. It was also observed that the crude fat content increased, as chickens were getting older across all the feeding level treatments. Chickens in the RA treatment had a highest increase compared to chickens in other treatments while those in the AR treatment had the lowest fat accumulation from 18 to 32 weeks of age. The highest crude fat percentage obtained from chickens that were in the RA treatment could possibly be attached to the compensatory growth shown by the same group of chickens.

The results of the present study are in accord with the findings of Renema *et al.* (1999a) who stated that the higher crude fat content was found in birds with heavy body weights compared to lower body weight chickens. Crounch *et al.* (2002c) also indicated that turkeys that were feed restricted had lower crude fat during rearing when compared to those that were full fed. Hassanabadi and Moghaddam (2004) concluded that the carcass fat content of restricted fed broiler chickens was lower ($p<0.05$) than that of control fed birds. Robinson *et al*. (1999) also indicated that carcass lipid remained significantly greater in the *ad libitum* fed broiler breeders than in the restricted fed ones.

Chickens reared in summer had insignificantly higher crude fat percentage (37.9%) than winter-reared ones (37.7%) during the rearing phase. The differences ($p<0.05$) in the percentage of crude fat were observed at the age of 32 weeks between chickens that were reared in summer and winter. Koekoek chickens that were in winter treatment outperformed their counterparts in summer by 6.7% in terms of crude fat content. The crude fat percentage increased with age despite of the season in which chickens were produced. Chickens that were subjected to summer conditions accumulated 7.7% while those raised in winter accumulated 10.6% of the crude fat between 18 and 32 weeks of age.

The results in the rearing phase (18 weeks) are supported by the findings of Chen *et al.* (2007) who reported non-significant differences in the total fat content of chickens that were subjected to different photoperiods. On the other hand, Bianchi *et al.* (2007) and Bogosavijevic-Boskovic *et al.* (2006) recorded higher lipid content in chickens that were kept in summer as opposed to those kept in winter. Barbour *et al.* (2010) also confirmed that birds that were heat acclimatized had a higher percentage of fat than those that were not exposed to heat. A higher crude fat percentage in chickens that were raised in winter is believed to be the outcome of high feed intake that resulted in more fat accumulation.

Koekoek chickens that were full-fed during the rearing phase obtained a lower percentage of crude protein (39.4%) while those that were raised under feed restriction had a crude protein of 50.4%. This indicates that an average crude protein percentage of restricted fed chickens was higher than the one of full-fed chickens by 21.9%. These results illustrate that chickens with a high body weight and fat content had reduced crude protein content hence why the crude protein is negatively correlated ($p<0.01$) with the slaughter body weight ($r = -0.467$), crude fat content ($r = - 0.627$), dry matter content ($r= -0.553$) and ash ($r = -0.295$; $p<0.05$).

At the age of 32 weeks, Koekoek chickens that were full-fed for the entire study (AA) obtained a lower ($p<0.05$) percentage of crude protein (39.7%) than those that were exposed to feed restriction for the entire study (RR) which had the highest protein content (45.1%). The crude protein percentages in the AR (41.9%) and RA (41.8%) treatments were statistically ($p>0.05$) similar and were different ($p<0.05$) from chickens that were in the AA and RR treatments. The results also showed a negative ($p<0.01$) correlation ($r= -0.547$) between the slaughter weight and crude protein.

The findings of the current study show that the crude protein percentage of chickens that were in the AR treatment increased by 2.8% while the one of chickens that were in the RA treatment declined drastically by 16.4%. Koekoek chickens that were full-fed for the two phases increased their protein content by 5.2% from 18 to 32 weeks of age. The protein percentage of chickens that were exposed to restricted feeding for the whole study (RR) decreased by 11.1%. These results indicate that despite chickens in restricted feeding having higher protein content there is a possibility of a decline in the crude protein percentage if they are slaughtered at an older age. This was also confirmed by de Beer and Coon (2007) who stated that the carcass protein content generally decreases with age in chickens.

The results of the present study are related to the findings of Renema *et al.* (1999a) who reported the similar percentages of protein in chickens that were in different feeding regimes, a the similar pattern to results observed in this study at 32 weeks of age.

The protein content of Koekoek chickens that were in summer treatment was 6.8% higher than in winter at the age of 18 weeks. The protein content responded positively to the body weight of chickens hence the meat produced from heavier chickens in summer yielded higher crude protein content. An opposite pattern of results was observed in chicken meat at the slaughter age of 32 weeks. Koekoek chickens that were exposed to winter conditions had a higher ($p<0.05$) crude protein content (46.2%) as compared to the ones that were subjected to summer treatment (38%). These results demonstrate that chickens with higher body weights had a lower crude protein percentage. It was also observed that the meat crude protein content of chickens that were exposed to warm summer conditions declined by 18.1% over a period of 14 weeks while the protein content in winter increased by 6.4%. These results reflect that the meat of chickens produced in summer deteriorates in value more than in winter as chickens get older.

The results of the present study are supported by the findings of Bianchi *et al.* (2007) and Blahova *et al.* (2007) who pointed out that the protein level was lower in chicken meat that was produced in summer, as was the case in this study, especially at the slaughter age of 32 weeks. Aksit *et al*. (2006) and Rosa *et al.* (2007) also argued that protein content corresponded negatively with the amount of heat allotted to chickens. Contrary to the findings of this study, other researchers reported a similar performance in chickens that were exposed to different temperatures (Chen *et al*., 2007 and Barbour *et al.*, 2010).

Table 4.2: Dry matter, ash, crude fat and crude protein percentages of meat from Koekoek chickens that were reared in either summer or winter

		Season		
Age (wks)	**Nutrient (%)**	**Summer**	**Winter**	**S.E**
18	DM	94.1^a	92.2^b	0.48
	Ash	8.5	8.5	0.21
	Fat	37.7	37.9	0.94
	CP	46.4^a	43.3^b	1.15
32	DM	96.2^a	95.3^b	0.19
	Ash	6.0^a	6.3^a	0.30
	Fat	45.2^a	48.5^b	1.37
	CP	38.0^a	46.2^b	1.36

ab Means within a row with no common superscript differ significantly (p>0.05), S.E- Standard Error

Table 4.3: Effect of the interaction between feeding level and season on the chemical composition of meat from Koekoek chickens

Meat chemical composition	SAA	S.E	WAA	S.E	SAR	S.E	WAR	S.E	SRA	S.E	WRA	S.E	SRR	S.E	WRR	S.E
% DM	97.0[a]	0.62	96.4[b]	0.62	96.5[a]	0.62	97.2[b]	0.62	91.7[a]	0.62	86.6[b]	0.62	91.3[a]	0.67	88.8[b]	0.62
% Ash	8.5	0.22	8.8	0.22	8.7	0.22	8.5	0.22	8.4	0.22	8.7	0.22	8.4	0.24	8.0	0.24
% Fat	43.5	1.30	43.4	1.30	43.1	1.30	40.0	1.30	32.9	1.30	34.1	1.30	31.5	1.41	34.0	1.41
% CP	39.4	1.41	36.5	1.41	42.3	1.41	39.2	1.30	53.5	1.41	46.5	1.41	50.6	1.52	51.0	1.41
% DM	96.1	0.27	94.3	0.27	96.3	0.27	95.5	0.27	96.3	0.27	95.7	0.27	96.2	0.29	95.7	0.29
% Ash	5.9	0.41	6.4	0.41	5.5	0.41	6.9	0.41	6.1	0.41	6.0	0.41	6.7	0.44	6.0	0.44
% Fat	47.8	1.88	56.0	1.88	43.0	1.88	47.5	1.88	49.7	1.88	50.7	1.88	40.5	2.05	39.6	2.05
% CP	35.7	1.86	43.7	1.86	39.9	1.86	43.9	1.86	35.8	1.86	47.8	1.86	40.8	2.01	49.5	2.01

[ab] Means within a row with no common superscript differ significantly (p<0.05 and p<0.01).

Footnote:

SAA- full feeding during rearing and laying in summer season. SAR- full feeding during rearing and restricted during laying in summer season, SRA-restricted feeding during rearing and full feeding during laying in summer season, SRR-restricted during rearing and laying in summer season, WAA- full feeding during rearing and laying in winter season. WAR-*ad libitum* feeding during rearing and restricted during laying in winter season, WRA-restricted feeding during rearing and full feeding during laying in winter season, WRR-restricted during rearing and laying in winter season, S.E-standard error, Sig- Significance level. %DM- Percentage Dry matter, % Ash- Percentage Ash, %Fat-Percentage fat, %CP-Percentage crude protein

4.4 Conclusion

- Full feeding increased the dry matter, ash and fat content while feed restriction improved the crude protein content of chickens during the rearing phase.
- Restricted feeding resulted in reduced fat accumulation and increased crude protein content in Koekoek chickens when slaughtered at the age of 32 weeks.
- Warm summer conditions improved the dry matter and crude protein contents during the rearing phase.
- Cold winter conditions during the laying phase increased the ash, fat and crude protein contents of chickens but lowered the dry matter percentage. Cold winter conditions have the potential of preserving the nutrient composition of chicken meat.

5.5 Recommendations

- In order to have chicken meat with higher protein content and low fat content it is recommended that Koekoek chickens be raised on feed restriction if a farmer is aiming at producing meat from 18 weeks old chickens.
- For farmers who are interested in chicken meat with higher protein and lower fat contents at the end of the laying phase the best feeding management would that the chickens be fed restrictedly for both rearing and laying phases (RR). The meat produced from chickens that were in the RA and AR treatments cannot be ruled out because of its higher crude protein except that it cannot be recommended to people with a problem in consuming fatty meat.
- It is also recommended that the best season to rear Koekoek chickens is summer if the target is to slaughter them at the age of 18 weeks based on the higher crude protein and dry matter contents.
- In a case where chickens would be slaughtered at an older age (32 weeks) it would be advantageous to keep them in winter so as to obtain higher ash (mineral and vitamin content) and crude protein percentages although a farmer would be compromising on the level of fat content which will not be a problem in winter since the human body needs that fat to generate warmth during the colder seasons.

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CHAPTER 5

Effect of restricted feeding and season on reproductive performance of Koekoek chickens

Abstract

The objective of this study was to determine the impact of feeding level and season on the reproductive performance of Koekoek chickens. Two hundred and seventy chickens were randomly allocated to four feeding level treatments and two seasons in a completely randomized factorial design. The four feeding level treatments were AA *(*full-fed during the rearing and laying phases), AR (full-fed during the rearing phase and restricted feeding during the laying phase) RA (restricted feeding during the rearing phase and full-fed during the laying phase) and RR (restricted during both the rearing and laying phases). The study was done in summer season and winter season. The General Linear Model (GLM) procedure (SPSS 17) was used to analyze the data set. Koekoek chickens that were full-fed during the rearing phase (AA and AR) had larger combs than those that were feed restricted. The comb sizes were 53.1, 51.5, 54.6 and 51.7mm for chickens in the AA, AR, RA and RR treatments respectively at the age of 32 weeks. The wattle sizes were higher in Koekoek chickens that were full-fed in the rearing phase. The pubic bone measurements were 23.6, 25.1, 16.1 and 15.1mm for chickens that were in the AA, AR, RA and RR treatments respectively at 18 weeks of age. At 32 weeks of age, chickens that were subjected to the AA and RA had wider pubic bones than chickens that were in the AR and RR treatments respectively. Combined ova and oviduct weights were higher in the full-fed chickens at the age of 18 weeks. The comb and lengths of chickens produced in summer were 37.8 and 58.5mm at 18 and 32 weeks of age while in winter the comb lengths were 22.2mm and 47mm at the age 18 and 32 weeks respectively. The wattle sizes were higher in chickens that were reared in summer at 18 and 32 weeks of age. The pubic bones were wider in chickens that were subjected to summer treatment than the ones that were in winter treatment during the puberty stage. The weights of the ovaries and oviducts were higher in summer than in winter. Koekoek chickens that were in the treatment AA had the highest average egg production. Birds that were in the AR treatments had lower average egg weights than those that were in the AA, AR and RR treatments. Chickens that were in the AA and AR treatments reached puberty earlier than those that were subjected to the RA and RR treatments. The eggs produced by chickens that were in the RR treatment had a higher average hatching percentage. The lowest hatching percentage was experienced from chickens that were in the AA and RA treatments. Chickens that were produced in summer had higher average laying percentage and egg weights. Chickens that were in summer were the first to reach puberty, 20%, 50% and 80% egg production. The interaction between feeding regime and season had an effect on the laying percentage, number of abnormal eggs and age at first oviposition.

Key words: Koekoek chickens, full-fed, restricted, season, comb, wattle, ova, oviduct and pubic bone, laying percentage, egg weight, abnormal and hatching percentage

5.1 Introduction

Chickens are the most accessible livestock species for people of lesser means, constituting a source of inexpensive protein (Alders and Spradbrow, 2001). An egg is very tender and palatable and its acceptability to consumers is high. Feeding is one of the greatest determinants to be considered in order to have a higher egg production. The fact that the costs of chicken feeds are increasing at an alarming rate makes it impossible for the poor resource farmers in the rural areas of Lesotho to keep laying chickens hence the spread of serious malnutrition. One of the strategies to reduce high feeding costs is through the use of restricted feeding as well as the proper timing for the rearing of chickens. Melnychuk *et al*. (2004) reported heavy oviducts in chickens that were fed *ad libitum*. Crounch *et al*. (2002b) also found similar results even though the study was done on turkeys. However, in a study done on quails Yildiz *et al.* (2006) found feed restriction as a strategy to reduce oviduct development. In terms of the ovary development, some studies indicated a greater weight in the *ad libitum* fed chickens (Melnychuk *et al.,* 2004 and Renema *et al*., 1999b). Despite the study being done on turkeys Crounch *et al*, (2002b) reported that feed restriction during the rearing phase resulted in heavier maturing ova. Joseph *et al*. (2003) reported a higher correlation between the age and comb size at first oviposition especially in the *ad libitum* fed chickens.

The oviducts and ovaries of chickens that are under cool environmental conditions develop more rapidly than those reared under warm weather conditions (Rozenboim *et al.*, 2007). The results of Chen *et al.* (2007) indicated larger ovaries, combs and wattles in pullets that were subjected to different sunlight hours in a day.

Feed restriction has the benefits of increased egg size, laying percentage and reduced mortality during the laying period (Robinson *et al.,* 1978). Feed restriction during the rearing phase increases the hen house production as stated by Bruggeman *et al.* (1999). Feed restricted birds normally reach a higher peak egg production than the *ad libitum* fed birds. However, the results of Hassan *et al*. (2003) showed a similar laying production between quails that were fed differently prior to sexual maturity. Richards *et al.* (2003) reported a smaller number of abnormal eggs in restricted fed broiler breeder chickens. On the other hand, some researchers established a slight decrease in egg weights of restricted fed chickens (Robinson *et al.,* 1978 and Miles and Jacgueline, 2000). In a study conducted in quails it was established that fertility and hatchability were not affected by the feeding regime (Hassan *et al.*, 2003) while in turkeys a higher hatchability was recorded in the feed restricted treatment (Crounch *et al.*, 2002b).

Some researchers reported that increased temperature affects egg production and egg weights in a negative manner (Garces *et al.*, 2001; Usayran *et al.*, 2001; Marshaly *et al.*, 2004; Smith, 2005 and Rozenboim *et al.*, 2007). Fertility and hatchability are reported to be similar in chickens that were reared in either summer or winter (Abdou *et al.*, 1977 and Babiker and Musharaf, 2008). The findings of Ozcelic *et al*. (2006) revealed a negative relationship between the level of temperature and hatchability.

Since the introduction of Koekoek chickens in Lesotho there have been scientific researches conducted on their feeding management. Therefore, it is important to establish the feeding level aimed at maximising egg production and hatchability at affordable feeding costs hence why a study on effects of restricted feeding and season on the laying and hatching performance of Koekoek chickens was conducted.

5.2 Materials and Methods

This research study was carried out at the National University of Lesotho, Faculty of Agriculture experimental farm. Chickens were bought at the age of 8 weeks and were fed commercial feeds. After their arrival, they were given a stress pack to reduce travelling stress that might cause death. Chickens were reared under the deep litter system. Each pen was equipped with 3 wooden nests of 40×40×40cm. From 8 to 18 weeks, birds ate pullet grower, then from 19 to 32 weeks, they were fed laying mash.

Birds were given water without restriction. A completely randomized factorial design of four feeding level treatments and two seasons was used. The four feeding level treatments were AA, AR, RA and RR. Each treatment had ten hens and one cock. Each treatment was replicated seven times except the RR treatment which was replicated six times meaning that there were 270 hens and 27 cocks. The experiment was done in two different seasons being summer and winter.

At the age of 130 days and at 32 weeks (224 days), seven Koekoek hens per treatment were killed by cervical dislocation. The birds were starved 24 hours prior to slaughtering. The ovaries and oviducts were collected and weighed. The oviducts were emptied of the contents. The ovaries were examined for follicular development. The diameter of pubic bones was measured. The wattle and comb measurements were taken after every two weeks from the age of 18 to 32 weeks. Eggs were collected on a daily basis and an average laying percentage was calculated for every week for the entire study period. The egg weights and abnormal eggs were recorded. Abnormalities in eggs included soft shelled, shell-less, cracked and double yolk eggs. The other parameters such as mortality rate, age at puberty (point of lay age), age at 20, 50 and ≥80% egg production were recorded. A sample of three (3) eggs weighing between 50 and 55g from each replicate in all treatments was taken and set in an incubator machine. The eggs that were less than eight (8) days old were placed in an incubator. During the incubation period, the eggs were not turned for the first three days. From the fourth day to the eighteenth day, egg turning was done three times a day. At the 18th day, the eggs were removed from trays and placed into the hatching trays until hatching time. The incubator was not disturbed for the last three (3) days of incubation. The chicks were removed from the incubator on the morning of the 22nd day. The hatching percentage of the eggs was calculated as follows:

$$\text{Hatching percent} = \frac{\text{Total number of eggs hatched}}{\text{Total number of eggs incubated}} * 100$$

An incubator was opted for instead of natural hatching due to the fact it would be difficult to control the experiment since it would difficult to get hens of the same age, size and behaviour. Above all, it would not be practical to assume that the hens would brood at the same time.

Data was stored in the computer under Microsoft excel. The transformed data was analyzed using SPSS (17.00) statistical package. General Linear Model (GLM) procedure (SPSS 17.00) was used to establish the effect of feed restriction and season on reproductive performance of Koekoek hens.

5.3 Results and Discussion

5.3.1 Effect of restricted feeding and season the reproductive characteristics of Koekoek chickens

The comb lengths of Koekoek hens that were full-fed (AA and AR) at puberty (18 weeks) were 10mm greater ($p<0.05$) than those under restricted feeding (RA and RR). At the age of 22 weeks hens that were subjected to the AA treatment had longer ($p<0.05$) combs as compared to those that were subjected to other treatments. This indicates that birds that were full-fed reached puberty earlier than those that were under restricted feeding. Koekoek hens that were full-fed only in the laying phase (RA) had their combs developed faster soon after they were allowed access to feed without restriction. This can be explained by the fact that the comb lengths of chickens that were in the RA treatment were not different ($p>0.05$) from the ones of chickens that were full-fed during the rearing phase at the age of 24 weeks. The comb measurements of the hens in the RR treatment were lower ($p<0.05$) than in the AA, AR and RR treatments by 11.9%, 6.7% and 7.9% respectively. These results indicate that from the age of 26 to 30 weeks Koekoek hens that were in the RR treatment had shorter comb lengths in comparison with birds in other treatments. However, an insignificant difference was noticed between birds in the AR and RR treatments during the 28th and 30th week.

5.1: Comb lengths (mm) of Koekoek chickens that were subjected to different levels of feeding from 18 to 32 weeks

	Treatment				
Age weeks	**AA**	**AR**	**RA**	**RR**	**SE**
18	35.4^{a}	34.4^{a}	25.9^{b}	24.9^{b}	0.26
22	43.4^{a}	41.7^{b}	38.2^{c}	37.1^{c}	0.31
24	48.7^{a}	46.0^{b}	46.6^{ab}	42.9^{c}	0.39
26	52.0^{a}	50.9^{a}	49.7^{a}	45.6^{b}	0.48
28	56.4^{a}	51.3^{bc}	53.7^{c}	50.2^{b}	0.49
30	55.5^{a}	50.0^{b}	53.5^{a}	48.3^{b}	0.52
32	53.1^{ab}	51.5^{a}	54.6^{b}	51.7^{ab}	0.52

^{ab} Means within a row with no common superscript differ significantly ($p<0.05$).
Footnote:
AA-full feeding during rearing and laying. AR-full feeding during rearing and restricted during laying, RA-restricted feeding during rearing and full feeding during laying, RR-restricted during rearing and laying, S.E-standard error.

At week 32, the results indicate that Koekoek hens that were in the RR treatment (51.7mm) were insignificantly different from birds in the AA (53.1mm), RA (54.6mm) and AR (51.5mm) treatments. Koekoek chickens in the RA treatment had longer ($p<0.05$) combs compared to those that were subjected to the AR treatment. The comb lengths of chickens that were in the RA treatment were statistically similar ($p>0.05$) to those that were in the AA and RR treatments. However, these results indicate that early restricted feeding improves the development of combs in hens as they advance in age. This can be verified by the fact that the higher development of the combs was noticed on chickens that were feed restricted during the rearing phase (RA and RR) as opposed to chickens that were fed *ad libitum* during the rearing phase (AA and AR) from 18 to 32 weeks of age. The comb sizes increased by 33.3%, 33.2%, 52.5% and 51.9% for the Koekoek hens that were allocated to the AA, AR, RA and RR treatments respectively over a period of 14 weeks. The comb lengths of hens at 18 weeks of age were positively ($r=0.617$) correlated ($p<0.01$) with the comb lengths at the age of 32 weeks. This indicates that the comb sizes of chickens at 32 weeks of age is determined by the size of the combs at sexual maturity (18 weeks) with the probability of 38.1% ($r2=0.\ 3807$).

The results of the present study are in agreement with the findings of Joseph *et al*. (2003) who indicated a positive correlation between comb size and feed intake.

The comb lengths of Koekoek hens that were subjected to summer treatment were significantly different from those that were raised in winter. At 18 weeks of age, the comb lengths of summer-reared pullets were 37.8mm as opposed to 22.2mm being an average comb size for those reared in winter. This reflects that the winter conditions delayed the development of combs by 41.3% than in summer at puberty. The chickens that were reared in summer had longer combs than those in winter throughout the entire study. At the age of 32 weeks, the comb sizes in summer were 19.8% higher in winter. This reflects that the gap between the summer and winter reared hens in terms of comb size decreases with increase in age. The comb development was positively correlated with age regardless of the season of rearing. This can be proved by the fact that hens that were in summer and winter increased their average comb length by 20.8 and 24.6mm respectively over the period of 14 weeks (18 to 32 weeks).

Despite the Koekoek hens reared in winter having a lower performance with reference to comb lengths it was revealed that their comb lengths were developing at the faster rate than those in summer. The results reflect that between the ages of 18 and 32 weeks the comb development of chickens that were in winter was 17.3% higher than the one of chickens that were exposed to summer conditions hence there was a narrower gap between the comb sizes of chickens in two season treatments at 32 weeks as opposed to earlier weeks (Figure 5.1). The increased growth of the combs was more pronounced from the 22nd to 30th week.

Table 5.2 Comb lengths (mm) of Koekoek chickens that were reared in either summer or winter from 18 to 32 weeks of age

	Seasons		
Age	**Summer**	**Winter**	**S.E**
18	37.8^{a}	22.2^{b}	0.52
22	45.1^{a}	35.1^{b}	0.61
24	54.0^{a}	38.1^{b}	0.79
26	53.3^{a}	45.8^{b}	0.97
28	56.1^{a}	49.7^{b}	0.97
30	55.3^{a}	48.4^{b}	1.04
32	58.5^{a}	47.0^{b}	1.05

^{ab} Means within a row with no common superscript differ significantly (p<0.05). S.E-Standard Error

The results of the present study are in agreement with the findings of Lamoreux (1943) who stated that the comb size increased greatly in winter. Similar results were observed in this study as the combs of the winter-reared hens were increasing at a higher rate than the summer reared ones in spite of the fact that Koekoek hens in summer had longer combs than in winter. The results showed an interaction ($p<0.05$) between feeding level and season on comb lengths of Koekoek hens from 18 to 26 weeks of age. Generally comb sizes of chickens that were in the AA and AR treatments in summer were 20mm longer ($p<0.01$) than in winter at the age of 18 weeks.

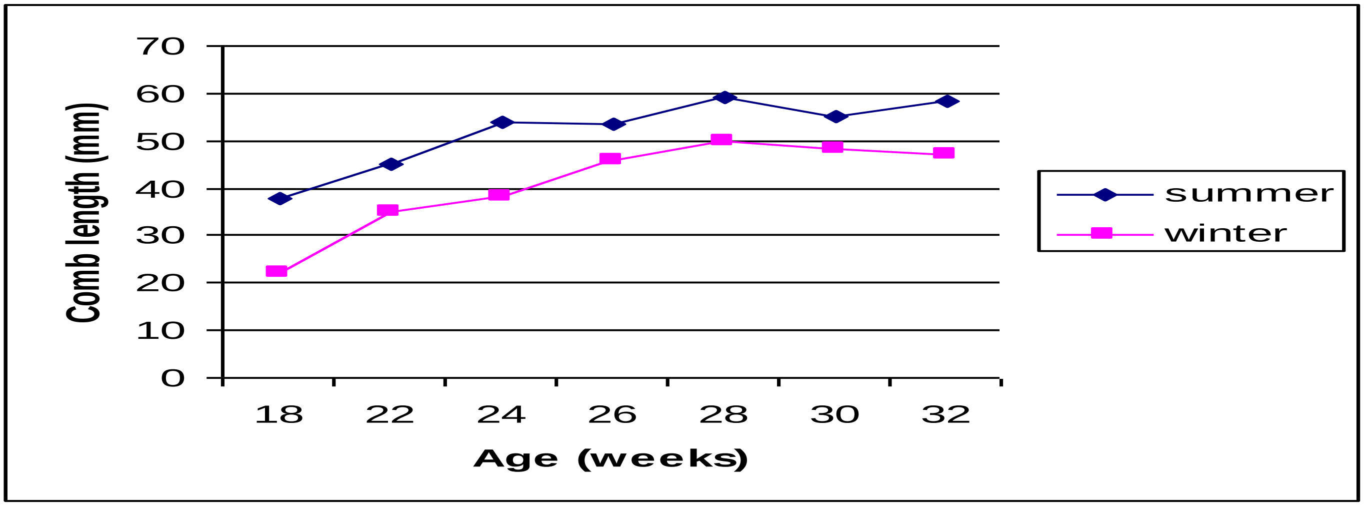

Figure 5.1: Comb lengths of Koekoek chickens reared under different seasons

On the other hand, the comb lengths of chickens that were in the RA and RR treatments were higher in summer than in winter. The results of this study indicate that rearing Koekoek hens in summer would on average improve the comb size by 45% and 35.9% in the full-fed and restricted fed pullets respectively at sexual maturity. The same trend of the results was observed at the age of 22 weeks with hens that were in the AA and AR treatments in summer having higher comb lengths than those in winter. However, it was noticed that Koekoek hens that were feed restricted in summer during the rearing phase (SRA and SRR) had larger combs than those that were fed without restriction in winter during the rearing phase (SAA and SAR). This means that rearing Koekoek hens in summer would still bring better results even if hens were fed restrictedly. A similar pattern of the results was observed during the 24^{th} and 26^{th} weeks of age. The comb sizes were statistically similar ($p>0.05$) from 28 to 32 weeks of age between Koekoek chickens that were subjected to different interaction treatments.

Table 5.3: Effect of the interaction between feeding level and season on the comb length (mm) of Koekoek chickens

Age (Weeks)	SAA	S.E	WAA	S.E	SAR	S.E	WAR	S.E	SRA	S.E	WRA	S.E	SRR	S.E	WRR	S.E
18	45.2[a]	0.72	24.9[b]	0.72	44.0[a]	0.72	24.1[b]	0.72	31.9[a]	0.72	20.0[b]	0.72	30.0[a]	0.78	19.7[b]	0.78
22	49.6[a]	0.84	37.2[b]	0.84	50.0[a]	0.84	33.4[b]	0.84	40.8[a]	0.84	35.6[b]	0.84	40.0[a]	0.91	34.3[b]	0.91
24	56.1[a]	1.09	41.4[b]	1.09	55.2[a]	1.09	36.7[b]	1.09	52.6[a]	1.09	40.5[b]	1.09	52.0[a]	1.18	33.8[b]	1.18
26	53.4[a]	1.34	50.5[b]	1.34	54.3[a]	1.34	47.5[b]	1.34	55.1[a]	1.34	44.3[b]	1.34	50.4[a]	1.45	40.7[b]	1.45
28	58.5	1.35	54.2	1.35	55.8	1.35	46.9	1.35	55.9	1.35	51.1	1.35	54.2	1.46	46.2	1.46
30	59.1	1.44	52.0	1.44	54.3	1.44	45.6	1.44	56.0	1.44	51.1	1.44	51.8	1.56	44.8	1.56
32	60.2	1.45	46.0	1.45	56.8	1.45	46.2	1.45	60.0	1.45	49.3	1.45	57.1	1.57	46.3	1.57

[ab] Means within a row with no common superscript differ significantly ($p<0.05$ and $p<0.01$).

Footnote:

SAA- full feeding during rearing and laying in summer season. SAR- full feeding during rearing and restricted during laying in summer season, SRA-restricted feeding during rearing and full feeding during laying in summer season, SRR-restricted during rearing and laying in summer season, WAA-*ad libitum* feeding during rearing and laying in winter season. WAR- full feeding during rearing and restricted during laying in winter season, WRA-restricted feeding during rearing and full feeding during laying in winter season, WRR-restricted during rearing and laying in winter season, S.E-Standard Error

Restricted feeding had a significant effect on the wattle development of Koekoek chickens as refected in Table 5.4. Koekoek hens that were subjected to different levels of feeding performed differently from 18 to 30 weeks of age.

Table 5.4: Wattle lengths (mm) of Koekoek chickens subjected to different feeding levels

		Treatments			
Age	**AA**	**AR**	**RA**	**RR**	**S.E**
18	20.9^{a}	20.0^{a}	16.5^{b}	16.9^{b}	0.20
22	26.7^{a}	25.2^{a}	24.6^{b}	24.3^{b}	0.23
24	28.5^{a}	26.2^{ab}	26.7^{ab}	24.9^{b}	0.21
26	25.9	25.3	26.4	24.7	0.29
30	25.9^{a}	24.2^{b}	26.2^{a}	24.3^{b}	0.29
32	26.4	25.0	26.0	25.1	0.30

^{ab} Means within a row with no common superscript differ significantly (p<0.05).
Footnote:
AA- full feeding during rearing and laying. AR- full feeding during rearing and restricted during laying, RA-restricted feeding during rearing and full feeding during laying, RR-restricted during rearing and laying, S.E-standard error.

The wattle lengths of Koekoek pullets that were fed without any restriction (AA and AR) during the growing phase were 18% and 5.8% longer (p<0.05) than those that were fed restrictedly (RA and RR) at 18 and 22 weeks of age respectively. This illustrates that birds that were full-fed reached sexual maturity earlier than those that were under restricted feeding since feed restriction delays sexual maturity (Melnychunk *et al.*, 2004). Koekoek hens that were under the AR and RA treatments had similar (p>0.05) wattle lengths at 24 weeks of age with wattle lengths of 26.2mm and 26.8mm respectively and they were neither different (p>0.05) to the wattle lengths of Koekoek hens that were in the AA treatment nor those that were in the RR treatment. An average wattle size for Koekoek hens that were in the AA treatment (28.5mm) was higher (p<0.05) than the one for those that were in the RR treatment (24.9mm). The effect of the compensatory growth was noticed during the 30th week with hens that were RA treatment having significantly larger wattles than those in the AR and RR treatments by 7.6% and 7.3% respectively but insignificantly larger than those in the AA treatment by 1.2%.

These results suggest that the wattle sizes in chickens that were feed restricted during the rearing phase (RA and RR) developed faster than those that were full-fed during the same phase (AA and AR). The wattles at 32 weeks of age increased by 5.6mm, 5mm, 9.5mm and 8.3mm for chickens that were in the AA, AR, RA and RR treatments respectively. This shows that the wattle sizes in chickens that were subjected to the RA treatment responded to the phenomenon of compensatory growth. The wattles of chickens that were in the RR treatment were growing at a constant rate which might be because of the fact that they were used to a small quantity of feed as opposed to chickens that were only restricted in the laying phase (AR).

The wattle length at the age of 18 weeks correlated ($p<0.01$) with the comb size at 18 weeks ($r=0.95$) and 32 weeks ($r=0.58$) of age. A higher correlation between the comb and wattle sizes suggests that the wattle size can be estimated through the use of comb size since 89% of the wattle length can be explained by the comb length at sexual maturity (18 weeks). It was also observed that the wattle length at 32 weeks of age was not dependent on the wattle size at the puberty stage in Koekoek hens and hence a non-correlation ($p>0.05$; $r=0.151$) between the wattle lengths at 18 and 32 weeks of age.

The season affected the wattle performance of Koekoek hens that were kept for a period of 14 weeks (Table 6.5). The wattle lengths were longer in chickens that were reared in summer than in winter during the first six weeks after the onset of laying (18 to 24 weeks). Summer conditions improved the wattle sizes by 6.6, 5.4 and 6.9mm during the 18th, 22nd and 24th weeks of age respectively. The wattle lengths were statistically similar ($p>0.05$) from the 26th to 32nd week.

Table 5.5: Wattle lengths (mm) of Koekoek chickens that were reared in either summer or winter from 18 to 32 weeks of age

	Seasons		
Age	**Summer**	**Winter**	**S.E**
18	21.9^{a}	15.3^{b}	0.39
22	27.9^{a}	22.5^{b}	0.61
24	30.1^{a}	23.2^{b}	0.42
26	26.0	25.2	0.58
28	25.8	26.1	0.51
30	25.3	25.0	0.62
32	25.9	25.4	0.60

^{ab} Means within a row with no common superscript differ significantly ($p<0.05$), S.E-Standard Error

This reflects that cold conditions of winter only had an impact at the younger age in chickens. It is also assumed that the reason for the season to have insignificant ($p>0.05$) effect once hens are older than 24 weeks might be because of the fully-grown feathers and therefore they were less susceptible to coldness.

The results of the present study indicate an interaction ($p<0.05$) between the feeding level and season on the wattle lengths of Koekoek chickens from 18 to 22 weeks of age (Table 5.6). The results pointed out that the wattle sizes were larger ($p<0.05$) in hens that were in the AA and AR treatments in summer than in winter by 8 and 7.8mm respectively during the rearing phase at the age of 18 weeks. The wattle lengths of chickens that were in the RA and RR treatments in summer were 4.8mm and 5.8mm larger ($p<0.05$) than those in winter at 18 weeks of age. The difference in the wattle lengths between summer and winter treatments was more prominent in the full-fed chickens.

At the age of 22 weeks, Koekoek hens that were reared in summer and full-fed in the rearing phase out-competed ($p<0.05$) those that were fed similarly in winter in terms of the wattle sizes. On the other hand, the wattles of hens that were feed restricted in summer were larger than those of hens that were feed restricted in winter. Generally, hens that were feed restricted in summer in the rearing phase even had larger wattles than those that were fed without limit in winter. It is worth noting that the lengths of the wattles were mainly affected by the effect of season rather than the level of feeding. The feeding level during the rearing phase contributed to the wattle size of chickens even beyond the puberty stage.

Table 5.6: Effect of the interaction between feeding level and season on the wattle length (mm) of Koekoek chickens

Age (Weeks)	SAA	S.E	WAA	S.E	SAR	S.E	WAR	S.E	SRA	S.E	WRA	S.E	SRR	S.E	WRR	S.E
18	24.9[a]	0.54	16.9[b]	0.54	23.9[a]	0.54	16.1[b]	0.54	19.0[a]	0.54	14.1[b]	0.54	19.8[a]	0.58	13.9[b]	0.54
22	30.5[a]	0.64	22.9[b]	0.64	28.4[a]	0.64	22.1[b]	0.64	25.9[a]	0.64	23.4[b]	0.64	26.9[a]	0.69	21.7[b]	0.69
24	32.5	0.59	24.5	0.59	29.6	0.59	22.9	0.59	29.4	0.59	24.1	0.59	28.7	0.64	21.1	0.64
26	25.9	0.81	25.9	0.81	25.6	0.81	25.1	0.81	26.7	0.81	26.2	0.81	25.8	0.87	23.7	0.87
28	25.6	0.70	27.6	0.70	25.5	0.70	24.8	0.70	26.3	0.70	27.5	0.70	25.8	0.76	24.6	0.76
30	25.8	0.79	26.1	0.79	25.0	0.79	23.4	0.79	26.3	0.79	26.3	0.79	24.3	0.86	24.3	0.86
32	26.8	0.83	26.0	0.83	25.5	0.83	24.9	0.83	26.3	0.83	25.8	0.83	25.1	0.89	25.2	0.89

[ab] Means within a row with no common superscript differ significantly ($p<0.05$ and $p<0.01$)

Footnote:

SAA- full feeding during rearing and laying in summer season. SAR- full feeding during rearing and restricted during laying in summer season, SRA-restricted feeding during rearing and full feeding during laying in summer season, SRR-restricted during rearing and laying in summer season, WAA- full feeding during rearing and laying in winter season. WAR- full feeding during rearing and restricted during laying in winter season, WRA-restricted feeding during rearing and full feeding during laying in winter season, WRR-restricted during rearing and laying in winter season, S.E-Standard Error

The level of feeding had an effect ($p<0.05$) on weight performance of ova and oviducts in Koekoek hens (Table 5.7). The combined weights of the ova and oviducts were 16g, 15.4g, 5.5g and 5.5g for Koekoek pullets that were in the AA, AR, RA and RR treatments respectively. This indicates that the ova and oviduct weight in pullets that were full-fed during the rearing phase were 64.6% higher than in the feed restricted treatment. Proportional to the body weight hens in the full-fed group had higher ova and oviducts weight (1.5%) than those that were under restricted feeding (0.4%).

The weights of ova and oviducts at the age of 18 weeks had a positive relationship ($p<0.01$) with the comb ($r=0.818$) and wattle ($r=0.704$) sizes of hens. This means that one can successfully estimate the sexual maturity of Koekoek hens by simply studying the development of the combs and wattles. This suggests that 66.9% and 49.6% of the ova and oviducts weights can be explained by the comb and wattle sizes respectively. These results explain that the comb size can be a reliable in estimating the development of ova and oviducts.

The results of this study are in accord with the findings of some previous researchers who stated no significant differences in the oviduct weights between chickens that were subjected to different feeding regimes at sexual maturity (Renema *et al.*, 1999b; 2007 and Tesfaye *et al.*, 2009). Yildiz *et al*. (2006) also suggested that feed restriction during the rearing period significantly delays oviduct development. In contradiction with the results of the present study, Bruggeman *et al*. (1999) indicated that birds on restricted feeding diet from 7 to 15 weeks of age had higher proportional masses of oviduct at the age of sexual maturity.

The results of Renema *et al.* (2007) agree with the findings of the present study as they stated that ovary weight was primarily influenced by body weight that is also related to the feed intake. The studies of Cassy *et al.* (2004) and Renema *et al*. (2007) also confirm that chickens that are exposed to restricted feeding during the growing period had a decreased number of large yellow follicles arranged in the multiple hierarchies at first oviposition. Melnychuk *et al*. (2004) also reported the higher stroma weights at sexual maturity in hens that were fed *ad libitum* compared with feed restricted chickens. Melnychuk *et al.* (2004) further more stated that the absolute weights of the ovaries were statistically similar at sexual maturity. Bruggerman *et al*. (1999) indicated that overfeeding birds during sexual maturation could directly increase the number reproductive hormones through stimulating the development of ovaries and hence accelerating sexual maturity.

Table 5.7: Pubic bones, ova and oviduct growth of Koekoek chickens subjected to different levels of feeding treatments

	Treatments				
Parameter	**AA**	**AR**	**RA**	**RR**	**S.E**
18 weeks					
Pubic bone (mm)	23.6^{a}	25.1^{a}	16.1^{b}	15.1^{b}	0.66
Ova &oviducts (g)	16.0^{a}	15.4^{a}	5.5^{b}	5.5^{b}	0.39
32 weeks					
Pubic bone (mm)	48.9^{a}	43.9^{b}	48.8^{a}	44.6^{b}	0.50
Ova weight (g)	46.1	46.6	45.5	47.8	0.78
Oviduct weight (g)	49.1	48.1	52.0	48.0	0.80

^{ab} Means within a row with no common superscript differ significantly (p<0.05).
Footnote:
AA- full feeding during rearing and laying. AR- full feeding during rearing and restricted during laying, RA-restricted feeding during rearing and full feeding during laying, RR-restricted during rearing and laying, S.E-standard error.

Koekoek hens that were reared in summer had higher (p<0.05) weights of ova and oviducts than in winter (Table 5.8). The combined ova and oviduct weights were 14.3g and 7g for hens that were reared in summer and winter respectively. These results indicate that the winter conditions delayed the development of ova and oviducts at sexual maturity by 51%. The results show a linear relationship between the slaughter weights, ova and oviducts weights in Koekoek hens since those with higher body weights had heavier ova and oviduct weights.

The findings of the present study disagree with the results of Chen *et al.* (2007) who stipulated similar ovary weights in pullets that were subjected to different seasons. The combined weight of the ova and oviducts was affected by the interaction between feeding level and season as reflected in Table 6.9. The ova and oviduct weights at the age of 18 weeks were higher (p<0.01) in chickens that were full-fed in summer than in winter. An average ova and oviduct weight in the AA and AR treatments in summer was 16.4g higher than in winter during the rearing phase. The ova and oviduct weights of hens that were in the RA and RR treatments in summer were 17.6% and 22.1% higher than in winter. This implies that rearing chickens in winter hindered the development of the ova and oviducts in hens that were fed similarly. The lower weights of the ova and oviduct weights in hens that were feed restricted in winter explain why chickens delayed to reach sexual maturity.

At the age of 32 weeks, Koekoek hens that were fed without restriction during the laying phase (AA and RA) had statistically similar ($p<0.05$) ova weights as compared to those that were feed restricted during the laying phase (AR and RR). In spite of the insignificant differences in ova weights between chickens that were subjected to different feeding levels, the ova weights of restricted fed chickens (RR) were higher ($p>0.05$) than the ones of hens that were in the AA, AR and RA treatments by 3.4%, 2.5% and 4.7% respectively. This suggests that restricted feeding during the laying phase stimulated the production of ova in Koekoek chickens. The ova weights were only correlated ($p<0.05$; $r=0.281$) with the wattle sizes in Koekoek hens that aged 32 weeks. This indicates that the formation of ova in hens aging 32 weeks cannot be estimated solely through the use of wattle size since the percentage of the ova weight that can be explained by wattle length is only 7.9%.

These results are in agreement with the findings of Crounch *et al*. (2002b) who stated that the maturing ova were heavier in turkey hens that were feed restricted during the rearing period than in those that were fed *ad libitum* in the rearing phase. To support this, Yildiz *et al*. (2006) demonstrated that feeding *ad libitum* starting from weeks of age significantly increased the weight of an ovary in quails. Contrary to the results of the present study Renema *et al.* (1999b) pointed out that, restricted fed birds were 38% lower than *ad libitum* fed birds in terms of the ovary weight. In addition to that, Robinson *et al.* (2007) reported that the ovary weight was influenced by the body weight and possibly the fatness level.

The ovarian weights were similar ($p>0.05$) in hens that were reared in summer (45.5g) and winter (47.5g) as shown in Table 6.8. However, the cold winter conditions significantly improved the ovarian development by 4.2% when compared to warm summer conditions.

The results of the present study support the findings of Rozenboim *et al.* (2007) who stated heat stress as the cause of reduced ovary weights in chickens due to the declining levels of lutenizing hormone and hypothalamic gonadotropin releasing hormone-1 content.

Despite the insignificance of the differences, oviduct weights in the RR treatments were 1.1, 0.1 and 4g lower ($p>0.05$) than in the AA, AR and RA treatments respectively. These results are in line with the results of Yildiz *et al*. (2006) who suggested that birds fed *ad libitum* show accelerated development of oviducts. This indicates that the oviduct development is not dependent on the growth of other reproductive organs hence the insignificant correlation with reproductive organs at this age. Therefore, it would probably be impossible to estimate the size of the oviduct through the use of external reproductive organs in mature chickens.

Koekoek hens that were reared in summer (50.7g) and winter (47.9g) had similar (p>0.05) oviduct weights. Nonetheless, the non-significant higher oviducts in summer signify that the oviducts weight corresponded positively to the body weights of Koekoek hens. It is believed that the heavier oviduct weights in chickens that were reared in summer were inherited from the puberty stage (18 weeks).

The results of the present study agree with the finding of Chen *et al.* (2007) who stated that the oviduct weight was not affected by the number of sunlight hours the chickens were exposed to in a day. However, Allee and Lutherman (1940) established heavier oviducts in chickens that were kept under cool environmental temperature.

At puberty age (18 weeks), Koekoek hens that were full-fed had higher (p<0.05) pubic bone measurements than those that were under feed restriction. On average the pubic bone widths of hens that were full-fed were 35.9% higher (p<0.05) than an average width of pubic bones in chickens that were subjected to restricted feeding at 18 weeks of age.

During the laying phase (32 weeks), Koekoek hens that were full-fed during the laying had higher (p<0.05) pubic bone widths than those that were feed restricted. The pubic bones of full-fed hens during the laying phase were 48.9mm and 48.8mm for chickens that were in the AA and RA treatments respectively as opposed to 43.9mm and 44.6mm respectively for those in the AR and RR treatments respectively (Table 6.6). When looking at the results of the present study critically it was recognised that Koekoek hens that were in the RA treatment had an accelerated pubic bone increase of 66.9% followed by chickens in the RR treatment with 66.2%. The lowest increase in pubic bone width was observed in chickens that were allocated to the AR treatment (40.5%) while chickens that were under the AA treatment (51.8%) ranked in the 3rd position as far as the rate of increase in the width of pubic bones from 18 to 32 weeks is concerned. These results portray that restricted feeding during the rearing phase enhance the development of the pubic bones more than full feeding during the same period.

The results for how Koekoek hens that were subjected to either summer or winter conditions performed in terms of the oviducts weights are presented on Table 5.8. Koekoek hens that were reared in summer (50.7g) and winter (47.9g) had similar ($p>0.05$) oviducts weights. Nonetheless, the non-significant higher oviduct weights in summer signify that the oviducts weights corresponded positively to the body weights of Koekoek hens. It is believed that the heavier oviducts weights in chickens that were reared in summer were inherited from the puberty stage (18 weeks).

At puberty stage (18 weeks) it was noticed that the spread of the pubic bones in Koekoek chickens correlated ($p<0.01$) with ova and oviduct weights ($r=0.788$), comb length ($r=0.745$) and wattle length ($r=0.704$). The current results show that the distance between the pubic bones can be used to approximate whether the eggs are already formed in the ovaries or not since 62.1% of the ova weight can be due to the space between the pubic bones. The comb and wattle sizes can be used to gauge the passage between the pubic bones. The space between the pubic bones in Koekoek hens can be explained by 55.5% and 49.6% of comb and wattle lengths respectively.

The spread of the pubic bones in Koekoek pullets was greater ($p<0.05$) in summer than in winter. The widths between the pubic bones were 24.3mm and 15.9mm for pullets that were kept in summer and winter respectively. This means that winter conditions delayed the widening of the passage between the pubic bones by 34.7% at the age of 18 weeks. The reason for the narrow space between the pubic bones of the winter-reared chickens could be attributed to the delay in reaching sexual maturity.

At 32 weeks of age, chickens that were reared in winter had wider distance between the pin bones as compared to those that were reared in summer even though the differences were not significant. The space between the pubic bones in chickens that were reared in summer and winter was 46mm and 47.1mm respectively. This suggests that the pubic bones of chickens that were subjected to winter conditions were spreading faster than the ones that were in summer after they have reached sexual maturity.

The passage between the pubic bones was also affected ($p<0.01$) by an interaction between the feeding level and season at the age of 32 weeks. The pubic bones in the AA and RA treatments were broader in winter than in summer by 6.9 and 0.4mm respectively. On the AR and RR treatments in summer and winter, the differences were 1.9 and 0.9mm respectively. The findings illustrate that the space between pubic bones was wider in winter in hens that were full-fed during the laying phase while the opposite was true in chickens that were feed restricted during the same phase.

The results of the present study agree with the finding of Chen *et al.* (2007) who stated that the oviduct weight was not affected by the number of sunlight hours the chickens were exposed to in a day. However, Allee and Lutherman (1940) established heavier oviducts in chickens that under cool environmental temperature. Satterlee and Marin (2004) concluded that the pin bones in avian species widen with age and sexual development in order to accommodate passage of shelled egg at oviposition without breakage.

Table 5.8: Pubic bones, ova and oviducts performance of Koekoek chickens that were reared in either summer or winter

		Seasons		
Age (weeks)	**Parameter**	**Summer**	**Winter**	**S.E**
18	Pubic bone (mm)	24.3[a]	15.9[b]	0.93
	Ova &oviducts wt (g)	14.3[a]	7.0[b]	0.56
32	pubic bone (mm)	46.0	47.1	0.71
	Ova weight (g)	45.5	47.5	1.10
	Oviduct weight (g)	50.7	47.9	1.14

[ab] Means within a row with no common superscript differ significantly (p<0.05), S.E-Standard Error

Table 5.9: Effect of the interaction between feeding level and season on ova, oviduct and pubic bones of Koekoek chickens

Variable	SAA	S.E	WAA	S.E	SAR	S.E	WAR	S.E	SRA	S.E	WRA	S.E	SRR	S.E	WRR	S.E
Ova &oviduct wt (g)18 weeks	23.0^{a}	1.09	9.0^{b}	1.09	27.7^{a}	1.09	9.0^{b}	1.09	6.4^{b}	1.09	5.3^{b}	1.09	6.2^{b}	1.97	4.8^{b}	1.97
Ova wt (32 weeks)	44.9	2.16	47.4	2.16	45.3	2.16	47.9	2.16	44.1	2.16	46.9	2.16	47.5	2.33	48.0	2.33
Oviduct wt (g) 32 weeks	49.3	2.23	48.3	2.23	50.0	2.23	46.3	2.23	53.4	2.23	50.6	2.23	50.0	2.41	46.0	2.41
Pubic bone (mm) 18weeks	29.3	1.82	17.9	1.82	31.4	1.82	19.4	1.82	19.0	1.82	13.3	1.82	17.3	1.97	12.8	1.97
Pubic bones (mm) 32 weeks	45.4^{a}	1.40	52.3^{b}	1.40	44.9^{a}	1.40	43.0^{b}	1.40	48.6^{a}	1.40	49.0^{b}	1.40	45.0^{a}	1.51	44.2^{b}	1.51

^{ab} Means within a row with no common superscript differ significantly (p<0.05 and p<0.01)
Footnote:
SAA- full feeding during rearing and laying in summer season. SAR- full feeding during rearing and restricted during laying in summer season, SRA-restricted feeding during rearing and full feeding during laying in summer season, SRR-restricted during rearing and laying in summer season, WAA- full feeding during rearing and laying in winter season. WAR-*ad libitum* feeding during rearing and restricted during laying in winter season, WRA-restricted feeding during rearing and full feeding during laying in winter season, WRR-restricted during rearing and laying in winter season, S.E-Standard Error, wt- weight, mm-millimeters

Table 5.10: Correlations between reproductive characteristics of Koekoek chickens at 18 and 32 weeks of age

Parameter	Ova &oviducts wt(g)	Ova wt (32 weeks)	Oviduct wt (32 weeks)	Pubic bone(mm)-18 weeks	Pubic bone (mm)-32 weeks	Comb length-18 weeks	Comb length-32 weeks	Wattle length-18 weeks	Wattle length-32 weeks
Ova& oviducts wt (g)	1	-0.181	-0.100	0.788**	-0.131	0.818**	0.370**	0.704**	0.074
Ova wt (32 weeks)	-0.181	1	-0.187	-0.100	-0.046	-0.165	-0.110	-0.133	0.281*
Oviduct wt (32 weeks)	0.005	-0.181	1	0.014	0.073	0.097	-0.078	0.101	-0.078
Pubic bone(mm)-18 weeks	0.788**	-0.100	0.014	1	-0.150	0.745**	0.370**	0.704**	0.074
Pubic bone (mm)-32 weeks	-0.131	-0.046	0.073	-0.150	1	-0.139	0.056	-0.157	0.136
Comb length-18 weeks	0.818**	-0.165	0.097	0.745**	-0.139	1	0.617**	0.945**	0.168
Comb length-32 weeks	0.394**	-0110	0.147	0.370**	0.056	0.617**	1	0.583**	0.482**
Wattle length-18 weeks	0.756**	-0.133	0.101	0.704**	-0.157	0.945**	0.583**	1	0.151
Wattle length-32 weeks	0.120	0.281*	-0.078	0.074	0.136	0.168	0.482**	0.151	1

** Correlation is significant at the 0.01 level.
* Correlation is significant at the 0.05 level.

5.3.2 Effect of restricted feeding and season on the laying and hatching performance of Koekoek chickens

The results indicate that Koekoek chickens that were subjected to different feeding levels performed (p<0.05) differently in terms of laying percentange from 18 to 32 weeks of age (Table 5.11). Koekoek chickens under the AA and AR treatments had higher (p>0.05) laying percentages at the age of 18 weeks in comparison with those that were under the RA and RR treatments. The laying percentage of chickens under the AA treatment was 1.3% while those under the AR treatment had 1.4%. Chickens under both RA and RR treatments had a laying percentage of 0%. In spite of the different laying percentages between chickens that were under different treatments the results were not statistically different (p>0.05). Koekoek chickens that were full-fed during the rearing phase (AA and AR) had significantly (p<0.05) higher laying percentage from 19 to 21 weeks old as compared to those that were feed restricted (RA and RR). Koekoek chickens that were feed restricted during the rearing phase (RA and RR) started to lay at the age of 21 weeks.

Table 5.11: The laying percentage of Koekoek chickens that were subjected to different feeding level treatments

	Treatments				
Age (weeks)	**AA**	**AR**	**RA**	**RR**	**S.E**
18	1.3	1.4	0.0	0.0	0.26
19	1.6^a	1.9^a	0.0^b	0.0^b	0.31
20	4.9^a	3.9^a	0.0^b	0.0^b	0.28
21	8.3^a	7.6^a	3.1^b	2.6^b	0.38
22	19.5^a	14.3^{bc}	15.4^b	11.3^c	0.67
23	29.6^a	24.4^b	25.7^b	21.4^c	0.43
24	39.2^a	33.4^b	35.5^b	30.6^c	0.62
25	51.6^a	43.5^b	48.3^a	39.6^c	0.59
26	68.1^a	56.9^b	60.7^b	47.8^c	0.98
27	77.1^a	66.1^b	73.4^a	61.5^c	0.78
28	78.4^a	71.8^b	78.6^a	68.7^b	0.59
29	78.1^a	70.4^b	78.8^a	67.9^b	0.61
30	78.7^a	71.8^b	81.9^c	71.1^b	0.49
31	76.5^a	70.2^b	78.7^a	65.2^b	0.53
Average	45.4^a	40.2^b	43.5^c	37.0^d	0.23

abc Means within a row with no common superscript differ significantly (p<0.05).
Footnote:
AA- full feeding during rearing and laying. AR- full feeding during rearing and restricted during laying, RA-restricted feeding during rearing and full feeding during laying, RR-restricted during rearing and laying, S.E-standard error.

These results are in agreement with Sekoni *et al. (*2002) who indicated that feed restriction delays the onset of egg production. Koekoek chickens that were full-fed for the entire study (AA) had the highest laying percentage followed by those that were feed restricted only during the rearing phase (RA). It was also discovered that birds that were under the RA treatment were not different (p>0.05) from chickens that were subjected to the AR treatment from 22 to 24 weeks while those that were feed restricted for the entire study (RR) had the lowest laying percentage during the same period. The results of the present study reveal that Koekoek chickens that were feed restricted only during the rearing phase (RA) responded positively to the full-fed diet after four weeks. It was also observed that the laying percentage of chickens that were in the RA treatment was statistically similar (p>0.05) to the one of chickens that were in the AA treatment from the 25th to 32nd week with the exception of the 26th and 30th weeks. At week 26 Koekoek chickens under the AA treatment had a higher (p<0.05) laying percentage (68.1%) compared to those that were under the AR (56.9%), RA (60.7%) and RR (47.8%) treatments. During the 30th week a laying percentage of chickens that were allocated to the RA treatment was 4%, 12.3%, 13.1% higher than the ones of chickens that were in the treatments AA, AR and RR respectively. It was also observed that the laying percentages of chickens that were feed restricted during the laying phase (AR and RR) were similar (p>0.05) from the age of 28 to 32 weeks regardless of whether they were feed restricted or full-fed during the rearing phase (8-18 weeks). In terms of average laying percentage chickens that were full-fed during the rearing and laying phases (AA) performed higher (p<0.05) than those that were under other feeding level treatments. A laying percentage of chickens that were under the RA treatment was more cumulative as compared to chickens that were in other treatments. This can be verified by the fact a laying percentage of chickens that were under the RA treatment was higher than the rest of the treatments during the last five weeks of the study though not different (p>0.05) from AA treatment.

The results from this research study are in agreement with Crounch *et al.* (2002b) who found that the total egg production was higher for birds that were full-fed. In support of the results of the present study, Bruggerman *et al*. (1999) also showed that chickens that are feed restricted during the rearing period had the highest average egg production. Lesson *et al*. (1996) also suggested that the laying performance is little affected by the ration given to hens before maturity and this is in accordance with the findings of this study as chickens that were in the RA treatment produced a significantly higher percentage of eggs once the delay in reaching sexual maturity was overcome. Gowe *et al.* (1960) and Blair (1972) also reported this. Gowe *et al.* (1960) and Blair (1972) also reported that restricted feeding during the laying period resulted in a lower egg production and this was true as chickens that were feed restricted during the laying phase had a lower laying percentage. This was also supported by Robinson *et al.* (1978) who stated that restricted feeding is more critical if it is imposed during the laying phase rather than if introduced during the rearing period.

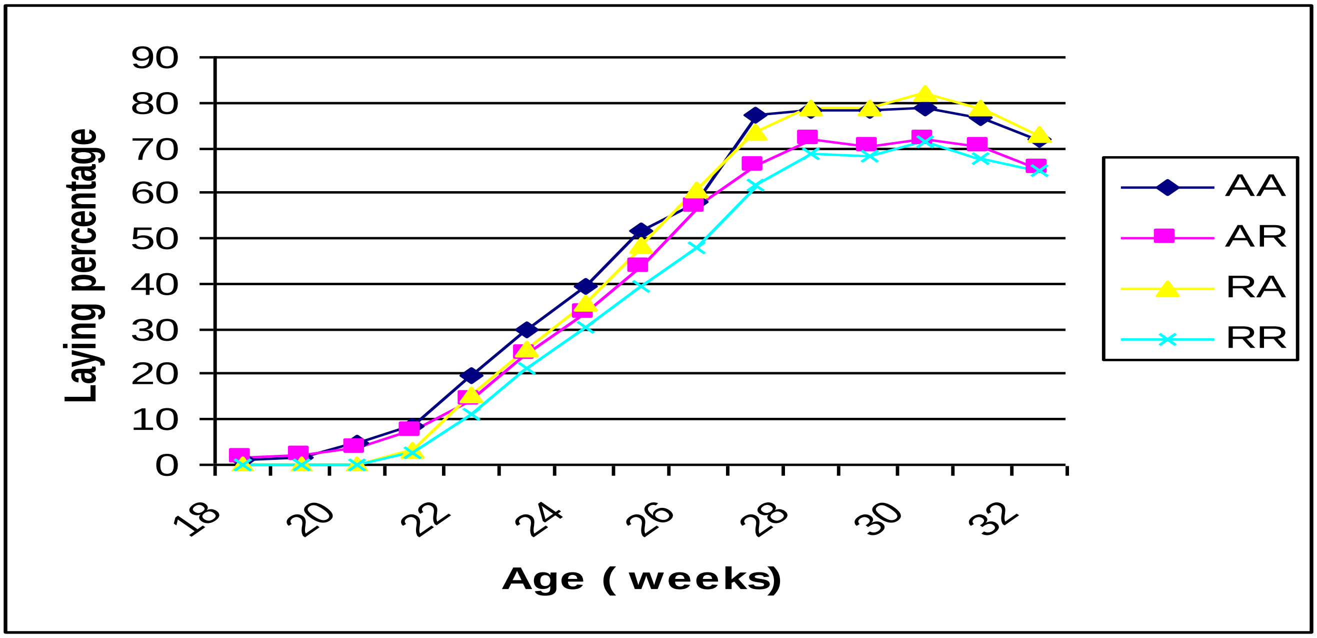

Figure 6.2: The laying percentage of Koekoek chickens subjected to different feeding levels

Footnote:
AA- full feeding during rearing and laying. AR- full feeding during rearing and restricted during laying, RA-restricted feeding during rearing and full feeding during laying, RR-restricted during rearing and laying.

The findings of this study illustrate that season had an effect ($p<0.05$) on the laying rate of chickens since the laying percentage of chickens that were reared in summer was different from that of chickens that were reared during the winter (Table 5.12). The findings of the present study illustrate that Koekoek chickens that were reared in summer had a higher ($p<0.05$) laying percentage as compared to those that were reared in winter.

Chickens in summer produced a higher number of eggs than their counterparts in winter from 18 to 28 weeks old. It was also observed that the winter conditions delayed the onset of laying by six weeks. The season had no effect ($p>0.05$) on the laying percentage of chickens from 29 to 31 weeks of age. At 32 weeks of age the laying percentage of chickens that were subjected to winter conditions were 10.9% lower than those that were exposed to summer conditions in terms of laying percentage.

Table 5.12: The laying percentage of Koekoek chickens that were reared in either summer or winter during both rearing and laying phases

	Treatment		
Age weeks	**Summer**	**Winter**	**S.E**
18	1.4[a]	0.0[b]	0.52
19	1.9[a]	0.0[b]	0.62
20	4.4[a]	0.0[b]	0.56
21	10.8[a]	0.0	0.77
22	30.3[a]	0.0	1.33
23	50.1[a]	0.0[b]	0.86
24	62.6[a]	6.8[b]	1.23
25	69.3[a]	22.2[b]	1.19
26	74.1[a]	42.6[b]	1.96
27	77.2[a]	59.9[b]	1.56
28	77.0[a]	71.9[b]	1.19
29	75.6[a]	72.0[b]	1.22
30	75.2	76.6	0.99
31	74.4	72.2	1.32
32	72.9[a]	64.9[b]	1.06
Average	50.5[a]	32.6[b]	0.47

[a b]Means within a row with no common superscript differ significantly ($p<0.05$), S.E- Standard Error.

As observed in figure 5.3 a gap between the number of eggs produced in summer and winter narrowed as chickens were getting older. This could be explained by the fact that at an early age the chickens were using a lot of energy to generate body heat, as their feathers were not yet fully developed whereas at a later stage their feathers were fully developed hence an increase in egg production. It was observed that the moment chickens in winter started laying their production was increasing at a faster rate since they were able to reach peak laying within seven weeks after the onset of laying while those that were raised in summer reached peak egg production after 10 weeks.

The results of the present study are not in accordance with the findings of Garces *et al.* (2001) who found that higher temperatures negatively affect egg production. In a study conducted by Marshaly *et al*. (2004) it was established that chickens that were housed in a hot chamber produced a smaller number of eggs in comparison with chickens that were in controlled chambers. Hsu *et al.* (1998) explained that a reduced egg production in chickens that are reared in high temperatures is caused by the low feed intake that is experienced under hot conditions. The work of Usayran *et al*. (2001); Rozenbiom *et al.* (2007) and Star *et al.* (2008) also confirmed that chickens exposed to heat had a reduced laying percentage.

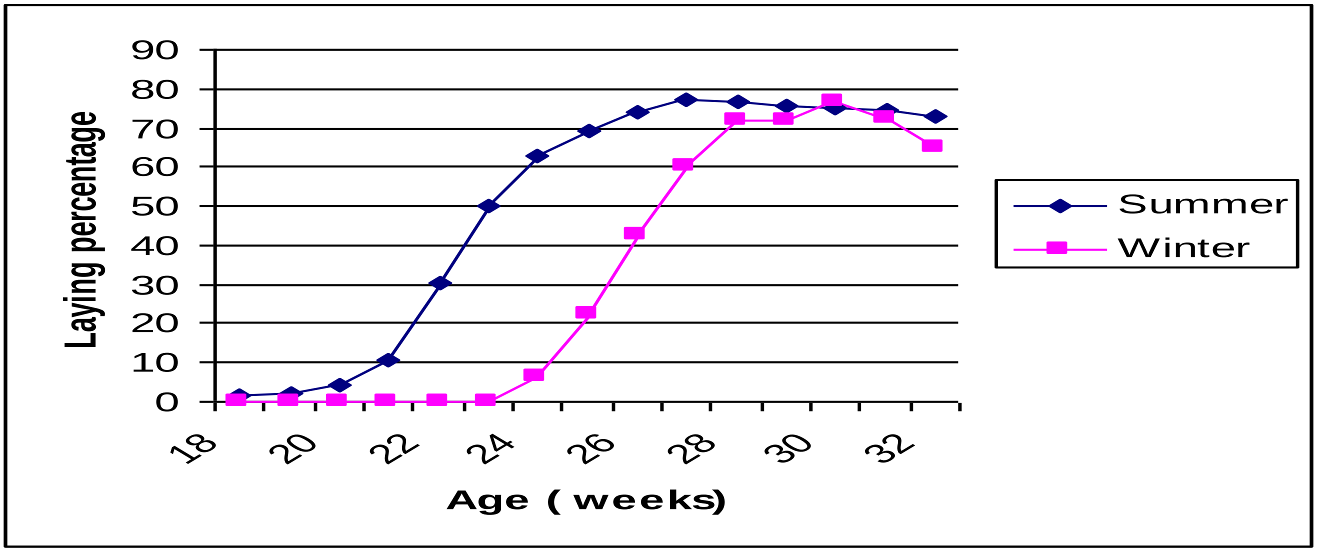

Figure 5.3: Effect of season on the laying percentage of Koekoek chickens

The reason for the results of the present study to contradict the prevous findings could be attributed to the fact that the present study was conducted in a different environmental condition compared to previous studies (Usayran *et al*., 2001; Rozenbiom *et al.*, 2007 and Star *et al.*, 2008). In Lesotho, the temperatures can fall below 0^{o}C in winter while the higher temperatures in summer cannot go beyond 28^{o}C. Therefore, it is possible that birds in summer still had a reasonable feed intake as feeding was done in the morning when the temperatures were still moderate while the feed intake was low in previous studies due to the hot temperatures that were beyond 32^{o}C hence a lower egg production in birds that were subjected to higher temperatures. The other reason for the chickens to produce a higher number in summer could be the photoperiodism.

An interaction between the feeding level and season was recognized throughout the entire study except when chickens were at the age of 18, 25, 26 29 and 31 weeks. It was discovered that at weeks 19 to 21 chickens that were full-fed during the rearing phase (AA and AR) in summer had a higher ($p<0.05$) laying percentage as compared to those that were in other interaction treatments. At the age of 24 weeks, chickens under the AA treatment in summer out-performed those that were under other interaction treatments in terms of the laying percentage. The laying percentage of chickens that were under the AA treatment in summer was 68.2% followed by the chickens under the RA treatment in summer (65.51%). The laying percentages of birds under the AR and RR in summer were 60.8% and

56% respectively. On the AA, AR, RA and RR treatments in winter the laying performances were 10.3%, 6.1%, 5.4% and 5.87% respectively. These results indicate that the laying percentage cannot be improved by feeding chickens unrestrictedly in winter as the performance of chickens that were feed restricted in summer performed better than those were that were full fed in winter. At week 27 and 28 it was noticed that Koekoek chickens that were reared in summer performed better ($p<0.02$) than the ones that were kept in winter when exposed to the same quantity of feed with regard to laying percentage. The highest laying percentage was observed in chickens that were full-fed for the entire study in summer (SAA) as compared to other treatments. During the 30th week chickens that were feed restricted during the rearing phase and full-fed during the laying phase in summer (SRA) had a highest laying percentage (82.9%) followed by those that were under the WRA (81%) while chickens that were under the SAA ranked third in egg production (79.8%). At the end of the study (32 weeks) the laying percentages of chickens in the AA, RA, AR and RR treatments in summer were higher than in winter by 11.7%, 5.8%, 11.2% and 3.3% respectively. The egg production of chickens that were feed restricted for the entire study in summer (SRR) was higher than the one of chickens that were full-fed for the entire study in winter (WAA) by 1.23 percent. These results show that the rearing of Koekoek chickens in summer will always result in higher egg production as compared to when chickens are reared in winter. It was also revealed from the present study that in order to increase egg production in winter one will have to increase the amount of feeding even though the egg production would still not match the one in summer reared chickens.

Table 5.13: Effect of the interaction between feeding level and season on the laying percentage of Koekoek chickens

Age							Treatments									
(weeks)	SAA	S.E	WAA	S.E	SAR	SE	WAR	S.E	SRA	SE	WRA	SE	SRR	S.E	WRR	S.E
18	2.6	0.71	0.0	0.71	2.8	0.71	0.0	0.71	0.0	0.71	0.0	0.71	0.0	0.77	0.0	0.77
19	3.8^{a}	0.86	0.0^{b}	0.86	3.8^{a}	0.86	0.0^{b}	0.86	0.0^{b}	0.86	0.0^{b}	0.86	0.0^{b}	0.93	0.0^{b}	0.93
20	9.7^{a}	0.78	0.0^{b}	0.78	7.8^{a}	0.78	0.0^{b}	0.78	0.0^{b}	0.78	0.0^{b}	0.78	0.0^{b}	0.84	0.0^{b}	0.84
21	16.5^{a}	1.07	0.0^{b}	1.07	15.1^{a}	1.07	0.0^{b}	1.07	6.3^{a}	1.07	0.0^{b}	0.07	5.3^{a}	1.15	0.0^{b}	1.15
22	39.0^{a}	1.85	0.0^{b}	1.85	28.6^{a}	1.85	0.0^{b}	1.85	30.5^{a}	1.85	0.0^{b}	1.85	22.6^{a}	2.00	0.0^{b}	2.00
23	58.4^{a}	1.19	0.9^{b}	1.19	48.3^{a}	1.19	0.5^{b}	1.19	51.2^{a}	1.19	0.2^{b}	1.19	42.6^{a}	1.29	0.3^{b}	1.29
24	68.2^{a}	1.71	10.3^{b}	1.71	60.8^{a}	1.71	6.1^{b}	1.71	65.5^{a}	1.71	5.4^{b}	1.71	56.0^{a}	1.85	5.8^{b}	1.85
25	77.4	1.64	25.8	1.64	65.4	1.64	21.6	1.64	71.4	1.64	25.1	1.64	63.1	1.78	16.3	1.78
26	81.6	2.72	54.6	2.72	71.6	2.72	42.2	2.72	75.1	2.72	46.3	2.72	68.1	2.94	27.5	2.94
27	85.1^{a}	2.16	61.1^{b}	2.16	73.9^{a}	2.16	68.1^{b}	2.16	71.0^{a}	2.33	52.1^{b}	2.33	82.7^{a}	1.65	74.2^{b}	1.65
28	82.7^{a}	1.65	74.2^{b}	1.65	71.2^{a}	1.65	72.5^{b}	1.65	82.0^{a}	1.65	75.2^{b}	1.65	71.9^{a}	1.78	65.6^{b}	1.78
29	81.2	1.69	75.1	1.69	70.2	1.69	70.6	1.69	82.3	1.69	75.3	1.69	68.8	1.82	67.0	1.82
30	79.8^{a}	1.37	77.5^{b}	1.37	69.6^{a}	1.37	74.1^{b}	1.73	82.9^{a}	1.37	81.0^{b}	1.37	68.6^{a}	1.48	73.7^{b}	1.48
31	79.4	1.83	73.7	1.83	69.2	1.83	71.2	1.83	80.6	1.83	76.9	1.83	68.3	1.97	67.1	1.97
32	77.8^{a}	1.47	66.1^{b}	1.47	68.4^{a}	1.47	62.7^{b}	1.47	78.4^{a}	1.47	67.2^{b}	1.47	66.9^{a}	1.59	63.5^{b}	1.59
Average	56.2^{a}	0.65	34.6^{b}	0.65	48.5^{a}	0.65	32.0^{b}	0.65	52.4^{a}	0.65	34.7^{b}	0.65	44.9^{a}	0.65	29.3^{b}	0.65

^{ab} Means within a row with no common superscript differ significantly (p<0.05 and p<0.01).

Footnote:

SAA- full feeding during rearing and laying in summer season. SAR- full feeding during rearing and restricted during laying in summer season, SRA-restricted feeding during rearing and full feeding during laying in summer season, SRR-restricted during rearing and laying in summer season, WAA- full feeding during rearing and laying in winter season. WAR- full feeding during rearing and restricted during laying in winter season, WRA-restricted feeding during rearing and full feeding during laying in winter season, WRR-restricted during rearing and laying in winter season, S.E-Standard Error

Egg weights of chickens that were subjected to different feeding level treatments differed (p<0.05) throughout the experiment except at the ages of 27 and 28 weeks (Table 5.14).

Table 5.14: Egg weights of Koekoek chickens that were subjected to different feeding level treatments

Age (Weeks)	Treatments AA	AR	RA	RR	S.E
25	37.5^{a}	35.6^{a}	39.6^{a}	27.6^{b}	1.06
26	45.5^{a}	39.7^{b}	45.0^{a}	39.0^{b}	0.73
27	46.3	45.7	47.2	46.9	0.32
28	46.0	45.0	47.1	46.9	0.42
29	48.4^{a}	46.3^{b}	48.1^{a}	46.7^{ab}	0.27
30	47.9^{ab}	47.3^{a}	49.2^{b}	48.1^{ab}	0.29
31	48.0^{a}	46.3^{b}	49.2^{a}	47.5^{ab}	0.29
32	49.2^{a}	43.9^{b}	50.2^{a}	46.9^{b}	0.70
Average	45.6^{a}	43.5^{b}	46.7^{a}	43.1^{b}	0.22

abc Means within a row with no common superscript differ significantly (p<0.05).
Footnote:
AA- full feeding during rearing and laying. AR- full feeding during rearing and restricted during laying, RA-restricted feeding during rearing and full feeding during laying, RR-restricted during rearing and laying, S.E-standard error.

The egg weights were collected with effect from the 25th week because it was the time when the majority of chickens in all replicates started to lay. At the age of 25 weeks the egg weights of Koekoek chickens that were feed restricted for the entire study (RR) were 27.4%, 22.6% and 30.4% lower (p<0.05) than the egg weights of chickens that were under the AA, AR and RR treatments respectively. The different pattern of the results was observed at the 26th week. The egg weights of chickens that were full-fed during the laying phase (AA and RA) were 45.5g and 45g respectively while the egg weights of chickens that were under restricted feeding during the laying phase (AR and RR) were 39.7g and 39g respectively. The egg weights of chickens that were subjected to restricted feeding were lower (p<0.05) than those of chickens that were full-fed. During the 29th week, the chickens that were under AA treatment had higher egg weights (48.4g) as compared to egg weights of those that were in the AR, RA and RR treatments even though they were not different (p>0.05) from the egg weights (48.1g) produced by those that were under the RA treatment. Koekoek chickens that were under the AR treatment had lowest (p<0.05) egg weights (46.3g) in comparison with those produced by chickens that were under other treatments though they were not statistically different (p>0.05) from the ones that were in the RR treatment (46.9g). At the 30th week up to the end of the study it was detected that chickens that were feed restricted for the entire study (RR) had statistically similar (p>0.05) egg weights as compared to chicken eggs that were under other treatments. The results demonstrate that chickens that were under the RA treatment had higher egg weights (51.2g) than those that were in the treatments AA, AR and RR with the egg weights of 49.2, 43.9 and 46.9g respectively. Nonetheless, the egg weights from chickens that were in the RA treatment were not significantly different from those produced from chickens that were under the AA and RR treatments. On average it was recognized that chickens that were full-fed during the laying phase (AA and RA) produced eggs with higher ($p<0.05$) weights than those that were exposed to restricted feeding (AR and RR) during the same phase. The average egg weights were 45.6, 43.5, 46.7 and 43.1g for chickens that were under the AA, AR, RA and RR treatments respectively. It was also observed that for the period of eight weeks (25-32 weeks) the egg weights of chickens that were subjected to restricted feeding throughout the study (RR treatment) increased by 41.2% which is higher in comparison with the egg weights from those in the treatments AA, AR and RR with 23.8%, 21.1% and 18.9% respectively.

The findings of the present study tally with the results of Oyedeji *et al*. (2007); Combs *et al.* (1961) and Pepper *et al.* (1966) who reported that the egg weight was significantly higher in hens that were fed *ad libitum* as compared to those that were rationed either once or twice a day. In support of these results, Hassan *et al.* (2003) also found that early feed restriction did not affect the average egg weights in quails. Miles and Jacqueline (2000) also showed that a feed restriction programme would result in a slight decrease in egg size, which is of less consequence once the majority of eggs are in the large category and this was obvious with the results of the present study with effect from the 30th week to end of the study. Sherwood *et al.* (1964) also suggested that the limiting of feed intake in birds had no consistent effect on egg weight. In the present study, the egg weights increased with the increase in age. This is in accordance with the findings of Robinson *et al.* (1978); Pevez *et al.* (1992) and Gous *et al.* (2000). Robinson *et al.* (1978) also concluded that restrictive feeding during the laying phase had an effect of depressing egg size. Similar results were observed in the present study as chickens that were feed restricted only during the laying (AR) had the lowest egg weights from the 27th to 32nd weeks of age.

The results indicate the significant (p<0.05) seasonal effects on egg weights throughout the study (Table 5.15). It was observed that chickens that were kept in summer had higher (p<0.05) weekly egg weights than those that were reared in winter.

Table 5.15: Egg weights of Koekoek chickens that were reared in either summer or winter during both rearing and laying phases

	Season		
Age (Weeks)	**Summer**	**Winter**	**S.E**
25	44.1^a	26.0^b	2.13
26	46.1^a	37.9^b	1.46
27	47.0^a	45.6^b	0.63
28	47.7^a	44.8^b	0.84
29	48.0^a	46.7^b	0.54
30	48.6	47.7	0.57
31	48.8^a	46.7^b	0.58
32	48.2	47.0	1.41
Average	46.8^a	42.6^b	0.44

[ab]Means within a row with no common superscript differ significantly (p<0.05), S.E-Standard Error

At the age of 25 weeks, an average egg weight of chickens that were in summer treatment was 41% higher than the one in chickens that were subjected to winter conditions. The eggs produced in summer were significantly (p<0.05) heavier than those produced in winter by 17.8%, 2.8%, 6.1%, 2.7% and 4.2% at the ages of 26, 27, 28, 29 and 31 weeks respectively. At the end of the study (32 weeks) the egg weights were insignificantly different between chickens that were reared in summer and winter. Overall, it was recognized that chickens that were reared in summer still had the highest (p<0.05) egg weights (46.8g) as compared to those that were reared in winter with an average egg weight of 42.6g.

The results indicate that although chickens that were reared in winter had smaller egg weights their egg weights were increasing at a faster rate as compared to the ones that were produced during in summer. This can be confirmed by the fact that the accumulated egg weight for chickens that were under winter treatment was 44.6% for the period covering 25 to 32 weeks while the one of chickens that were exposed to summer conditions was 5.8% during the same period of time. These results show that the egg weights increased positively with age in Koekoek chickens.

At the age of 32 weeks the results of the present study tally with the findings of Lin *et al.* (2002) who stated the non-significant differences between the egg weights produced under high temperature and the ones produced under controlled temperature. Contrary to the findings of the present study, the previous studies indicate that higher temperatures contribute significantly to the lower egg weights (Rozenboim *et al.*, 2007; Smith, 2005: Usayran *et al.*, 2001 and Hsu *et al.*, 1998). Garces *et al*. (2001) also reported that the egg weights of chickens that started laying in summer were lighter than the ones that started laying in winter.

The results of the present study signify a significant ($p<0.01$) interaction between feeding level and season at the 25th week of age (Table 6.16). The findings reflect that Koekoek chickens that were reared during the summer had the highest ($p<0.05$) egg weights irrespective of whether they were full-fed or restricted fed. This can be verified by the fact that the egg weights of birds that were fed restrictedly in summer for the entire study (SRR) were heavier than the ones of chickens that were full-fed throughout the study (WAA) by 13.7g. The average egg weights were also affected by an interaction between feeding level and season. The highest egg weights were observed in chickens that were under the AA (47.5g) and AR (47.6g) treatments in summer followed by chickens that were fed restrictedly in both rearing and laying phases in summer (SRR) with 46.7g. The lowest egg weights (39.6g) were recorded in chickens that were under the RR treatment in winter.

These results reflect that season rather than the feeding level affected the egg weights. It was also established that irrespective of the quantity of feed given to Koekoek chickens the egg weights produced in summer were heavier than the ones produced in winter.

Table 6.16: Effect of the interaction between feeding level and season on egg weights of Koekoek chickens

Age (weeks)	SAA	S.E	WAA	S.E	SAR	S.E	WAR	S.E	SRA	S.E	WRA	S.E	SRR	S.E	WRR	S.E
25	44.3^{a}	2.82	30.6^{b}	2.96	44.1^{a}	2.89	27.2^{b}	2.82	43.9^{a}	2.82	35.4^{b}	3.33	44.3^{a}	3.33	10.8^{b}	3.33
26	48.3	1.94	42.7	2.03	46.4	1.98	33.0	1.94	47.1	1.94	42.9	2.29	44.9	2.09	33.0	2.29
27	46.9	0.84	45.7	0.88	46.1	0.86	45.3	0.84	47.4	0.84	47.1	0.99	47.4	0.91	44.5	0.99
28	47.2	1.11	44.8	1.17	46.6	1.14	43.4	1.11	48.2	1.11	45.9	1.31	48.8	1.20	44.9	1.31
29	49.2	0.72	47.5	0.75	46.3	0.74	46.4	0.72	48.7	0.72	47.5	0.85	47.9	0.78	45.5	0.85
30	48.8	0.76	47.0	0.80	48.1	0.78	46.5	0.76	49.1	0.76	49.3	0.90	48.4	0.82	47.8	0.90
31	48.8	0.77	47.2	0.81	48.0	0.79	44.6	0.77	49.2	0.77	49.1	0.92	48.9	0.84	46.1	0.92
32	50.8	1.86	47.6	1.91	42.2	1.91	45.7	1.87	50.8	1.87	49.7	2.21	48.9	2.01	44.9	2.21
Average	47.5^{a}	0.59	43.6^{b}	0.62	45.5^{a}	0.60	41.4^{b}	0.59	47.6^{a}	059	45.8^{b}	0.70	46.7^{a}	0.64	39.6^{b}	0.70

^{ab} Means within a row with no common superscript differ significantly ($p<0.05$ and $p<0.01$).

Footnote:

SAA- full feeding during rearing and laying in summer season. SAR- full feeding during rearing and restricted during laying in summer season, SRA-restricted feeding during rearing and full feeding during laying in summer season, SRR-restricted during rearing and laying in summer season, WAA- full feeding during rearing and laying in winter season. WAR- full feeding during rearing and restricted during laying in winter season, WRA-restricted feeding during rearing and full feeding during laying in winter season, WRR-restricted during rearing and laying in winter season, S.E-standard error

The results on how chickens that were either full-fed or restricted fed performed in terms of age at puberty, 20%, 50% and 80% egg production are presented in Table 5.17. The results indicate that restricted feeding had an effect on the number of days to reach different egg production phases.

Table 5.17: The number of days taken by Koekoek chickens to reach first oviposition, 20%, 50% and ≥ 80 % egg laying production

	Treatments				
Variable	**AA**	**AR**	**RA**	**RR**	**S.E**
No. of days to 1st oviposition	150.1[a]	152.4[a]	159.0[b]	159.8[b]	0.61
No. of days to 20% production	163.5[a]	164.1[b]	166.9[ab]	168.3[b]	0.79
No. of days to 50% production	174.1	172.8	175.0	176.1	0.79
No of days to ≥ 80 % production	191.7[a]	190.7[a]	189.1[a]	199.4[b]	1.19

[ab] Means within a row with no common superscripts differ significantly ($p<0.05$)
Footnote:
AA- full feeding during rearing and laying. AR- full feeding during rearing and restricted during laying, RA-restricted feeding during rearing and full feeding during laying, RR-restricted during rearing and laying, S.E-standard error.

The results of the present study confirm the findings of Ezieshi *et al*. (2003) who indicated that feed restriction in layers depressed egg production as it was noticed from this study that chickens that were feed restricted for the entire study (RR) were the last to reach any of the egg production stages. In a study conducted on quails Hassan *et al.* (2003) also supported the findings of the present study by reporting that feed restriction delays the onset of laying which was observed in the findings of this study since chickens that were feed restricted during the rearing phase (RA and RR) delayed reaching sexual maturity. Gowe *et al.* (1960) also confirmed this. The results of the present study are also in agreement with the findings of Onagbesan *et al.* (2006) who found that chickens that are feed restricted would take a longer period to reach peak egg production compared with chickens that are full fed. The findings of the present study show that chickens that were under the RA treatment reached egg peak production slightly earlier. This is partially in line with the results of Crounch *et al.* (2002b) who revealed that turkey hens that were fed restricted earlier had a significantly higher peak egg production in comparison with hens that were full-fed early during the growing period.

Season played an important role on the period chickens took to reach the different production stages (Table 6.18). The results from the present study indicate that Koekoek chickens that were reared in summer reached sexual maturity earlier than chickens that were reared in winter and this can be attributed to the fact that winter conditions delayed the onset of laying by 17.3 days. Koekoek chickens that were subjected to summer conditions reached 20%, 50% and ≥80% egg production in 22.93, 23.5 and 29.6 days respectively earlier than those that were exposed to winter conditions. In order to accomplish peak egg production chickens that were in summer treatment took an average of 31.3 days as compared to 43.6 days for those that were kept in winter.

Table 5.18: Seasonal effect on the number of days to 1st oviposition, 20%, 50% and ≥80% egg production in Koekoek chickens

	Seasons		
Variable	**Summer**	**Winter**	**S.E**
No. of days to 1st oviposition	146.7^{a}	164.0^{b}	1.23
No. of days to 20% production	154.2^{a}	177.8^{b}	1.58
No. of days to 50% production	162.8^{a}	186.3^{b}	1.24
No of days to ≥80 % production	178.0^{a}	207.6^{b}	2.37

^{ab} Means within a row with no common superscript differ significantly ($p<0.05$), S.E- Standard Error

The reason for Koekoek chickens that were exposed to winter conditions to remain longer days before the onset of laying could be attached to the slow growing rate of chickens that were kept in winter and as a result, they delayed reaching puberty. The delay in the sexual maturity of chickens that were reared in winter had possibly contributed in Koekoek chickens to attain 20%, 50% and ≥80% laying percentages later than those that were in summer. The results of Chen *et al.* (2007) also stated that exposure to different photoperiods significantly affected the age at sexual maturity.

The results show the effect ($p<0.01$) of the interaction between feeding level and season on the number of days to reach 1st oviposition as illustrated on Table (Table 5.19). Koekoek chickens that were in the AA and AR treatments in summer were the first to lay eggs. This reflects that winter conditions delayed the commencement of laying by 24 and 23.7 days for chickens that were in the AA and AR treatments respectively in comparison to chickens that were kept in summer but fed similarly. Chickens that were in the RA and RR treatments in summer performed better than those in winter in terms of the time taken before sexual maturity. Chickens that were under the RA and RR treatments in summer reached their first oviposition 12 and 9.5 days earlier than in winter. The findings of this study show that Koekoek chickens that were reared in winter failed to mature faster regardless of the quantity of feed intake. This can be confirmed by the fact that chickens that were feed restricted during the rearing phase in summer (SRR and SRA) attained the onset of laying before chickens that were fed without any limit in winter (WAA and WAR). On average chickens that were feed restricted in summer arrived at sexual maturity 9.2 days prior to the ones that were full-fed in winter. This show that feed efficiency was better in summer as compared to winter. The best interaction combination was accomplished when rearing chickens in summer but on unrestricted feeding. The interaction between feeding level and season did not exist on the number of days to reach 20%, 50% and ≥80% egg laying production. In spite of an insignificant effect of feeding level and season interaction it was observed that Koekoek chickens that were reared in summer were first to reach any of the egg production stages when fed similar to their counterparts in winter.

Table 5.19: Effect of the interaction between feeding level and season on the number of days to reach first oviposition, 20%, 50% and 80% egg production in Koekoek chickens

	Treatments															
Variable	**SAA**	**S.E**	**WAA**	**S.E**	**SAR**	**S.E**	**WAR**	**S.E**	**SRA**	**S.E**	**WRA**	**S.E**	**SRR**	**S.E**	**WRR**	**S.E**
Days to 1st Oviposition	138.1[a]	1.70	162.1[b]	1.70	140.6[a]	1.70	164.3[b]	1.70	153.0[a]	1.70	165.0[b]	1.70	155.0[a]	1.84	164.5[b]	1.84
Days to 20% Production	150.1	2.19	176.9	2.19	151.0	2.19	177.4	2.19	157.1	2.19	176.5	2.19	158.7	2.36	177.8	2.36
Days to 50% Production	160.7	1.72	187.6	1.72	161.7	1.72	184.0	1.72	164.1	1.72	185.9	1.72	164.5	1.86	187.7	1.86
Days to ≥80% Production	175.4	3.28	208.0	3.28	177.9	3.28	203.6	3.28	174.0	3.28	204.3	3.28	184.5	3.55	214.3	3.55

[ab] Means within a row with no common superscript differ significantly (p<0.05 and p<0.01)

Footnote:

SAA- full feeding during rearing and laying in summer season. SAR- full feeding during rearing and restricted during laying in summer season, SRA-restricted feeding during rearing and full feeding during laying in summer season, SRR-restricted during rearing and laying in summer season, WAA- full feeding during rearing and laying in winter season. WAR- full feeding during rearing and restricted during laying in winter season, WRA-restricted feeding during rearing and full feeding during laying in winter season, WRR-restricted during rearing and laying in winter season, S.E-standard error

Table 5.20: The percentage of abnormal eggs (cracks, Soft shells, shell-less and double yolked) in Koekoek chickens that were subjected to different levels of feeding treatments

	Treatments				
Age	**AA**	**AR**	**RA**	**RR**	**S.E**
18	0.0	0.0	0.0	0.0	0.00
19	0.0	0.0	0.0	0.0	0.00
20	0.0	0.0	0.0	0.0	0.00
21	0.0	0.0	0.0	0.0	0.00
22	0.0	0.0	0.0	0.0	0.00
23	0.7	0.3	0.3	0.1	0.35
24	0.3	0.3	0.5	0.4	0.38
25	1.8	0.5	0.9	1.2	1.09
26	0.6	1.0	0.8	0.9	0.83
27	0.5	0.3	0.6	1.1	0.61
28	0.3	0.5	0.6	1.0	0.61
29	1.2	1.3	0.7	1.2	0.68
30	0.7	0.8	0.3	0.6	0.59
31	0.7^{ab}	0.2^{b}	1.1^{a}	0.8^{a}	0.71
32	0.7	0.6	0.3	0.5	0.55
Av	0.5	0.4	0.4	0.5	0.46

^{ab} Means within a row with no common superscript differ significantly ($p<0.05$).
Footnote:
AA- full feeding during rearing and laying. AR- full feeding during rearing and restricted during laying, RA-restricted feeding during rearing and full feeding during laying, RR-restricted during rearing and laying, S.E-standard error.

Eggs from the four feeding level treatments had no abnormalities for the first five weeks from the onset of laying (Table 6.20). The percentage of the abnormal eggs was observed with effect from 32 weeks of age. There was an insignificant difference between chickens that were either full-fed or restricted fed in terms of the non-settable eggs. The only significant difference was observed at the 31st week of age in which chickens that were under RA treatment had the highest percentage (1.1%) of abnormal eggs with the ones that were under restricted feeding for the whole study (RR) occupying the second position (0.7%). The weekly average number of abnormal eggs at the 31st week in chickens that were subjected to the RA and RR treatments was non-significant. Koekoek chickens that were in the AR treatment had the lowest ($p<0.05$) percentage (0.2%) of abnormal eggs in comparison with those that were exposed to the RA and RR treatments. The quantity of abnormal eggs in chickens that were full-fed for the entire study (AA) was statistically similar (0.7%) to that encountered by chickens in other treatments.

When looking at the overall performance it was recognized that the restricted feeding had no effect

($p>0.05$) on the egg quality since the differences in the percentages of the abnormal eggs between the treatments were minor. The overall percentages of abnormal eggs were 0.5%, 0.4%, 0.4% and 0.5% for chickens in the AA, AR, RA and RR treatments respectively.

When considering the production of abnormal eggs at the 31st week these results tally with the findings of Crounch *et al.* (2002b) who stated that the number of cracked and soft-shelled eggs was higher in turkeys that were feed restricted early in their lives. This was the case in the present study as chickens that were in the RA and RR had a highest number of abnormal eggs. The findings of Robinson *et al*. (1978) indicated that the proportion of the cracked eggs decreases with the increase in the severity of the restricted feeding and this was noticed in chickens that were in the AR treatment that had the lowest number of abnormal eggs at the age of 31 weeks. Richards *et al*. (2003) and Hocking (1992a) also found a low incidences of abnormal eggs in restricted fed hens. In contradicting with the findings of the present study, Bruggeman (1999) emphasized that chickens with access to unrestricted feeding throughout had the lowest number of settable eggs.

The results on Table 6.21 show the role of the season on the production of abnormal eggs in Koekoek chickens on a weekly basis. The results indicate that chickens that were subjected to different seasons performed differently in terms of the percentage of the abnormal eggs despite the non significant differences in the quantity of unsettable eggs between the two seasons for the larger part of the study period. It was observed that chickens that were in winter produced 100% settable eggs during the first six weeks from the onset of laying while those in summer produced 100% normal eggs for the first four weeks excluding the 20th week.

Generally, chickens that were in winter treatment had the highest weekly percentage of settable eggs with the exception of the 27th, 28th 30th and 32nd weeks. At the age of 25 weeks, Koekoek chickens that were subjected to summer treatment had a higher ($p<0.05$) percentage of abnormal eggs (1.8%) than those that were allotted to winter treatment (0.3%).

When considering an overall average production of the abnormal eggs it was observed that chickens that were in summer treatment had a higher percentage compared to those that were in winter treatment even though the difference was not statistically significant (p>0.05). The weekly average production of abnormal eggs was less than 1% in chickens that were in summer and winter treatments and the only exception was recognized at the age of 25 weeks in chickens that were reared in summer. The results indicate that eggs with more weight were more prone to abnormalities. This can be confirmed by the fact that chickens produced a smaller number of abnormal eggs at a younger age compared to when they were advancing with age and the younger the age the lighter the egg. The feeding level and season interaction had no effect (p>0.05) on the production of abnormal eggs in Koekoek chickens throughout the entire study as demonstrated on Table 6.22.

Table 6.21: The percentage of abnormal eggs (cracks, Soft shells, shell-less and double yolked) in Koekoek chickens that were reared either in summer or winter during both rearing and laying phases

	Seasons		
Age	**Summer**	**Winter**	**S.E**
18	0.0	0.0	0.00
19	0.0	0.0	0.00
20	0.4	0.0	0.37
21	0.0	0.0	0.00
22	0.0	0.0	0.00
23	0.7	0.0	0.23
24	0.5	0.3	0.19
25	1.8[a]	0.3[b]	0.34
26	0.8	0.1	0.23
27	0.5	0.7	0.23
28	0.5	0.7	0.20
29	1.4	1.0	0.25
30	0.5	0.6	0.24
31	0.8	0.6	0.20
32	0.5	0.6	0.20
Av	0.5	0.4	0.44

[ab] Means within a row with no common superscript differ significantly (p<0.05), S.E-Standard Error

Table 5.22: Effect of the interaction between feeding level and season on the production of abnormal eggs in Koekoek chickens

	Treatments															
Age (weeks)	**SAA**	**S.E**	**WAA**	**S.E**	**SAR**	**S.E**	**WAR**	**S.E**	**SRA**	**S.E**	**WRA**	**S.E**	**SRR**	**S.E**	**WRR**	**S.E**
18	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
19	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
20	0.0	0.05	0.0	0.05	0.1	0.05	0.0	0.05	0.0	0.05	0.0	0.05	0.0	0.06	0.0	0.06
21	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
22	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
23	1.4	0.32	0.0	0.32	0.7	0.32	0.0	0.32	0.5	0.32	0.0	0.32	0.3	0.35	0.0	0.35
24	0.5	0.26	0.2	0.26	0.2	0.26	0.3	0.26	0.5	0.26	0.5	0.26	0.8	0.29	0.0	0.29
25	2.9	0.60	1.1	0.60	0.9	0.60	0.0	0.60	1.6	0.60	0.2	0.60	2.4	0.64	0.0	0.64
26	0.2	0.44	0.9	0.44	1.4	0.44	0.7	0.44	0.9	0.44	0.7	0.44	0.5	0.48	1.3	0.48
27	0.2	0.45	0.7	0.45	0.5	0.45	0.2	0.45	0.7	0.45	0.9	0.45	0.8	0.49	1.2	0.49
28	0.2	0.39	0.5	0.39	0.0	0.39	0.9	0.39	0.7	0.39	0.5	0.39	1.1	0.43	1.1	0.43
29	1.6	0.50	0.9	0.50	1.6	0.50	0.9	0.50	0.7	0.50	0.7	0.50	1.6	0.54	1.3	0.54
30	0.7	0.48	0.7	0.48	0.5	0.48	1.1	0.48	0.5	0.48	0.2	0.48	0.5	0.52	0.5	0.52
31	0.5	0.39	0.9	0.39	0.5	0.39	0.0	0.39	1.4	0.39	0.9	0.39	1.1	0.43	0.5	0.43
32	0.9	0.40	0.5	0.39	0.8	0.40	0.5	0.40	0.0	0.40	0.7	0.40	0.3	0.43	0.8	0.43
Av	0.6	0.10	0.4	0.10	0.5	0.10	0.3	0.10	0.5	0.10	0.4	0.10	0.6	0.11	0.5	0.11

Footnote:
SAA- full feeding during rearing and laying in summer season. SAR- full feeding during rearing and restricted during laying in summer season, SRA-restricted feeding during rearing and full feeding during laying in summer season, SRR-restricted during rearing and laying in summer season, WAA- full feeding during rearing and laying in winter season. WAR- full feeding during rearing and restricted during laying in winter season, WRA-restricted feeding during rearing and full feeding during laying in winter season, WRR-restricted during rearing and laying in winter season, S.E-Standard Error

Table 5.23: Egg hatching percentage of Koekoek chickens that were subjected to different feeding level treatments

	Treatments				
Age (weeks)	**AA**	**AR**	**RA**	**RR**	**S.E**
28	62.1^{a}	75.7^{b}	65.7^{a}	85.0^{b}	1.66
30	75.0^{a}	89.3^{b}	78.6^{a}	92.5^{b}	1.26
32	80.7^{a}	85.0^{a}	83.6^{a}	93.3^{b}	1.25
Av	72.6^{a}	83.3^{b}	76.0^{a}	90.3^{c}	0.85

^{ab} Means within a row with no common superscript differ significantly (p<0.05).
Footnote:
AA- full feeding during rearing and laying. AR- full feeding during rearing and restricted during laying, RA-restricted feeding during rearing and full feeding during laying, RR-restricted during rearing and laying, S.E-Standard Error

Eggs produced by Koekoek chickens that were subjected to feed restriction during the laying period (AR and RR) hatched higher (p<0.05) than the eggs that were from those that were fed without restriction during the laying phase (AA and RA) at the age of 28 weeks (Table 5.23). The highest hatching percentage (85%) was recorded in chickens that were fed restrictedly for the entire study (RR) though they were not significantly different from the ones that were feed restricted only during the laying phase (AR) with a hatching percentage of 75.7%. The hatching percentage of eggs produced by chickens that were full-fed for the entire study (AA) was lower by 13.6%, 3.1% and 22.9% in comparison with chickens that were under the AR, RA and RR treatments respectively. The hatching percentages of eggs in chickens that were under the AA and RA treatments were statistically similar (p>0.05).

Eggs produced by chickens on the AR and RR treatments during laying had a significantly higher hatchability than eggs hatched by birds from the other two treatments at all ages except in the 32nd week when birds on the RR treatment had a higher hatchability (p<0.05) than eggs laid by birds on all other treatments. The hatching percentage of eggs on the RR treatment was 13.5%, 8.9% and 10.5% higher (p<0.05) than the ones from chickens that were allotted to the AA, AR and RA treatments respectively.

It was also discovered that hatchability increases with age in Koekoek chickens. There was a rise of 23%, 10.9%, 21.4% and 8.9% in the hatching percentages of eggs produced from chickens that were under the AA, AR, RA and RR treatments respectively. These results suggest that regardless of the lower hatching percentages in eggs produced by chickens that were full-fed during the laying phase

(AA and RA) their hatching percentages were increasing at an increasing rate as compared to the ones that were subjected to restricted feeding during the laying phase. This could further mean that restricted fed chickens simply maintained their initial egg hatching percentage for the entire study (Figure 6.4).

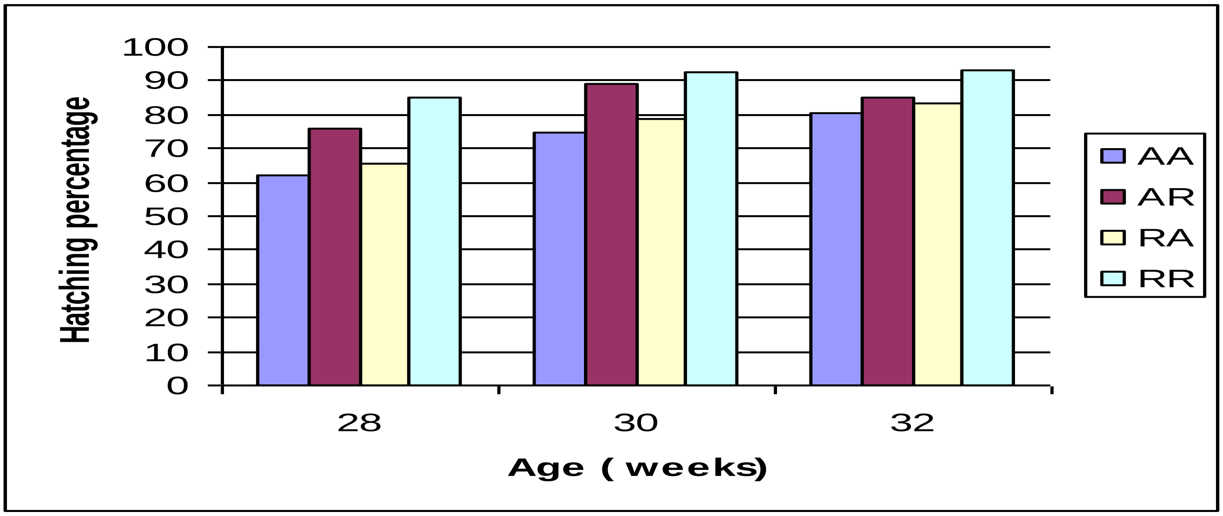

Figure 5.4: The effect of restricted feeding on egg hatching percentage of Koekoek chickens

Footnote:
AA- full feeding during rearing and laying. AR- full feeding during rearing and restricted during laying, RA-restricted feeding during rearing and full feeding during laying, RR-restricted during rearing and laying.

When considering an average hatching percentage it was noticed that eggs produced from chickens that were feed restricted in both phases of the study (RR) hatched higher ($p<0.05$) than those from chickens that were subjected to the AA, AR and RA treatments. The hatching percentage of the eggs from Koekoek chickens that were under the AA (72.6%) and RA (76%) treatments was significantly lower in comparision with eggs produced by chickens from other treatments. Eggs produced by chickens that were allotted to the AR treatments were second (83.3%) after eggs from chickens that were under the AA treatments. Generally, the results on egg hatchability suggest that feed restriction during the laying period has the potential of increasing the number of hatching eggs as compared to full feeding during the laying phase. The possible reason for the lower hatchabilty in chickens that were full-fed during the laying phase could the higher fat content. This means that hatching percentage is negatively related to feed intake and hen body weight during the laying phase. The results also reveal that egg hatchability on Koekoek chickens was not affected by the egg weights. This can be verified by the lack of correlation ($p>0.05$) between the hatching percentage and egg weights from 28 to 32 weeks of age (Table 5.25).

In support of the results of the present study, Crounch *et al*. (2002b) indicated that turkeys that were shifted from restricted feeding during the rearing phase to *ad libitum* feeding during the laying phase had a significantly higher embryonic mortality and hence a lower hatching percentage compared with other treatments. Hassan *et al.* (2003) also reported that mortality for full fed quails was 56% more than from 15 or 30% feed restricted quails. Hassan *et al.* (2003) also reported non-significant differences between the eggs from *ad libitum* fed quails and restricted fed ones. Crounch *et al.* (2002b) also showed a higher hatchability in turkeys that were feed restricted during the rearing phase as compared to those that were fed *ad libitum* during the rearing phase. This was not the case with the results of this study as the eggs from Koekoek chickens that were fed restrictedly in the laying phase were the ones that had a significantly higher hatching percentage.

Eggs produced by chickens that were reared in summer had a similar hatchability as compared to those that were laid in winter (Table 5.24). The results indicate that egg hatchability increases with age in Koekoek chickens. This can be proved by the fact that from the age of 28 to 32 weeks there was an increase of 13.7% in egg hatchability of Koekoek chickens that were reared in summer while 17.8% was for the eggs that were produced by Koekoek chickens in winter. Despite the insignificant differences between the hatching percentages of eggs that were either produced in summer or in winter it was noticed that eggs laid in winter hatched more than those produced in summer. The difference of 4% between the two hatching percentages numerically would mean a lot to a rural farmer in Lesotho despite being statistically insignificant. This difference would make a difference in the livelihoods of the people since the estimated cost of a Koekoek chick in Lesotho is above M6.50. This suggests that 4% of 100 chicks would give a farmer approximately M26.00 in a 21 days incubation period.

The results of the present study are in accordance with the findings of Babiker and Musharaf (2008) who recorded an insignificant difference between the two seasons with respect to egg hatchability caused by embryonic death at early stages of development. The same findings were also shared by Abdou *et al*. (1977) who indicated no differences in fertility and hatchability in eggs laid in summer and winter. In contradiction with the findings of the present study, the work of Gonzalez-Redondo (2006) showed that fertility and hatchability were high in eggs produced in winter as compared to those produced in summer. This was also confirmed by the findings of Ozcelic *et al.* (2006) who indicated a lower hatchability during the periods when temperatures are higher. In justifying a lower hatchability during the hot seasons Brake *et al.* (1997) indicated that the relative increase in temperatures of the nest boxes, storage and pre-setting area would reduce egg hatchability as result of change in the albumen quality.

The results as illustrated in Table 6.25 show that the interaction between the feeding level and season failed to impact on the hatchability of eggs from Koekoek chickens. This means that the two treatment factors (4 feeding levels and 2 seasons) worked independently from each other in relation to the eggs hatching percentage.

Table 5.24: Egg hatching percentage of Koekoek chickens that were reared in either summer or winter

	Seasons		
Age (weeks)	**Summer**	**Winter**	**S.E**
28	73.1	71.2	3.32
30	83.7	84.0	2.52
32	84.8	86.6	2.50
Av	80.5	80.6	1.71

[ab] Means within a row with no common superscript differ significantly ($p<0.05$), S.E- Standard Error

Table 5.25: Correlations between egg weights and hatching percentages of Koekoek chickens at 18 and 32 weeks of age

Variable	**Hatching % (28 weeks)**	**Hatching % (30 weeks)**	**Hatching % (32 weeks)**	**Average hatching %**
Egg weight (28 weeks)	0.104	-0.120	-0.051	-0.130
Egg weight (30 weeks)	0.084	0.08	0.079	0.109
Egg weight (32 weeks)	0.059	-0.202	-0.103	-0.093
Average egg weight	-0100	-0.215	-0.152	-0.202

** Correlation is significant at the 0.01 level. * Correlation is significant at the 0.05 level.

Table 5.26: Effect of the interaction between feeding level and season on egg hatching percentage of Koekoek chickens

Age (weeks)	SAA	S.E	WAA	S.E	SAR	S.E	WAR	S.E	SRA	S.E	WRA	S.E	SRR	S.E	WRR	S.E
28	62.9	4.60	61.4	4.60	72.9	4.60	78.6	4.60	70.0	4.60	61.4	4.60	86.7	4.97	83.3	4.97
30	74.3	3.49	75.7	3.49	87.1	3.49	91.4	3.49	80.0	3.49	77.1	3.49	93.3	3.77	91.7	3.77
32	81.4	3.47	80.0	3.47	85.7	3.47	84.3	3.47	78.6	3.47	88.6	3.47	93.3	3.74	93.3	3.74
Average	72.9	2.37	72.4	2.37	81.9	2.37	84.8	2.37	76.2	2.37	75.7	2.37	91.1	2.56	89.4	2.56

Footnote:
SAA- full feeding during rearing and laying in summer season. SAR- full feeding during rearing and restricted during laying in summer season, SRA-restricted feeding during rearing and full feeding during laying in summer season, SRR-restricted during rearing and laying in summer season, WAA- full feeding during rearing and laying in winter season. WAR- full feeding during rearing and restricted during laying in winter season, WRA-restricted feeding during rearing and full feeding during laying in winter season, WRR-restricted during rearing and laying in winter season, S.E-Standard Error, Sig- Significance

5.4 Conclusion

- Full feeding in the rearing phase resulted in reduced comb size, wattle size, pubic bones, ova and oviducts development, delayed oviposition and 20% egg production.
- Early restricted feeding followed by full feeding resulted in rapid development of combs, wattles and pubic bones from 18 to 32 weeks of age.
- Full feeding in the laying phase resulted in higher laying percentage and egg weights despite of whether chickens were on the full-fed or restricted feeding in the rearing phase.
- Restricted feeding in the laying phase reduced egg abnormality and increased hatching percentage in Koekoek chickens.
- Summer conditions improved the comb, wattle, pubic bones, ova and oviducts development, laying percentage and egg weights of Koekoek hens.

5.5 Recommendations

- Koekoek chickens should only be feed restricted in the rearing phase since it was established that their performance was statistically similar to those that were full-fed during the entire study (AA) with reference to laying percentage, egg weight and early peak egg production.
- It is also recommended that Koekoek chickens be reared in summer in order to maximize the laying percentage, increase egg weight and reduce number of days to first oviposition as well as other egg production stages.
- In the case where a farmer is interested in producing eggs for hatching purposes, feed restriction (RR) would be an ideal practice in order to maximize egg hatchability and reduced number of abnormal eggs in Koekoek chickens.
- Generally, the better results were achieved when feeding hens without restriction in summer.
- It is further recommended that this study be done for duration of at least 72 weeks in order to investigate the sustainability of restricted feeding and season on the reproductive characteristics of Koekoek chickens.

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CHAPTER 6

Summary and General Conclusion

6.1 Summary

This research project incorporates four studies. The first study was aimed at establishing the effect of feeding level and season on the growth performance of Koekoek chickens. The growth performance parameters studied included weight for age, body weight gain, feed intake and feed conversion ratio (FCR). The feeding level and season played a significant ($p<0.05$) role on the growth performance of Koekoek chickens. At 18 weeks of age, the body weights of chickens that were full-fed in the rearing phase (AA and AR) were 0.39 kg heavier than those of chickens that were fed restrictedly (RA and RR). Restricted feeding hindered the body weight gains of chickens by 42.1% as compared to chickens that were full-fed in the rearing phase (10-18 weeks). Koekoek chickens that were full-fed during the rearing phase were more ($p<0.05$) efficient in converting feed into body weight (5.4) than the ones that were fed restrictedly (6.74). During the laying phase (19 to 32 weeks), the average body weight of Koekoek chickens that were allotted to the RA treatment was 0.2 kg , 0.8 kg and 0.7 kg higher ($p<0.05$) than the ones in chickens that were in treatments AA, AR and RR respectively. In terms of the body weight gain chickens in the AR treatment scored significantly ($p<0.05$) lower (164.6g) body weight as compared to chickens that were in the AA, RA and RR treatments with the weight gains of 1126g, 721.7g and 501.9g respectively. Restricted feeding only in the rearing phase (RA) improved the feed conversion ratio by 37.1%, 79.6% and 40.2% when compared to chickens that were in the AA, AR and RR treatments respectively. On the other hand season had a significant ($p<0.05$) effect on the growth performance of Koekoek chickens. The body weights of chickens that were reared in winter were significantly ($p<0.05$) lower (1223g) than those of chickens reared in summer season (1547g) at first oviposition (18 weeks). The final body weights of chickens that were reared in summer were higher than those in winter. Koekoek chickens that were reared during the summer gained more than chickens that were kept in winter for the period from 10 to 18 weeks of age. From 19 to 32 weeks of age, winter conditions suppressed the weight gain of Koekoek chickens by 7.05% as compared to the weight gain of chickens that were exposed to summer conditions. An average feed conversion ratio (FCR) of chickens that were reared during the summer was lower (4.4:1 than the FCR of chickens that were reared during the winter (7.8:1). The summer conditions improved the overall feed efficiency by 25.55% compared to winter conditions. The mortality rate and feed intake were high in chickens that were reared in winter. The body weights, weight gains, feed intakes and FCR were significantly ($p<0.05$) affected by the interaction between the feeding level and season.

The second study focused on the effect of feeding level and season on the carcass characteristics of Koekoek chickens at the ages of 18 and 32 weeks. At puberty (18 weeks) feed restriction lowered the slaughter weight, defeathered weight, dressing weight, skin weight, breast muscle weight, chest width and heart girth by 21.5%, 25.9%, 13.8%, 7.6%, 21.2%, 18.6% and 28.8% respectively in Koekoek chickens as compared to those that were full-fed. The mean weights of the intestines, liver and abdominal fat were significantly ($p<0.05$) higher in full-fed chickens (64.6g, 58.4g and 31.7g) compared to feed restricted chickens (22.4g, 54.2g and 26.2g). The shank width, slaughter weight, defeathered weight, chest width, heart girth, dressing weight, breast muscle weight, skin weight and skin percentage of chickens that were reared in summer were 33.5%, 16.7%, 12.9%, 39.3%, 12.2%, 29.9%, 24.9% and 9.5% respectively higher ($p<0.05$) than those of chickens that were reared in winter. The shank length, defeathered percentage, carcass dressing percentage and muscle dressing percentage were significantly ($p<0.05$) higher in chickens that were reared in winter (67.4mm, 86.0%, 71.6% and 5.3%) compared to chickens reared in summer (64.4mm, 82.3%, 68.4% and 4.1%). The summer conditions increased the abdominal fat pad weight, abdominal fat percentage, intestine weight and liver weight by 15.6g, 0.6%, 10.3g and 4.6g compared to winter conditions. The gizzard weights and gizzard percentage were lower ($p<0.05$) in chickens that were reared during summer by 2.8g and 0.6% respectively compared to those reared in winter. Carcass characteristics (defeathered weight, dressing weight, dressing percentage, breast muscle weight, breast muscle percentage, skin weight and skin percentage) abdominal fat pad and internal organs were not statistically ($p<0.05$) affected by the interaction between the feeding level and season during the rearing period (18 weeks). At the age of 32 weeks, Koekoek chickens that were full-fed during the laying phase (AA and RA) performed better ($p<0.05$) than chickens that were subjected to restricted feeding during the laying phase (AR and RR) in terms of slaughter weight, defeathered weight, heart girth, dressing weight and breast muscle weight. The shank length and chest width of chickens that were under RR treatment (67.3mm and 59.3mm) were significantly ($p<0.05$) lower than that of chickens in treatments AA (69.6mm and 65.2mm) and RA (69.6mm and 63.9mm) but statistically similar ($p>0.05$) to the shank lengths and chest widths of chickens that were under AR treatment (67.3mm and 59.3mm). The skin weights of chickens that were under AA treatment were heavier ($p<0.05$) than the skin weights of chickens that were subjected to AR, RA and RR treatments. The relative skin percentage for chickens that were allotted to AA treatments (7.5%) was higher ($p<0.05$) than that of chickens that were under AR (6.7%), RA (6.8%) and RR (6.7%) treatments. The slaughter weight, defeathered weight, chest width, heart girth, carcass dressing weight, and skin weight of chickens that were exposed to summer conditions were 25.7%, 18.1%, 21.9%, 9.2%, 23.2% and 9.2% higher than the ones that were exposed to winter conditions. On the other hand the shank length, shank width and skin percentage were higher in winter (70.6mm, 12.1mm and 7.1%) than in summer (66.9mm, 10.8mm and 6.5%). The defeathered percentage, carcass dressing percentage, breast muscle weight and breast muscle percentage were similar between the different seasons. The feeding level and season interaction played a significant ($p<0.05$) role on shank width, slaughter weight, defeathered weight, chest width, dressing weight, breast muscle weight, skin weight and skin percentage. The abdominal fat weight, liver weight and gizzard weight were significantly ($p<0.05$) higher in Koekoek chickens that were full-fed during the laying phase (AA and RA) compared to those that were fed restrictedly during a similar period (AR and RR). The abdominal fat and gizzard percentages were higher ($p<0.05$) in chickens that were under AA treatment (5.3% and 1.6%) compared to those that were under AR treatment (3.8% and 1.8%) and RR treatment (4.1% and 2%) but not significantly ($p>0.05$) different from those that were subjected to RA treatment (4.5% and 1.7%). The feeding level had no effect ($p>0.05$) on the performance of chickens in terms of intestine weights and liver percentage. The winter conditions impacted ($p<0.05$) positively on abdominal fat weight, abdominal fat percentage, intestine weight, intestine percentage and liver percentage of Koekoek chickens with the records of 95.8g, 5%, 69.1g, 3.7g and 2% in comparison to those that were exposed to summer conditions (91.3g, 3.8%. 69g, 3.1% and 1.6%) respectively. The liver weight and gizzard percentage were statistically ($p>0.05$) similar regardless of the season. The feeding level and season significantly ($p<0.05$) affected the relative weights of the intestine and liver as percentage of body weights.

The third study was conducted to determine the effect of restricted feeding and season on the carcass chemical composition of Koekoek chickens. The chemical composition was done in meat from chickens of 18 and 32 weeks of age. At the age of 18 weeks both feeding level and season had a significant ($p<0.05$) effect on the chemical composition of meat from Koekoek chickens. The meat produced by Koekoek chickens that were fed without restriction (AA and AR) had higher ($p<0.05$) fat content (43.4% and 41.5%) than those that were on restricted feeding (RA and RR) with the fat content of 33.5% and 32.7% respectively. The dry matter and crude protein percentages were on average higher (p<0.05) in full-fed chickens (96.8%) compared to feed restricted ones (89.6%) while the percentage of crude protein was significantly (p<0.05) higher in chickens that were feed restricted (50.4%) than in full-fed chickens (39.4%). Dry matter and crude protein percentages were significantly (p<0.05) higher in chicken meat produced during the summer (94.1% and 46.4%) than those fed restrictedly (92.2% and 43.3%). The ash and fat contents were not affected by the season. Dry matter content was significantly (p>0.05) lower (95.2%) in the meat of chickens that were subjected to AA treatment than from the meat produced in Koekoek chickens that were subjected to AR (95.9%), RA (96%) and RR (96%) treatments. Chickens that were full-fed during the laying phase (AA and RA) had higher (p<0.05) fat content (51.9% and 50.2%) followed by the ones that were under AR treatment (45.3%) with Koekoek chickens that were feed restricted in both phases (RR) registering the lowest (p<0.05) fat content (40%) at the age of 32 weeks. The crude protein content from meat produced by chickens that were subjected to RR treatment were 12%, 7.1% and 7.5% respectively higher than those from chickens that were in treatments AA, AR and RA. The ash content was similar across the four feeding level treatments. At the age of 32 weeks, it was discovered that the dry matter content in meat produced during the summer was 1% higher than that in winter. The winter conditions enhanced the ash, fat and crude protein contents by 4.4%, 6.7% and 17.7% compared to summer. The feeding level and season interaction only had a significant (p<0.05) effect on the dry matter content of meat from Koekoek chickens.

The fourth study was conducted to establish the effect of restricted feeding and season as well as their interaction on the reproductive performance of Koekoek chickens from 18 to 32 weeks of age. The reproductive performance in Koekoek chickens was done through the evaluation of combs, wattles, pubic bones, oviducts and ova. At the age of 18 weeks the comb and wattle lengths of Koekoek chickens that were full-fed during the rearing phase (AA and AR) were longer (p<0.05) than the combs and wattles of chickens that were feed restricted (RA and RR). The combs of chickens that were allocated to RA (54.6mm) and AA (53.1mm) were longer (p<0.05) than the ones that were subjected to AR (51.5mm) and RR (51.7mm). However, the comb lengths of chickens that were under AA and RR treatments were not significantly (p>0.05) different. The wattle lengths were similar among the four feeding level treatments at the age of 32 weeks. The combs and wattles were significantly (p<0.05) longer in Koekoek chickens that were reared during the summer (37.8mm and

21.9mm) compared to those of chickens that were reared in winter (22.2mm and 15.3mm) at the age of 18 weeks. Fourteen weeks later the comb lengths of chickens reared in summer were 19.8% longer than the combs of their counterparts that were reared in winter while the wattle lengths were not significantly ($p>0.05$) affected by the feeding level. The interaction between the feeding level and season played a significant ($p<0.05$) role on the enlargement of combs and wattles during the first eight and four weeks respectively from the onset of puberty. At 18 weeks of age the distance between the pubic bones was wider ($p<0.05$) in chickens that were fed without restriction (AA and AR) as compared to the ones that were fed restrictedly during the rearing phase (RA and RR) with the records of 24.4mm and 15.6mm respectively. At the age of 32 weeks chickens that were in AA and RA treatments (48.9mm and 48.8mm) had a wider ($p<0.05$) distance between the pubic bones than those that were in AR and RR treatments (43.9mm and 44.5mm). The ova and oviduct weights of Koekoek chickens that were full-fed (AA and AR) were heavier (16.00g and 15.36g) than those of chickens that were in RA (5.6g) and RR (5.5g) at the slaughter age of 18 weeks. At the age of 32 weeks the ova and oviduct weights were statistically ($p>0.05$) similar between the different feeding level treatments. The distance between the pubic bones and the combined weight of ova and oviducts of chickens reared during summer were 34.7% and 51% higher than that of chickens that were reared during winter respectively at 18 weeks of age. The weights of the ova (45.5g) and oviducts (50.7g) of chickens produced during summer were heavier ($p<0.05$) than the ova and oviducts of chickens produced in winter (47.5g and 47.9g) during the laying phase (32 weeks). The spread of the pubic pins was not affected by season at the age of 32 weeks in Koekoek chickens. The feeding level and season interaction had an effect ($p<0.05$) on the ova and oviduct weights at the age of 18 weeks as well as the spread of the pubic bones at 32 weeks of age.

At the age of 18 to 20 weeks only chickens that were full-fed during rearing (AA and AR) started laying while those that were in restricted fed treatments (RA and RR) commenced their laying cycle on the 21^{st} week. However, a week later (22 weeks) chickens under RA treatment were second (15.4%) from the ones that were under AA treatment (19.5%) with respect to laying percentage though they were not significantly different from chickens that were subjected to AR treatment (14.3%). During the last week of the study the laying percentage of chickens that were under RA treatment (72.8%) were statistically similar to chickens that were in AA treatment (71.9%) while the laying percentages of chickens that were feed restricted during the laying phase (AR and RR) were lower with the records of 65.5% and 65.2% respectively. Winter delayed egg laying by six weeks in Koekoek chickens as compared to summer. At the age of 23 weeks, the laying percentage in chickens that were reared in summer was 50.1% higher than the laying percentage of chickens that were reared in winter. The final egg laying percentages (32 weeks) were 72.9% and 64.9% for Koekoek chickens that were reared during summer and winter respectively. The feeding level and season interaction influenced egg production of Koekoek chickens ($p<0.05$). Egg weights of chickens were initially lower ($p<0.05$) in chickens that were feed restricted during the rearing and laying phases (RR) (up to 25 weeks). At the age of 32 weeks the egg weights produced from chickens that were in RR treatments (46.9g) were statistically($p>0.05$) similar to egg weights from chickens that were under AA (49.2g), AR (43.9g) and RA (50.2g) treatments. The average egg weights of chickens that were full-fed during the laying phase (AA and RA) were heavier (45.6g and 46.7g) than those of chickens that were feed restricted during the same phase (AR and RR) with 43.5g and 43.1g respectively. At the age of 25 weeks, the eggs produced during the summer season were 18.1g heavier than the ones produced in winter. Seven weeks later the egg weights from Koekoek chickens that were reared in summer (48.2g) were not different ($p>0.05$) from the ones that were reared in winter (47g) even though the average egg weights were higher in chickens that were reared in summer (46.8g) compared to the ones laid in winter (42.6g). The average egg weights were affected by the interaction between the feeding level and season. Full feeding during the rearing phase (AA and AR) reduced the number of days to first oviposition by 8.2 days as compared to restricted feeding during the similar phase (RA and RR). Koekoek chickens that were subjected to RR treatment (168.3 and 199.4 days) delayed to reach 20% and 80% egg production in comparison to those that were under AA (163.5 and 191.7 days), AR (164.1 and 190.7 days) and RA (166.9 and 189.1 days) treatments. The summer conditions shortened the number of days to 1st oviposition, 20%, 50% and 80% egg production by 17.3, 22.93, 23.5 and 29.6 days as compared with winter conditions respectively ($p<0.05$). The feeding level and season interaction did not influence the number of days for different egg production stages except for the number of days to first oviposition. The feeding level and season as well as their interaction had no effect ($p>0.05$) on the production of abnormal eggs (cracks, soft-shelled, shell-less and double yolked) in Koekoek chickens. Restricted feeding during both rearing and laying phases (RR) resulted in higher average egg hatchability (90.9%) than AA, AR and RA treatments with the egg hatching percentages of 72.6%, 83.3% and 76% respectively. The egg hatching percentage in Koekoek chickens was neither affected

($p>0.05$) by warm summer conditions nor cold winter conditions. There was no significant interaction between the feeding level and season on the hatching percentage of Koekoek chickens.

6.2 General Conclusion

This study was aimed at determining the effect of restricted feeding and season on the productive and and reproductive characteristics of Koekoek chickens. The compensatory growth was evident during the laying phase as Koekoek chickens that were feed restricted during the rearing phase and later shifted to full feeding during the laying phase had improved body weight, body weight gain and feed conversion ratio. Unrestricted feeding during the rearing phase resulted in improved carcass characteristics excluding the relative percentage of the intestine, liver and gizzard. In chickens that were slaughtered at the age of 32 weeks full feeding during the laying phase resulted in improved carcass characteristics. Feed restriction reduced the dry matter, ash and fat content and improved the crude protein percentage of meat from Koekoek chickens. Slaughtering Koekoek chickens during the puberty stage in summer enhanced the dry matter and crude protein percentages of meat while ash, fat and crude protein percentages of those that were slaughtered at the age of 32 weeks were higher. The summer conditions enhanced the growth performance, slaughter weight, carcass dressing weight, breast muscle weight, skin weight, gizzard weight and chest width of Koekoek chickens. On average, the winter conditions hindered the laying percentage, egg weights and the number of days to 1^{st} oviposition, 20%, 50% and 80% egg production.

Full feeding during the rearing phase appears to be an appropriate feeding management starategy with regard to growth performance, carcass characteristics, laying performance and the development of the reproductive organs. In order to have improved results from Koekoek chickens but with low feeding inputs, it would be more suitable if feed restriction is followed full feeding during the summer. Still there is a problem of rearing chickens in winter and therefore this call for further investigations on the housing system that will make it possible for the Koekoek chickens to remain productive throughout the year.

If this study was conducted for a longer period, it is ancipated that the effect of restricted feeding would be more evident. Therefore, further research is required to determine the productive and reproductive performance of Koekoek chickens for at least 72 weeks. This study should be extended to include an economic analysis of the fourr feeding systems over a full production cycle of 52 weeks using appropriate housing for the particular seasonal requirements in Lesotho.