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.

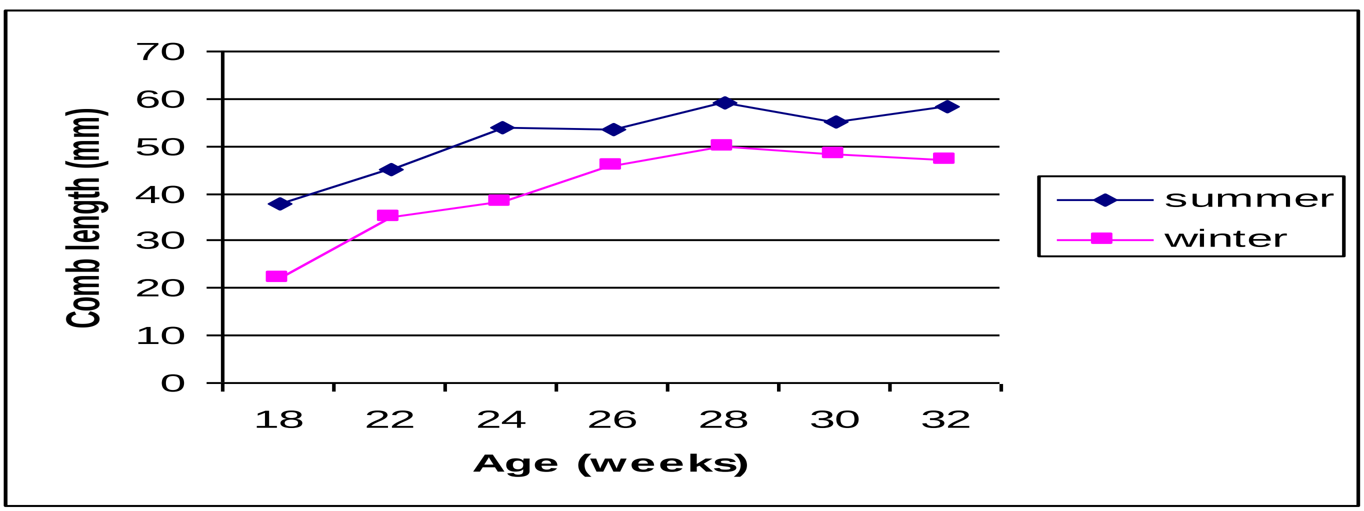

Figure 5.1: Comb lengths of Koekoek chickens reared under different seasons

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 24th and 26th 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 25^{th} to 32^{nd} week with the exception of the 26^{th} and 30^{th} 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 30^{th} 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.

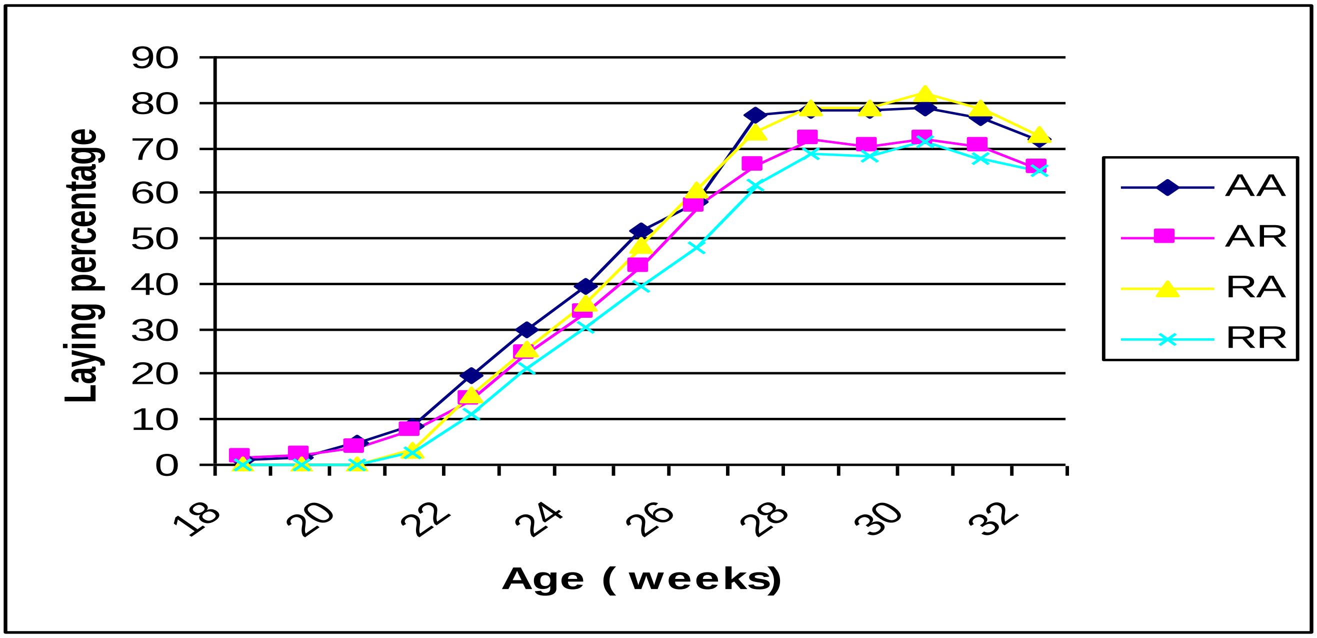

Figure 6.2: The laying percentage of Koekoek chickens subjected to different feeding levels

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.

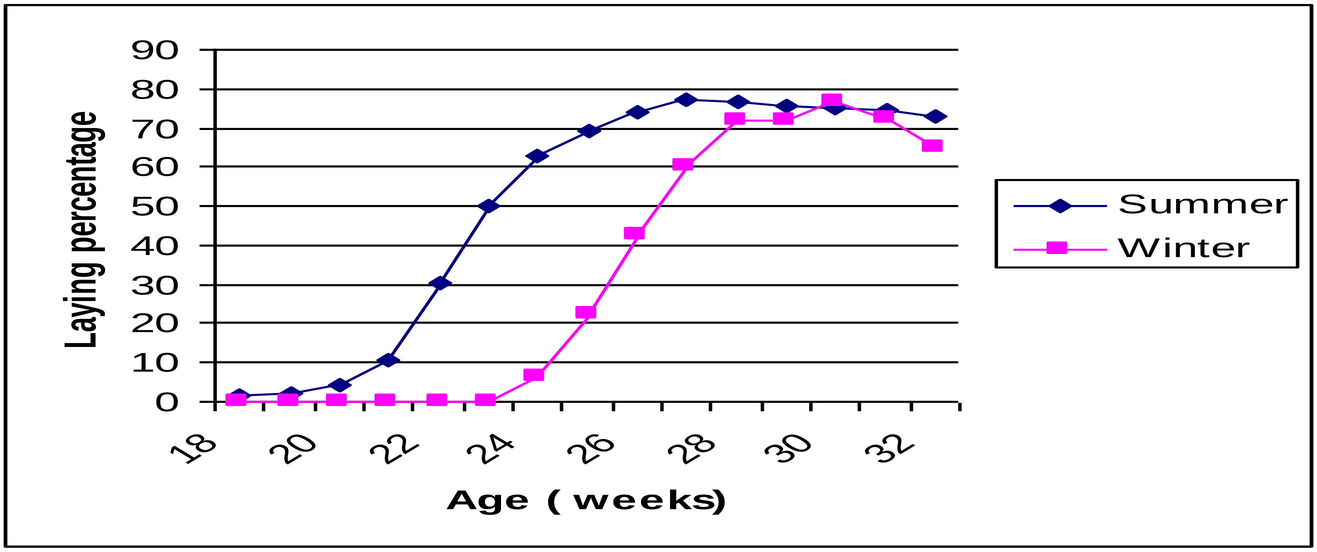

Figure 5.3: Effect of season on the laying percentage of Koekoek chickens

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°C in winter while the higher temperatures in summer cannot go beyond 28°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°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 1[st] 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).

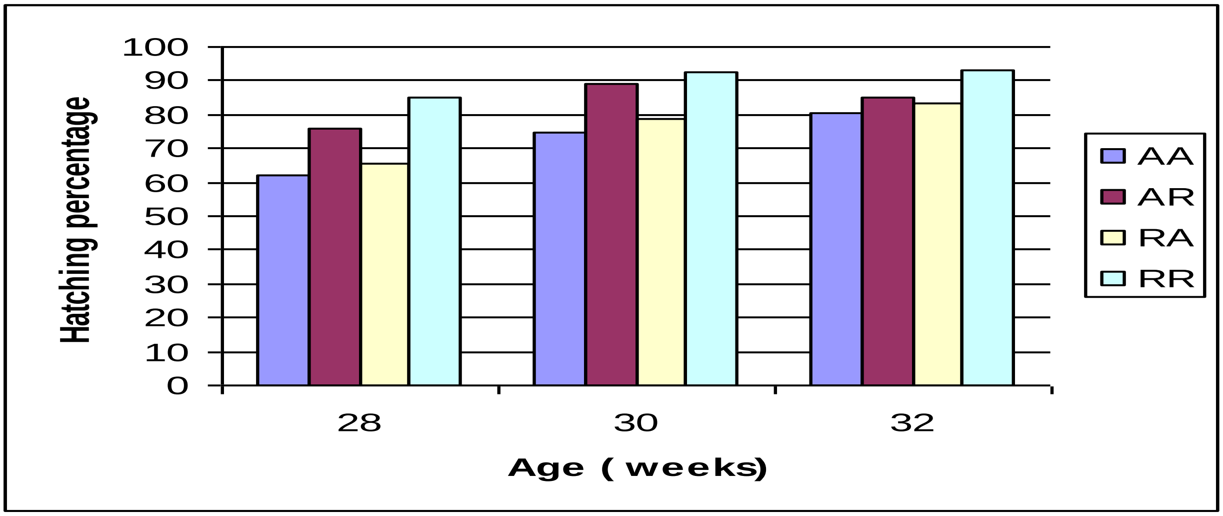

Figure 5.4: The effect of restricted feeding on egg hatching percentage of Koekoek chickens

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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