EFFECT OF PHOTOPERIOD ON SEXUAL DEVELOPMENT, GROWTH AND PRODUCTION OF QUAIL (*COTURNIX COTURNIX JAPONICA)*

by

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DECLARATION

I, ***PIETER HERODES DE JAGER*** *hereby declare that this research project submitted for the degree* ***Master of technology: Agriculture*** *is my own independent work that has not been submitted before to any institution by me or anyone else as part of my qualification.*

……………………… *………………*

Signature of student *Date*

ABSTRACT

The aim of the study was to determine the effect of photoperiod on production of quail in South Africa. Day old chicks were randomly divided into two groups. One group (n=74) received continuous light (LL) while the other group (n=77) received 13 h of light (LD) per day. Traits measured were sexual characteristics (age at sexual maturity and testis weight, egg production and egg weight) and growth (body weight) development in males and females respectively. Significant differences in growth existed between sexes; females were 171.44±17.15 and 182.91±17.75 g compared to the 151.77±13.20 and 155.00±16.86 g for males in both LL and LD groups respectively. Both males and females in the LL group initially outperformed the LD group in growth rate but, by day 72 the LD group had compensated and were 4.6% heavier than the LL group. A similar trend was observed for sexual maturity between the LL and LD groups. However, photoperiod did significantly influence initial egg production in favour of the LL group. The LL group had 80% of the females in production by day 44 compared to the 60% of the LD group. The initial egg weight of the LL group was 14 % higher than those of the LD group. Quail subjected to continuous light attained earlier sexual maturity and production with lower final weight compared to quail subjected to an intermediate photoperiod. The application of a longer photoperiod would therefore favour an egg production system.

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ABBREVIATIONS

%	Percentage
°C	Degree Celsius
avg	Average
BW	Body weight
cm	Centimeter
cm^2	Squared centimeter
EP	Egg production
EW	Egg weight
exp	Exponential
F	Female
FI	Feed Intake
FSH	Follicle stimulating hormone
GR	Growth rate
h	Hour
IU	International unit
kcal	Kay calories
kg	Kilogram
kj	kilo joule
LH	Luteinizing hormone
LD	Intermediate lighting schedule
LL	Continuous lighting schedule
M	Male

m^2	Squared meters
m^3	Cubic meters
max	Maximum
ME	Metabolizable energy
mg	Milligram
Min	Minimum
MJ	Mega joule
MW	Mature body weight
n	Number
p	Level of significance
r	Correlation
SD	Standard deviation
SM	Sexual mature
TW	Testis weight
ug	Microgram

PREFACE

The objective of this study was to investigate the effect of different photoperiods on the growth and reproduction of Japanese quail (*Coturnix coturnix japonica*). Photoperiod is considered an important management tool to manipulate reproductive behaviour and performance in poultry. Although extensive work on the effect of photoperiod on the performance of poultry exists, there is limited information on its influence on quail. Furthermore, the aim of this study was also to obtain a better understanding of factors influencing production of quail, since formation on commercial quail farming in South Africa is scarce.

This dissertation comprises six chapters. Chapter one focuses on an overview of the history and importance of quail throughout the world. Chapter two contains a literature review focusing on the most important factors that affect growth and reproduction in quail. Chapter three focuses on the materials and methods that were used during the study, while the results of the study are presented in chapter four. The interpretation of results is discussed in chapter five and finally, a general conclusion with recommendations is presented in chapter six.

CHAPTER 1

GENERAL INTRODUCTION

Japanese quail (*Coturnix coturnix japonica*) are a small, domesticated avian species of the order Galliformes and the family Phasianidae. Earliest records are from Japan dating from the 12^{th} century where it would appear that the species was domesticated as early as the 11^{th} century (Mills, Crawford, Domjan and Faure, 1997). It has assumed importance worldwide as a laboratory animal (Wilson, Abbott and Abplanalp, 1961), largely due to the many characteristics and behaviour patternsit has in common with the domestic chicken. Furthermore, it is increasingly being used as an experimental model for other poultry (Mills *et al.*, 1997). Although the amount of research involving *Coturnix coturnix japonica* has been considerable, the species has largely been used as a model or for comparative purposes, and little attention has been paid to the bird itself (Gildersleeve, Sugg, Parkhurst, and McRee, 1987). However, to a lesser degree to that of poultry (chicken), quail have also been commercially exploited for meat and egg production. This can be ascribed to its distinct characteristics which include rapid growth, early sexual maturity, short generation interval, high rate of lay, and less feed and space requirements per bird than those for chicken (*Gallus gallus domesticus*).

Quail were originally kept for song and it is believed that light stimulation was practiced to induce the birds into early sexual maturity and hence to make them sing throughout the winter months (Mills *et al.*, 1997). Various aspects of quail behaviour are influenced by photoperiod. One of the most important physiological effects of long day length is to stimulate gonadal growth and increase plasma sex steroids by stimulating gonadotropin production and release. Therefore, long photoperiods stimulate sexual maturation whereas short photoperiods inhibit or delay sexual maturation (Boon, Visser and Daan, 2000). Growth in juvenile animals is also affected by day length through the effect of day length on daily energy intake and energy expenditure (Boon, Watt, Smith and Visser, 2001).

These reports support the findings and practices concerning the application of photoperiod regimes in commercial egg production summarized by Morris (1967). Some of these practices applied in parallel for quail have not exclusively been demonstrated to operate similarly for quail. Furthermore, Morris (1967) distinguished clearly between two aspects, growth and reproductive maturity. The gradual change in day length at different latitudes influences the age of reproductive maturity and even the duration of reproductive function. Skeleton and muscle development are not affected by the change in day length but are profoundly influenced by the absolute amount of light needed to consume food. Likewise intensity of light, which controls activity and thus the expenditure of energy, plays a role in the growth process. Thus with the aid of artificial lighting, conditions of either constant or changing photoperiods could be created, to investigate the effect on performance.

In South Africa, the production of quail meat and eggs is a relatively new concept, as only a few commercial quail farms contribute to this niche market, created by foreign tourists. Although investing in this niche market may contribute to the South African economy, small scale quail farming in rural communities may also be beneficial as a source of high quality protein.

The aim of this study was to investigate the effect of a continuous lighting schedule versus a near natural (intermediate) lighting schedule on the growth and reproduction of Japanese quail (*Coturnix coturnix japonica*).

CHAPTER 2

FACTORS AFFECTING GROWTH AND PRODUCTION OF JAPANESE QUAIL.

2.1 PHOTOPERIOD

Photoperiod is known to affect rates of weight gain in juvenile animals (Boon *et al.*, 2001; Lewis, Morris and Perry, 1998). This effect is primarily produced by the effect of photoperiod on energy intake and energy expenditure. The interaction between these two parameters as a function of photoperiod determines overall body weight gain (Boon *et al.* 2000). By modulating the duration of the light, and consequently the dark period, opportunities for birds to either increase energy intake or reduce energy expenditure will vary, with consequences in overall body weight gain (Boon *et. al.,* 2000; Classen, Riddell and Robison, 1991). Boon *et al.* (2000) clearly demonstrated that longer photoperiods are related to both higher energy intake and energy expenditure levels, resulting in increased weight gains. Photoperiod can also influence weight gain via an effect on the balance between food intake and digestion (Charles, Robinson, Hardin, Yu, Feddes and Classen, 1992). Food intake occurs throughout the light period, whereas during the dark period, when food intake and activity are suppressed, digestion can continue.

Boon *et al.* (2000) mentioned that the effect of a reduction in photoperiod on body weight was basically during the first days, whereafter the rate of weight gain was the same as for longer photoperiods. Crop filling is a generally adopted feeding strategy by birds that enables them to tide over prolonged fasting periods (Boon *et al.*, 2000; Jackson and Duke, 1995). It can be concluded that changes in feeding behaviour and energy expenditure shown under shorter photoperiods are part of a strategy that allows chicks to gain weight continuously.

In contrast, Chaturvedi, Dubey and Phillips (1992) found that the body weight of quail raised under long- and intermediate photoperiods increased up to 5th week, and remained constant thereafter, but quail maintained under short day length showed spontaneous body weight increase and were much heavier.

Classen *et al.* (1991) showed that an increasing lighting schedule for broiler chickens restricts early growth, but results in compensatory growth during later growth stages, so that the final body weight is equal to that of a near-continuous lighting schedule. The increasing lighting schedule also showed a reduction in skeletal diseases. These results are similar to those found by Charles *et al.* (1992) with their experiment on feed restriction, which once again shows the clear relationship between photoperiod and food availability as stated by Boon *et al.* (2000).

Lewis *et al.* (1998) developed a hinged model for the effect of constant photoperiods on the rate of sexual maturation in pullets, which predicts that, under *ad libitum* feeding conditions, chicken pullets reared on constant 10 h photoperiods will be earlier maturing than birds of the same genotype reared on either shorter or longer constant photoperiods. This is in contrast with research results on photoperiod for quail, as quail reach sexual maturity faster on long photoperiods of at least 12 h. Male broiler chickens that are raised under low light intensity reached a heavier body weight than broilers raised on high light intensity, but light intensity has no effect on sexual development (Charles *et al.*, 1992).

In quail, sexual development is known to depend on the length of the daily light period: long photoperiods stimulate sexual maturation, while short photoperiods inhibit or delay sexual maturation (Boon *et al.*, 2000; Mills *et al.*, 1997; Chaturvedi, Bhatt and Phillips, 1993). Although photoperiod has a significant influence on sexual maturation, food restriction seems to delay sexual maturation, rather than inhibit the process (Boon *et al.* 2000; Lewis *et. al.*, 1998). Sexual maturity also influences body weight gain in female quail chicks. Females that do not reach sexual maturity remain as small as males (Boon *et al.*, 2000).

Sexual maturity can be delayed by the use of a step-down light regimen (declining photoperiod) during the growing period of pullets (Keshavarz, 1998). Therefore, when pullets were exposed to natural declining daylight hours during the growing period, birds had a heavier body weight and sexual maturity was delayed, but egg production rate was significantly greater and heavier eggs were produced than others reared under a constant short photoperiod. Lewis, Perry, and Morris (1997) suggest that body weight at first egg rather than age at first egg is the factor controlling egg weight.

Results from Eitan and Soller (1996) suggest that genetic factors affecting photoperiod drive are similarly expressed in males and females. Therefore, selection for increased photoperiodic drive in broiler line males may possibly increase photoperiodic drive in broiler line females and in this way improve female reproduction performance.

The pineal hormone melatonin controls reproduction of photoperiodic mammals and is an integral part of the circadian rhythm in birds (Binkley, 1988). Recent findings also indicate an involvement of this hormone in more basic physiological processes, including growth, development, and aging (Zeman, Buyse, Lamosova, Herichova and Decuypere, 1999). Pineal melatonin production is restricted to night, or the dark phase of the lighting cycle, and the duration of elevated melatonin levels is proportional to the night length (Underwood and Siopes, 1985). Endocrinologically, testicular function in birds appears to be controlled in much the same manner as in mammals with FSH and possibly testosterone regulating spermatogenesis, while LH is the primary steroidgenic hormone (Follett and Maung, 1978). Furthermore, once the photoperiod exceeds about 11.5h/day, testicular growth in quail begins and the rate of growth is proportional to daylight, until maximum rates occur when the duration of the light period reaches 14 h/day (Follett *et al.*, 1978). Mills *et al.* (1997) stated that hypothalamic weight, anterior pituitary weight and gonadotropin content of the hypothalamus, increase with long photoperiods.

From a study done by Moore and Siopes (2000), it was clear that quail placed in daily light-dark cycles (LD), possessing a diurnal rhythm of melatonin, had significantly elevated immune responses when compared to those birds in constant light (LL). Furthermore, melatonin supplemented to birds exposed to LL was immune - enhancing. They also suggest that melatonin may be a mediator of the differences seen between LD and LL lighting conditions and may have important immune modulating properties. Similar results were found on mice (Charles *et al.*, 1992).

When the environmental temperature was lowered under a short day photoperiod, Coturnix testis showed regression within a week, but not under continuous light (Oishi and Konishi, 1978; Kato and Konishi, 1967). Oishi *et al.* (1978) also found that when ambient temperature is lowered under short day photoperiod, the size of the cloacal gland (*glandula proctodealis*), a secondary sex character in Japanese quail, was significantly reduced, whereas mature cloacal glands during long photoperiods, remained unchanged by transferring birds to low temperature. Similar effects of temperature and photoperiod were found for LH release (Wada, Hatanaka, Tsuyoshi, and Sonoda, 1990). These results suggest that ambient temperature is involved in the mechanism of controlling an annual reproductive cycle, especially at the termination of the reproductive activity in Japanese quail (Wada et. al., 1990), but the effect of the length of photoperiod on gonadal activity is predominant over ambient temperature (Mills *et al.*, 1997). It is also known that auditory stimulation given during a nonstimulatory photoperiod causes significant gonadal development in male and female quail (Mills *et al.*, 1997).

The effect of photoperiod and melatonin treatment on cold resistance and thermo genesis of quails was studied by Saarela and Heldmaier, (1987). The results show that short day, cold and melatonin treatment improved cold resistance and thermal insulation of quails when compared with quail acclimatized to long day conditions.

2.2 NUTRITION

It is well known that feed is the most expensive component in the production of live poultry (May, Lott, Simmons, 1998.) Growing quail are frequently exposed to variations in food supply due to environmental factors such as bad weather conditions in nature or due to poor management in a commercial enterprise. Because of the reduction in food intake, normal growth is suppressed. Such a reduction in growth rate may also affect the chick's developmental pattern of metabolism and temperature regulation as well as its rate of sexual maturation.

Food restriction and subsequent growth retardation have no effect on mortality, but affect the chicks' attainment of body mass at all stages as well as the achievement of female sexual maturity (Van der Ziel and Visser, 2001; Morse and Vohra, 1970). When chicks are fed *ad lib*, homeothermy is achieved at a younger stage (7 d of age) as when food is restricted (Van der Ziel *et al.*, 2001).

However, feed restriction does not always have a negative influence on productivity. Charles *et al.* (1992) showed a reduction in skeletal disease resulting from either qualitative (diet dilution) or quantitative (limited daily and skip-a-day) feed restriction in broilers. Although early growth rate was reduced, skeletal development continues, and therefore the bird is physiologically more capable of sustaining the stress of rapid growth.

Feeding and drinking behaviour are closely related to the photoperiod and occur most frequently at the beginning and the end of the light phase (Mills *et al.*, 1997). It is known that apart from photoperiod, control of food intake appears to depend more on the emptying and filling of the gastrointestinal tract than on circulating levels of nutrients (Mills *et al.*, 1997; Savory, 1981).

2.2.1 Water Intake

Farrell, Atmannihardja and Pym (1982) found that the water intake for quail chicks was 4.2, 3.1 and 2.7 g per g body weight during 12 to 15, 19 to 22, and 26 to 29 days of age respectively. The water/feed ratios for the respective periods were 2.3, 2.0, and 1.7.

2.2.2 Energy needs of Quail

Food intake depends upon the amount of metabolizable energy (ME) content of the diet, age of the birds, their reproductive status and the ambient temperatures (Shim and Vohra, 1984). Energy requirements of Japanese quail are 12.1 MJ ME/kg from zero to two weeks, 12.5 MJ ME/kg from two to four weeks and 12.9 MJ ME/kg feed from four to six weeks (Shanaway, 1994). In the studies of Farrell et al. (1982), the daily ME intake of growing quail was 239 kj (57 kcal), 196 kj (46.8 kcal), and 218 kj (52 kcal) per kg body weight at 12, 19 and 26 days of age. A regression equation for predicting the ME requirements of growing Japanese quail from hatching to 42 days of age, was developed by Blem (1978). Energy efficiency (= 100 ME/gross energy intake) increased from 44.8% at about 3 days to 64% by 2 weeks of age. Begin (1968) observed no significant difference in the determined metabolizable value of the diet using either quail or chicken. Low or high-energy diets were utilized with equal efficiency on the basis of feed/gain ratio, but quail could utilize low energy diets more efficiently than chicken.

2.2.3 Protein and Amino acid Requirement

In a review of the nutrition of Japanese quail, Shim *et al*., (1984) summarized the data of several researchers that have reported on the dietary metabolizable energy and protein requirements of Japanese quail. The data for growing quail varies between 2800 and 3200 kcal ME, while crude protein content of diets varies between 24 and 32.2 % crude protein. The metabolizable energy requirements for laying quail varies between 2600 and 3004 kcal ME, while crude protein content of diets varies between 16 and 24%. According to Lee, Shim and Tan (1977), a dietary crude protein level of 24 to 25% is needed in starter diets for quail. An initial level of 28-32% crude protein gave better growth, but the differential between 28%-32% and 24-25% groups disappeared by the 3rd week of age. A level of 16% crude protein for breeder hens caused a depression in egg production, egg weight and hatchability as compared to a level of 20% (Begin and Insko, 1972).

2.2.4 Mineral Requirements

Calcium and Phosphorus: Nelson, Lauber and Mirosh (1964) observed an egg production of 90% with good hatchability from quail fed a diet containing 2.5% to 3% calcium and 0.8% total phosphorus. Consuegra and Anderson (1967) found that when 0.3% available phosphorus was present, the dietary calcium requirement was not greater than 0.8% at 2 weeks and 0.48% at 4 weeks of age. If the ratio between calcium and phosphorus was wider than this, growth of quail was depressed at 2 weeks of age, and rickets developed along with elevated plasma alkaline phosphatase activity. Ong and Shim (1972) observed that growing as well as laying quail were in positive calcium balance as long as the diets contained 0.8%, 1.5%, 2.6% or 3.5% calcium. They also found that a level of 3.5% dietary calcium reduced hatchability. A dietary deprivation of supplementary calcium or vitamin D_3 reduced feed intake significantly without significantly influencing body weights of male and female quail. However egg production was reduced from 74% to 10% and 20% in the calcium and vitamin D_3 deprived females respectively (Vohra *et al.*, 1979). These deficiencies caused a reduction in egg weight, shell thickness, tibia ash of female quail, but no change in ovary and oviduct weights. In males, tibia ash and testes weights were not affected.

Sodium: Growing Japanese quail, fed a purified type of diet containing 0.042 - 0.051 % sodium, had poor growth, high mortality rate, adrenal enlargement, elevated haematocrit, and depressed plasma sodium suggestive of an aberration in fluid and electrolyte haemostasis. However, a dietary sodium level of 0.1 % overcame these difficulties (Lumijarvi and Vohra, 1976).

Magnesium: Harland, Fox and Fry (1976) found the magnesium requirement for quail to be 300 mg/kg diet. A deficiency of magnesium caused poor growth, excitability, gasping, convulsions and death.

Iron and copper: Growing Japanese quail require 90-120 mg/kg iron and 5 mg/kg diet copper as based on EDTA extracted isolated soybean protein trials (Shim *et al.*, 1984). Iron and copper deficit diets, caused a rapid and severe reduction in growth, packed cell volume and haemoglobin concentration, while liveability was only slightly affected (Shim *et al.*, 1984).

Zinc: Zinc deficiency (10 mg/kg diet) in quail chicks was characterized by slow growth, abnormal feathering, laboured respiration and an uncoordinated gait, low tibia ash, and a low concentration of zinc in liver and tibias (Spivey-Fox and Harrison. 1964). However, the deficiency was overcome when the diet contained 25 mg zinc/kg diet. Birds fed an initial level of 75 mg zinc/kg grew significantly better than those fed initially 25 mg zinc/kg. Bone might store zinc and it might be mobilized during zinc deprivation (Shim *et al.*, 1984).

Fluoride: Levels up to 200 mg fluoride per litre drinking water in the form of sodium fluoride were well-tolerated, but a level of 500 mg/litre was lethal. It was also found that high dietary fluorine (0.075%) caused an acceleration of bone mineralization, but a decrease in bone strength (Shim *et al*., 1984).

Selenium: Impaired reproduction was observed in Japanese quail fed a diet low in selenium and vitamin E from hatching to maturity. Oviposition rate and fertility were not affected, but the hatchability of fertile eggs, viability of male and female adults and newly hatched chicks were reduced. Dietary supplementation with either 1 mg selenium or 30 IU Vitamin E/kg diet prevented the impaired reproduction (Shim *et al*., 1984).

Fat-soluble Vitamins:

Vitamin A: There were no differences in growth of male and female quail over a range of 550-4400 IU vitamin A per kg diet. A level of 2500 IU vitamin A/kg diet was required for egg production and fertility of females (Shim *et al.,* 1984).

Vitamin E: A deficiency of Vitamin E did not affect the body weight, feed consumption, or egg production of Japanese quail. However, it caused sterility in males, which was overcome by restoring 40 IU Vitamin E/kg to the diet for about 2 weeks. The fertility and hatchability of quail eggs were severely depressed after the birds were fed a diet deficient in Vitamin E for 20 weeks. The requirement for vitamin E is more than 2 IU/kg diet (Shim *et al.,* 1984).

Vitamin D_3: Mature male quail that were fed a Vitamin D_3 deficient diet remained in good physical condition for 1 year. But a mortality of about 90% was observed in females and 16% in males even when both were in negative calcium balance of about the same order (Shim *et al.,* 1984). In another experiment, purified diets were supplemented with 0 to 16 ug Vitamin D_3/kg diet and found the following requirements for overcoming different adverse effects of the vitamin deficiency: mortality, 4 ug; reduction in bone ash, 12 ug; elevation of plasma alkaline phosphatase, 8 ug; reduction in plasma calcium 5 ug. Except for bone deformity, no other gross defects were observed in the Vitamin D_3-free groups (Shim *et al.*, 1984). Dietary deprivation of supplementary Vitamin D_3 did not affect body weight of male and female Japanese quail despite a reduction in feed intake. The production of eggs was reduced from 74% to 20%, but the effect was less severe than that of a calcium deficiency (Vohra *et al.*, 1979).

Water-soluble Vitamins:

Thiamin: Classical symptoms of polyneuritis in newly hatched quail chicks were reported from a flock fed turkey breeder diet that contained 3.2 mg thiamin/kg (Shim *et al.*, 1984).

Niacin: Park and Marquardt (1982) fed a niacin-free diet to 4-week old quail and found a subsequent depression in growth, but no other classical deficiency symptoms. However, newly-hatched quail chicks died within 9 days of this deficient diet. The age of the birds determines the severity of symptoms of niacin deficiency. A marked depression in growth, closure of eyes, reduced activity and a marked atrophy of the pectoral muscle were observed in quail on niacin deficient diets.

Pyridoxine: It was found that the mature body weight of quail chicks fed a purified diet containing 1.0 mg pyridoxine hydrochloride/kg diet was much lower than those fed 1.5 mg to 3.5 mg (Shim *et al*., 1984).

Pantothenic Acid: The requirement of calcium pantothenate is said to be 40 mg/kg diet for quail up to 5 weeks of age (Shim *et al*., 1884). A supplementary level of 7.5 mg calcium pantothenate/kg diet was needed in purified diets for prevention of mortality and for normal growth of quail chicks, while 10-30 mg was needed for normal feathering (Cutler and Vohra, 1977).

Breeding quail needed 15 mg supplementary calcium pantothenate per kg diet for optimal fertility and hatchability. Eggs from pantothenic acid deficient hens were characterized by embryonic mortality late in incubation period, haemmorhagic embryos, oedema and embryos with crooked legs (Cutler *et al.*, 1977).

Folacin: Poor feathering, high mortality, leg weakness and cervical paralysis were caused by folacin deficiency in growing quail. These symptoms were similar to those observed in turkey. Quail chicks also suffered from a mild anemia and a curled toe syndrome. The folacin requirement of growing quail was 0.3-0.36 mg/kg casein-gelatine based diet (Shim *et al.,* 1984).

Choline: Growing Japanese quail required higher levels of dietary choline than chickens to support maximum growth, prevent perosis, maintain maximum egg weight, egg production and hatchability (Shim *et al.,* 1984). They suggest the choline requirement for layer quail to be 3100 mg/kg diet.

Riboflavin: A minimum requirement of 8 mg riboflavin/kg diet in absence of Vitamin B_{12} and Vitamin C is suggested, but it decreased to 4 mg per kg in presence of these Vitamins. The characteristic symptoms of riboflavin deficiency were slow growth, high mortality, impaired gait and posture. Feathering was absent other than down at the end of two weeks of riboflavin deficiency (Shim *et al.,* 1984).

The nutrient requirements of Japanese quail suggested by various investigators are summarized in Table 1.1 (Shim *et al.,* 1984).

TABLE 1.1 Suggested nutrients in quail diets (per kg diet).

NUTRIENT	QUAIL	QUAIL	NUTRIENT	QUAIL	QUAIL
	Growing	Laying		Growing	Laying
ME, kcal/k	2800	2800	Vitamin A, IU	4000	4000
Protein, %	24	20	Vitamin D, ICU	600	600
Lysine, %	1.2	0.9	Vitamin E, IU	40	40
Cystine,	0.4	0.35	Vitamin K, mg	5	5
Methionine,	0.5	0.45	Biotin, mg	0.12	0.4
Met. + Cys.,	0.9	0.8	Choline, mg	3500	2000
Arginine, %	1.4	1.25	Folacin, mg	0.4	0.5
Histidine, %	0.4	0.4	Niacin, mg	40	40
Isoleucine, %	1.1	1.0	Pantothenic acid, mg	40	40
Leucine, %	1.9	1.7	Pyridoxine, mg	2	2
Phenylalanine,	1.1	1.1	Riboflavin, mg	2	4
Tvrosine, %	1.0	0.9	Thiamin, mg	2	2
Phi. + Try. %	2.1	2.0	Calcium, %	0.8	2.5
Threonine, %	1.2	1.1	Total phosphorus, %	0.8	0.8
Trytophan, %	0.25	0.25	Avail. P, %	0.3	0.3
Valine, % Glycine, %	1.1 1.0	1.0 1.0	Sodium, % Potassium, %	0.12 0.4	0.12 0.4
Serine Gly. + Ser. %	0.7 1.7	0.7 1.7	Copper, mg Manganese, mg	5 80	5 80
			Zinc, mg	75	75
			Selenium, mg	0.1	1.0
			Iron	120	120

2.3 TEMPERATURE

High temperatures have a negative effect on food:gain ratio and decreases performance in poultry (Cooper and Washburn, 1998; May *et al.*, 1998; Meltzer, 1985). MacLeod and Dabutha (1997) found that increasing ambient temperature had no significant effect on food intake by weight, but energy intake is negatively correlated with increasing ambient temperature, while protein intake per unit of energy intake increase, allowing the birds to gain weight at about the same rate at all temperatures. Therefore, Japanese quail will select a dietary mixture which maintains similar growth rates over a wide range of ambient temperature, by sustaining protein intake but altering energy intake in line with thermoregulatory energy demands (Boon *et al.* 2001). Results from Chahil, Johnson and Humes (1975) showed that selection at high temperatures for growth is quite effective to enable quail to perform better both under further stress as well as in the absence of stress.

Chicks respond vigorously to changes in ambient temperature. In cold environments, chicks give a particular call known as the "sifflement juvenile de froid" (juvenile whistling in response to cold) and will huddle together if housed in groups, or against objects or in corners if housed in isolation (Mills *et al.*, 1997). In adult birds, the primary mechanisms of heat loss are panting (guttural fluttering), sleeking of the feathers, and spreading of the wings so as to increase radiation from those parts of the body not covered with feathers (Kovack, 1974). When ambient temperature falls, birds initially respond by ruffling of the feathers and shivering, but if cold stress persists, metabolic and breathing rates increase, non-shivering thermo genesis supplements shivering thermo genesis, and an increase in food consumption takes place (Mills *et al.*, 1997).

The optimum temperature for the first 3 days of brooding is 35°C and gradually decreases to 21°C at 3 weeks of age when the chicks are fully feathered

(Shanaway, 1994). The optimal ambient temperature range for adult quail lies between 21 and 27°C, and the minimum ventilation norms vary from 0.4 to 0.5 m^3/kg live weight per hour (Shanaway, 1994).

2.4 SEX

In an experiment done by Du Preez and Sales (1997) on the growth rate of different sexes of the European quail (*Coturnix coturnix*), the mature body weight for males were 30 percent lower than for females. The females reached the point of maximum growth 4.7 days later than males. Similar results were found by Boon *et al.* (2000) and Mills *et al.* (1997). Bobek, Niezgoda and Pierzcha (1982) indicate that female quail have a greater resistance to cold in comparison with male quails. Greater resistance to cold was accompanied by an increase in thyroid activity and earlier decrease in blood glucose level, which may suggest that mobilization of these compounds for thermo genesis processes is faster in females than in males. Boon *et al.* (2000) made a statement that the effect of photoperiod on body weight gain differed per sex: females showed a stronger retardation in body weight gain with decreasing photoperiod than males. Weight gain rate attained its highest value at a later stage in quail raised on short day lengths versus long day lengths. Wilson *et al.* (1961) made an interesting note that the larger body weight of the female is due primarily to the heavier gonads, liver, and intestines, and that the male have relatively more muscle tissue than the female.

2.5 SPACE REQUIREMENTS

Inadequate floor space has a significant reduction in body weight, whereas a larger floor space than the minimum required, has no effect on body weight (Keshavarz, 1998; Carey, 1987). Otis and Ringer (1973) found that when Japanese quail are exposed to reduced living areas caused by an accumulation of their own eggs, birds began to destroy their eggs at the same rate they laid them, to maintain about 0.026 m^2 of clear floor area. They suggest that quail housed under reduced living space will first utilize behavioural processes to take control of living space while physiological mechanisms are only activated under more severely stressed conditions. Furthermore, Ernst and Coleman (1966) found lowered egg production, fertility and hatchability when population densities allowed less than 0.023 m^2 per bird. Wilson *et al.* (1961) found delayed maturity in quail allowed 0.0132 m^2 per bird. Adult quail will live and produce successfully if they are allowed 250 cm^2 of floor space per bird (table 2.1).

TABLE 2.1 Suggested space requirements for Japanese quail (Vet helpline India, 2000).

Age (weeks)	Space requirements (cm^2/bird)		Feeding space (cm^2/bird)	Watering space (cm^2/bird)
	Deep litter system*	Cage system		
0-4	75	75	2.0	1.0
4-6	200	150	2.5	1.5
6 onwards	250	175	2.5-3.0	1.5

*A system of rearing birds on the floor.

Adult quail need 1.5 cm of feeder space per bird and clean, fresh water should be provided at all times with a minimum of 1.5 cm of trough space per quail. Nipple drinkers and cups are suitable for adult quail. One nipple or cup should be provided for every 5 birds (Shanaway, 1994).

2.6 CONCLUSION

The objective of this chapter was to review the most important factors that influence growth and reproduction of Japanese quail in a commercial farming operation. From the literature cited, it is evident that these factors make a major contribution to the physiological behaviour and performance of quail. Although it has not been discussed in this chapter, management, which includes long term selection for genetic improvement, manipulating the age of the breeding flock, and disease prevention, are the most important secondary factors contributing to the productivity of a quail production unit.

CHAPTER 3

MATERIALS AND METHODS

3.1 ANIMALS AND HOUSING

The research was done on the George Campus of the Port Elizabeth Technikon. Japanese quail (*Coturnix coturnix japonica*), obtained from the Animal Improvement Institute at Irene were used to conduct the research project. Chicks were reared in an environmental chamber, where the temperature, photoperiod, ventilation and floor area could be controlled. On the day of hatching, quail chicks were separated in two groups, each in its own controlled environment. Both groups received continuous light for the first 3 days. One group (108 chicks) received continuous light (LL) up to 5 weeks of age, whereas the other group (111 birds) received an intermediate photoperiod (LD) of 13 hours of daylight in a 24 hour cycle up to 5 weeks of age. Brooders were maintained at 36°C for the first week and gradually reduced to 21°C when chicks were fully feathered at 3 weeks of age.

Food and water were constantly available. For the first 3 weeks, chicks were fed a commercial broiler starter diet that was supplemented with fish meal to increase the crude protein content of the diet to 26% (table 3.1). From 3-5 weeks of age, chicks were fed a commercial broiler starter diet (table 3.2). Up to 5 weeks of age, chicks were reared on a deep litter system, where the stocking density was 70 chicks/m^2 for the first 3 weeks and 45 chicks/m^2 thereafter.

At the age of 5 weeks, both groups were transferred to battery breeding cages where they were individually accommodated in wire mesh cages that provided 0.1 m^2 of floor space per bird. The quail were given free access to food and water. Following 5 weeks onwards they were given a complete layer mash (table 3.3). Following then both groups had the same environmental conditions and received 15 hours of light and 9 hours of darkness per 24 h cycle.

TABLE 3.1 Composition of broiler starter diet fed for first three weeks.

Composition		
Protein	250g/kg	Min.
Fibre	50g/kg	Max.
Moisture	120g/kg	Max.
Fat	25g/kg	Min.
Calcium (Ca)	12g/kg	Max.
Calcium (Ca)	8g/kg	Min.
Phosphorus (P)	6g/kg	Min.
Total Lysine	11g/kg	Min.

TABLE 3.2 Composition of commercial broiler starter mash fed from the 3rd- 5th week.

Composition		
Protein	220g/kg	Min.
Fibre	50g/kg	Max.
Moisture	120g/kg	Max.
Fat	25g/kg	Min.
Calcium (Ca)	12g/kg	Max.
Calcium (Ca)	8g/kg	Min.
Phosphorus (P)	6g/kg	Min.
Total Lysine	11g/kg	Min.

TABLE 3.3 Composition of complete layer mash.

Composition		
Protein	150g/kg	Min.
Fibre	70g/kg	Max.
Moisture	120g/kg	Max.
Fat	25g/kg	Min.
Calcium (Ca)	40g/kg	Max.
Calcium (Ca)	30g/kg	Min.
Phosphorus (P)	6g/kg	Min.
Total Lysine	7g/kg	Min.

3.2 EXPERIMENTAL SETUP

Growth: Birds were weighed to an accuracy of 0.2 g as a group on day 0, 2, 3, 4 and 5. From day 7, wing bands were used for identification of individual birds as birds were individually weighed at 7, 9, 12, 16, 22, 30, 40, 54 and 72 days.

Feed intake (FI): Feeders were refilled every morning so that feed was available *ad lib* to the birds during the entire trial. Feed intake was measured daily by weighing the feeder with the previous day's leftover feed as well as the refilled weight every time the feeders were filled up. To calculate the daily feed intake, the difference in weight of the feeder with the leftover feed and the previous refilled weight was taken as the previous day's feed intake of the group

Sexual maturity (SM): To assess the effect of photoperiod on sexual maturity, age at sexual maturity was taken as the day at which females laid their first egg.

Therefore, from day 35, when the first eggs were laid, the number of females producing their first egg was calculated daily. Sexual maturity in males was identified at each weighing date. When males were weighed, the cloacal gland on the posterior side of the cloaca, a secondary sex character in Japanese quail, was examined. When white foam, the secretion from the gland, was detectable, the bird was classified as sexually mature. It was decided that the examination of the posterior cloacal gland alone is not an accurate measurement for sexual maturity. Therefore testis weight (TW) has been monitored over the period of sexual maturation (day 30 to day 68). Four males of each group which represent the body weight of their group were slaughtered to remove and weigh (to 0.0001 g) their testis. Their body weight was also taken to determine the correlation between body weight and testis weight. This procedure was done on day 30, 38, 46, 55 and 68.

Egg production (EP): Individual egg production as well as eggs produced per group was calculated every morning. Percentage egg production per day was taken as the amount of females that produced eggs out of the total amount of females in the group for the specific day.

Egg weight (EW): Eggs were individually weighed to an accuracy of 0.2 g on a daily basis. In quail, 75 % of eggs are laid just before lights off and 25 % just after lights on. Therefore, eggs were weighed every morning just after lights on to minimize the lost of moisture from the eggs.

3.3 DATA ANALYSIS

Body weight: Data was statistically analyzed using SAS V8.1 (SAS, 2000). In order to determine body weight, regression analyses per treatment*sex group was plotted in order to demonstrate the distribution around the axis. The following model was used:

$$Y=7.5+A*(1-\exp(-B*days^2))$$

Y = body weight

7.5 = constant (hatching weight)

A = asymptotic body weight

B = rate of weight gain

The value of the Y-axis where x=0 was fixed at 7.5 (average hatching weight for all groups), as values of more than 10 were estimated by the model used. Therefore, the actual asymptote for this model is A+7.5. The values of A and B were analyzed using a one way analysis of variance (ANOVA). Each quail measured was regarded as an experimental unit and therefore each bird was considered a repeat of a specific treatment*sex combination. There was no significant interaction reported for the treatment*sex interaction when analyzed in the ANOVA, however, statistically significant main effects were reported for treatment and sex in both A and B. Levene's test for homogeneity of variance was done and indicated that variation of the four groups (treatment*sex – LL M, LL F, LD M and LD F) did not differ. Data had a normal distribution when tested for normality using the Univariate procedure using the Shapiro-Wilk test.

Feed intake: For feed intake the same procedure was followed as for that of body weight. But for feed intake, the following equation was used:

Y=A*(1-exp(-B*x))

Y = Feed intake (g)

A = Asymptotic weight of feed

B = Rate of increase in feed intake

In this case a constant was not used, because it is assumed that the feed intake at day 0 (hatching) equals zero.

Sexual maturity: For age at sexual maturity, a standard one way analyses of variance (ANOVA) was attempted. However, due to not having a normal distribution which could be corrected by transformation, a frequency table was drawn up in order to adequately describe the percentage of birds that became sexual matured at a given time. A chi-square test was performed to test the relationship between age at sexual maturity and age for treatment group. This procedure was done for both male and female groups.

In order to determine testis weight, the following function was used:

$$Y = k+A*(1-exp(-B*x^2))$$

Y = Testis weight

k = constant

A = asymptotic testis weight

B = rate of weight gain

The Pearson's Rho test was used to determine the correlation coefficients between the dependent variables in order to determine relationships between variables.

Egg production: For egg production, the following function was used:

$$Y = k+A*(1-exp(-B*x))$$

Y = % Egg production

k = constant

A = Asymptotic egg production

B = rate of increase in egg production

The same as with the function used for egg weight x=day=days-35 so that k is the value where x=0.

Egg weight: Egg weight was determined by means of regression using the average egg weight measured for each day. The following function was used:

$$Y = k+A*(1-exp(-B*x))$$

Y = Egg weight

k = constant

A = Asymptotic egg weight

B = rate of weight gain

A constant was used where x=day=(days-36) so that k is the value where x=0, in other words days=36.

Finally, the data was reanalyzed using the Gompertz equation as described by Du Preez *et al.* (1997):

$$Y_t=A*exp(-exp(-k*(days-t_i)))$$

Y_t = weight at day t

A = the weight at maturity

k = growth rate constant

t_i = age at which the growth rate reaches its maximum value

CHAPTER 4

RESULTS

4.1 BODY WEIGHT

TABLE 4.1 The average (avg) mature body weight in grams (MW) and standard deviation (SD) for the intermediate light group (LD), continuous light group (LL), gender groups (male (M); female (F)) and groups x gender interaction.

	Mature weight (MW) (g)			
	n	**avg**	**SD**	**Pr>F**
Group				
LD	77	172.77	±21.97	0.0054
LL	74	165.06	±18.40	
Gender				
F	99	177.12	±18.30	0.0001
M	52	153.51	±15.22	
Group x Gender				
LDxF	49	182.92	±17.75	0.1537
LDxM	28	155.00	±16.86	
LLxF	50	171.44	±17.16	
LLxM	24	151.77	±13.20	

The results in table 4.1 illustrate the influence photoperiod has on the average mature body weight of both male and female quail subjected to the intermediate and continuous lighting schedule. A significant difference (p=0.0054) in mature weight of 4.7 % in favour of the LD group was reported. Mature weight of the female quail was significantly ($p<0.0001$) heavier by 23.61g compared to the male quail in both the LD and LL groups. However, no group x gender interaction in both the LD and LL groups were reported for male and female quail.

TABLE 4.2 The average (avg) growth rate (GR) and standard deviation (SD) for the intermediate light group (LD), continuous light group (LL), gender groups (male (M); female (F)) and groups x gender interaction.

		Growth rate (GR)		
	n	**avg**	**SD**	**Pr>F**
Group				
LD	77	0.00158223	±0.00031109	0.0001
LL	74	0.00188872	±0.00035135	
Gender				
F	99	0.00161973	±0.00030837	0.0001
M	52	0.00194699	±0.00036891	
GroupxGender				
LDxF	49	0.00147308	±0.00024288	0.3883
LDxM	28	0.00177325	±0.00032873	
LLxF	50	0.00176346	±0.00029969	
LLxM	24	0.00214968	±0.00030871	

The average growth rate for the LD, LL, gender groups and groups x gender interaction are presented in table 4.2 The results clearly indicate the LD group had a significantly ($p<0.0001$) lower growth rate (16.23 %), compared to the LL group before reaching maturity (35 days). The male quail had a significantly ($p<0.0001$) greater growth rate of 20.2 % compared to female quail in both the LD and LL groups before 35 days of age. No difference in results was observed for group x gender interactions.

Similar results for final weight and growth rate were found when analyzing the data by using the Gompertz equation. However, the Gompertz equation was more useful to express the age at which the growth rate reaches its maximum value. The age at which the growth rate reaches its maximum value for the LD, LL, gender groups and groups x gender is presented in table 4.3. It is evident that the LD group reached their maximum growth rate significantly ($p<0.0001$) later (1.6 days) than the LL group. Female quail reached their maximum growth rate significantly later (1.5 days) than the male quail in both the LD and LL groups. No difference in results was observed for group x gender interaction

TABLE 4.3 The average (avg) age at which the daily growth rate (GR) reaches its maximum value and standard deviation (SD) for the intermediate light group (LD), continuous light group (LL), gender groups (male (M); female (F)) and groups x gender interaction.

		Age at max. Growth rate (t_i) (days)		
	n	**avg**	**SD**	**Pr>F**
Group				
LD	77	16.42	±1.73	0.0001
LL	73	14.82	±1.51	
Gender				
F	98	16.17	±1.70	0.0001
M	52	14.64	±1.59	
GroupxGender				
LDxF	49	17.01	±1.53	0.8687
LDxM	28	15.38	±1.59	
LLxF	49	15.33	±1.43	
LLxM	24	13.78	±1.09	

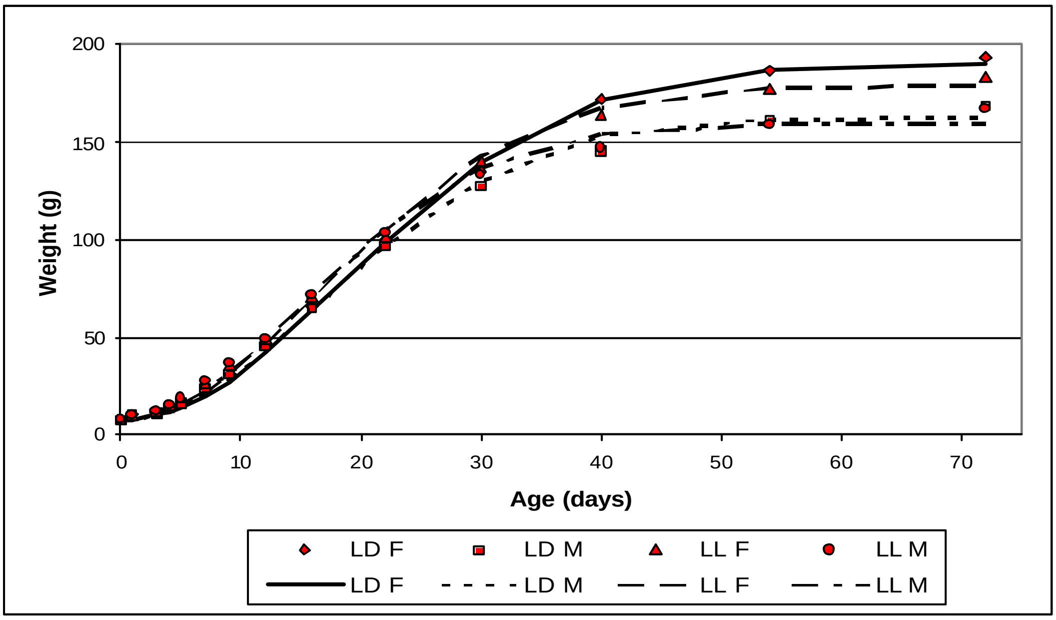

FIGURE 4.1 The relationship between bodyweight (BW) and age for the male (M) and female (F) quail in the intermediate light (LD) and continuous light (LL) groups.

The relationship between age and body weight for the male and female quail in the LD and LL groups are presented in figure 4.1. With the start of the trial no difference in initial weight was reported between the groups. It is evident, however, that from day 7 following hatching the LL group were heavier than the LD group for both the male and female groups. Although the magnitude of the difference in body weight started to decrease as the birds started to mature, this advantage in body weight was maintained for approximately 35 days in favour of the LL group for both male and female groups. At approximately 35 days following hatching an inversion is evident with the LD group maintaining a greater body weight compared to the LL group for the remainder of the trial. This trend is similar in both male and female groups of the LD group. However, female quail from both groups (LD and LL) were able to continue growing for a longer period compared to the male quail, before reaching mature weight.

4.2 FEED INTAKE

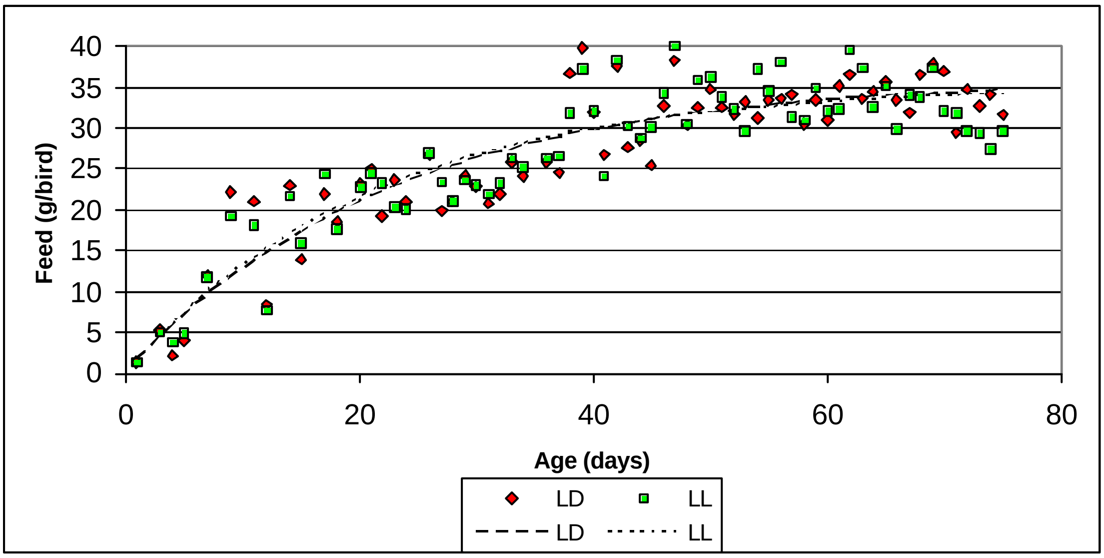

FIGURE 4.2 The relationship between feed intake (FI) and age for the intermediate light (LD) and continuous light (LL) groups.

The effect that photoperiod has on feed intake for quail at different stages in the trial are represented in figure 4.2. The results clearly indicate that no difference for feed intake is evident between the LD and LL groups. As would be expected, feed intake increased dramatically in the early stages of development, but as the birds reached maturity, the rate of feed intake decreased. The trend observed for the relationship between feed intake and age follows a similar trend for the relationship between body weight and age (figure 4.1).

4.3 SEXUAL MATURITY

TABLE 4.4 The percentage (%) sexual mature (SM) male (M) and female (F) quail in the intermediate light (LD) and continuous light (LL) treatment groups.

Group: Gender	Age range (days)					Total	Pr>F
		30_40	40_50	50_60	60_70		
LD: F	n	14	36	2	1	53	0.0001
	%	26.42	67.92	3.77	1.89	100.00	
LL: F	n	45	8	0	0	53	
	%	84.91	15.09	0.00	0.00	100.00	
LD: M	n	11	31	1	0	43	0.0001
	%	25.58	72.09	2.33	0.00	100.00	
LL: M	n	48	0	0	0	48	
	%	100.00	0.00	0.00	0.00	100.00	
LD: Group	n	25	67	3	1	96	0.0001
	%	26.04	69.79	3.13.	1.04	100.00	
LL: Group	n	93	8	0	0	101	
	%	92.08	7.92	0.00	0.00	100.00	

The results presented in table 4.4 represent the percentage male and female quail that became sexual mature in the LD and LL treatment groups at various intervals during the study. A highly significant difference (p<0.0001) in rate of sexual maturity between the females in the LD and LL groups is evident. The LL females were all sexually mature by 50 days post hatching while those from the LD group had only reached sexual maturity between 60 and 70 days post hatching. Furthermore most of the LL female group (85%) had reached sexual maturity between 30 and 40 days post hatching compared to the mere 26 % of the LD female group for the corresponding time period (figure 4.3).

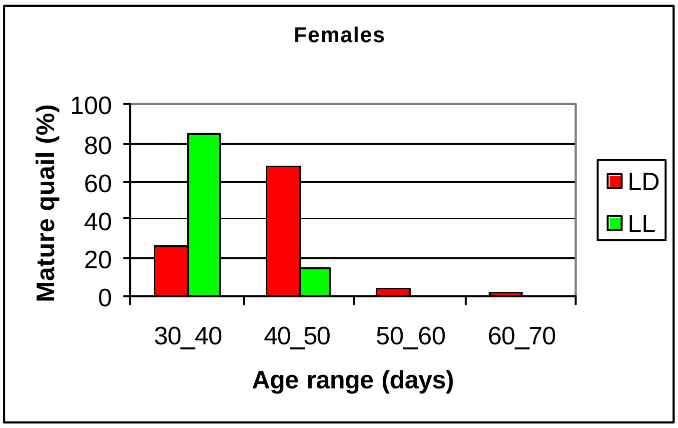

FIGURE 4.3 The time period (days) required by the intermediate light (LD) and continuous light (LL) female (F) groups to reach sexual maturity (%).

A similar trend was evident between the male quail in the LD and LL groups. However, by days 30 to 40, males in the LL group had all (100 %) reached sexual maturity which is significantly ($p<0.0001$) earlier than the males in the LD group. Only 26 % of the males in the LD group had reached sexual maturity for the corresponding time period (figure 4.4).

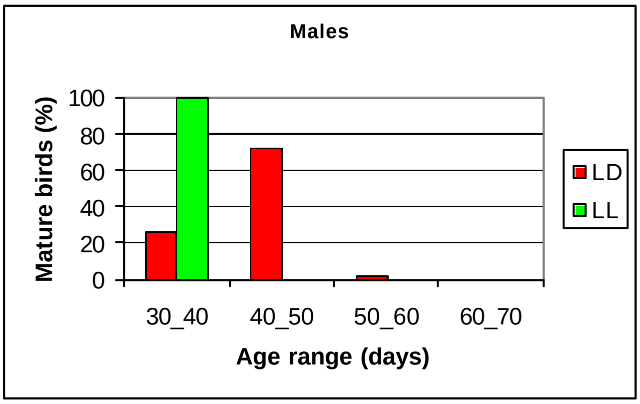

FIGURE 4.4 The time period (days) required by the intermediate light (LD) and continuous light (LL) male (M) groups to reach sexual maturity (%).

Although the LL male group reached sexual maturity before the LD group, the males had reached sexual maturity before female quail in both the LD and LL groups. As would be expected, when the LD and LL groups (males and females) were analysed as a whole, the LL group reached sexual maturity significantly ($p<0.0001$) earlier than the LD group.

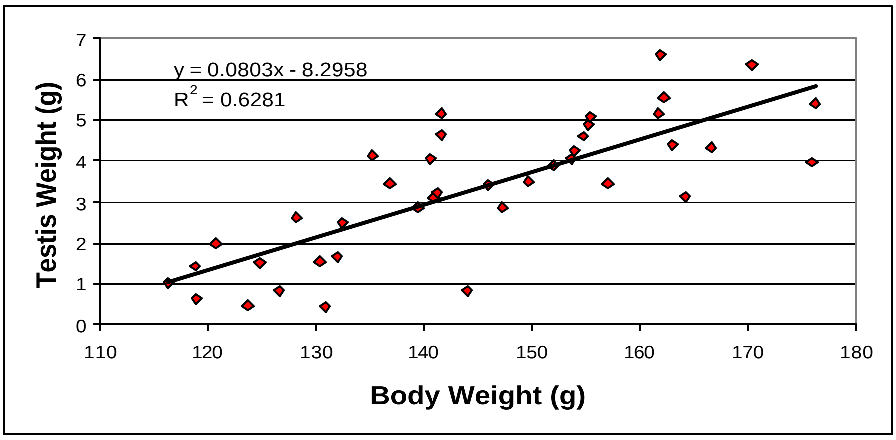

FIGURE 4.5 Correlation between testis weight (TW) and body weight (BW) for male quail of both the intermediate light (LD) and continuous light (LL) groups.

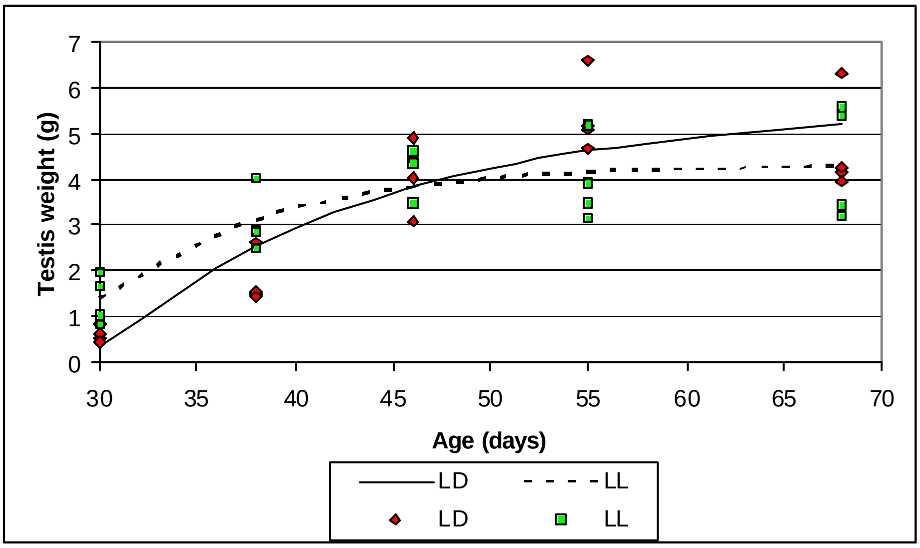

FIGURE 4.6 The relationship between testis weight (TW) and age for the intermediate light (LD) and continuous light (LL) groups.

The correlation between testis weight and body weight for male quail of both the LD and LL groups are presented in figure 4.5. While the relationship between testis weight and age for the LD and LL groups are presented in figure 4.6. A significant correlation ($r=0.79$; $p<0.0001$) exists between testis weight and body weight. The results in figure 4.5 indicate the strong linear relationship between testis weight and body weight. This clearly indicates that as body weight increases, testis weight also increases which is reflected in the results presented in figure 4.6. The results on the relationship between testis weight and age (figure 4.6) also shows a similar trend to that observed for body weight and age (figure 4.1) of quail subjected to the intermediate and continuous lighting schedules. Initially the males in the LD group had lighter testis weights 30 days post hatching compared to the LL group. However, at approximately 45 days post hatching, an inversion is evident and by the end of the trial the testis weight of males from the LD group were comparatively heavier than those of the LL group.

4.4 EGG PRODUCTION

TABLE 4.5 The average (avg) percentage egg production (EP) and standard deviation (SD) for intermediate light group (LD) and continuous light group (LL).

Group	n	Percentage egg production		Pr>F
		AVG	SD	
LD	41	74.16	±28.73	0.0001
LL	41	82.11	±17.26	

Table 4.5 represents results for the average percentage egg production and standard deviation for the LD and LL groups. Female quail in the LL group produced 8 % more eggs ($p<0.0001$) compared to the quail in the LD group for the same period. The advantage the LL group have in percentage egg production is ascribed to the greater number of female quail in the LL group that were in production during the initial stages of the trial (35 to 55 days). However, by 55 days post hatching (20 days of egg production) there was no difference in the percentage of eggs laid per day between the LD and LL groups (figure 4.7). Once this stage was reached, both groups showed a similar trend in egg production per day until the end of the trial

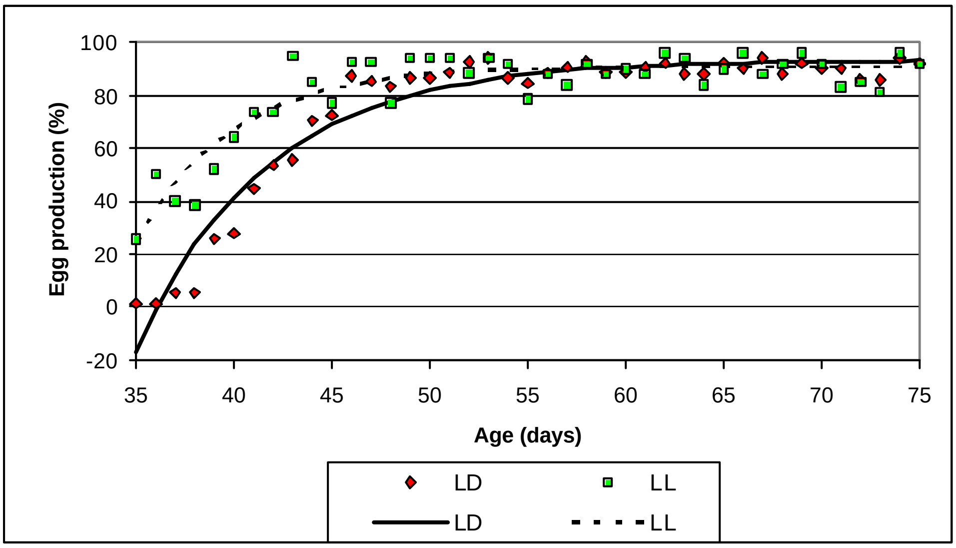

FIGURE 4.7 The relationship between percentage (%) egg production (EP) and age of quail for the intermediate light (LD) and continuous light (LL) groups.

4.5 EGG WEIGHT

TABLE 4.6 The correlation between age, body weight (BW) and egg weight in grams for both the natural (LD) and continuous light (LL) groups.

Trait		Age (d)	Body weight (g)	Egg weight (g)
Age (n=48) (days)	r	1.00000	0.32710	0.22888
	p	.	0.0012	0.0257
Body weight (n=48) (g)	r	0.32710	1.00000	0.24181
	p	0.0012	.	0.0182
Egg weight (n=48) (g)	r	0.22888	0.24181	1.00000
	p	0.0257	0.0182	.

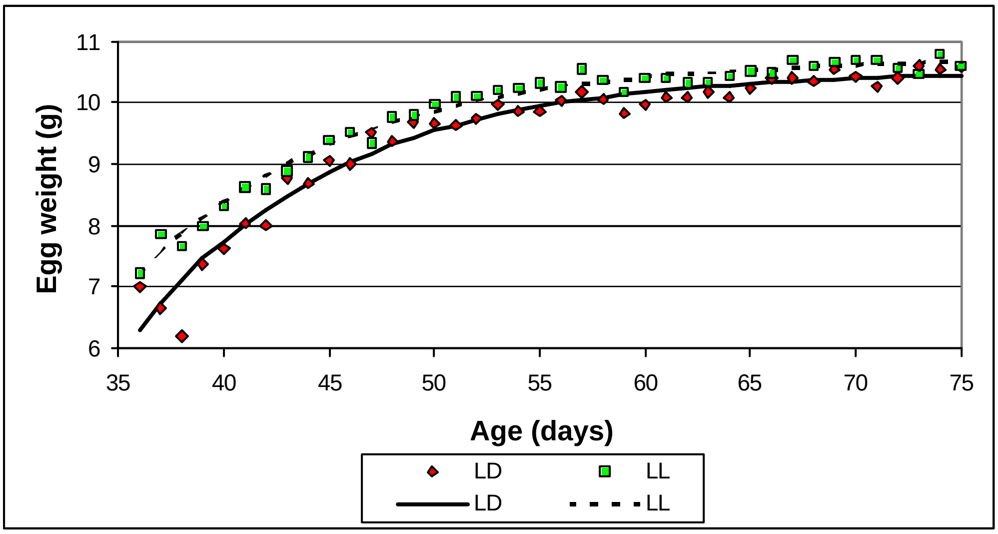

FIGURE 4.8 The relationship between egg weight (EW) and age for the intermediate light group (LD) and continuous light group (LL).

The results in table 4.6 represent the correlation between age, body weight, and egg weight for the LD and LL groups. While figure 4.8 represents the relationship between egg weight and age for the LD and LL groups. From the results presented in table 4.6 it is evident that a significant correlation (r=0.32; p=0.0012) exists between age and body weight and between age and egg weight (r=0.23; p=0.025). Similarly, a significant correlation exists between body weight and egg weight (r=0.24; p=0.018). Therefore it would seem that egg weight is a function of body weight and age.

Initially the egg weights of the female quail from the LL group were heavier than those from the LD group. By approximately 55 days post hatching the rate of increase in egg weight in both the LD and LL groups seemed to decrease and although not significant, the egg weight from the female quail in the LL group were still heavier than those from the LD group at the end of the trial.

CHAPTER 5

DISCUSSION

5.1 BODY WEIGHT

Figure 4.1 shows that the final mature weight difference in favour of the female birds can be ascribed to the greater development of the reproductive organs associated with the female quails (Wilson *et al.*, 1961). Similarly, Wilson *et al.* (1961) ascribes the larger body weight of the females to the heavier gonads, liver and intestines of the female quail while the male had relatively more muscle tissue than the female, but despite having more muscle tissue the male were generally lighter. Furthermore, female quail had a significantly lower growth rate than males in both the LD and LL groups and reached the point of maximum growth 1.5 days later than males. The results for this study support the findings by Du Preez *et al.* (1997) for growth rate of different sexes in the European quail. The mature body weight for males were 30 % lower than for females. Females reached the point of maximum growth 4.7 days later than males. However, the significant difference in growth rate observed in this study between male and female quail before 35 days post hatching is difficult to explain and it would seem to be the effect of unknown factors or a combination of factors, since it is unlikely that by 35 days post hatching, the development associated with anabolic hormone activity derived from the testis and ovaries would influence growth, and therefore unlikely to be an important consideration. The results in the study were also contrary to the results reported by Siopes, Baughman and Parkhurst (1993), who could not report a difference in growth rate before 16 weeks (mature) in turkeys for both male and female. Due to the further development of the reproductive organs in the female quail, a continued weight gain was observed resulting in female quail reaching sexual maturity later than males. Furthermore, Boon *et al.* (2000) reported that female quail that did not reach sexual maturity had comparable body weights to those of males. The results presented in table 4.1 and figure 4.1 are similar to those reported by Boon *et al.*, 2001; Lewis *et al.*, 1998 and Du Preez *et al.*, 1997.

The final mature body weight for the LD group was significant heavier than the LL group (table 4.1 and figure 4.1). But the initial growth rate (before 35 days post hatching) was higher in the LL group compared to the LD group and the LL group reached the point of maximum growth earlier than the LD group (table 4.2 and table 4.3). Feed intake was similar for both the LD and LL groups throughout the trial. Similarly, Rozenboim, Robinzon and Rosenstrauch (1999) found that in broiler chickens, photoperiod had no effect on growth until 42 days of age, but at 49 days of age, broilers reared under a short photoperiod were significant heavier than those reared on a long photoperiod. Therefore, it may be a possible explanation that the LL group utilized their feed for body tissue and reproductive growth up to 35 days post hatching whereas the LD group used their feed for body tissue and therefore reaching a higher final body weight. It is then expected that the larger (8 g) increase in body weight of the LD group compared to the LL group after 35 days post hatching, was due to reproductive development in the LD group as most of the birds in the LL group were already sexual mature. Because the increase in body weight for the LD group after 35 days post hatching is due to reproductive development, it may explain why the difference in body weight between the LD and LL groups for the females is bigger than the difference for the males as the reproductive organs of the females are heavier than those of the males.

Photoperiod is known to affect rates of weight gain in juvenile animals (Boon *et al.*, 2001; Lewis *et al.*, 1998; Prabakaran, Babu and Sundararasu, 1991). Photoperiod can also influence weight gain via an effect on the balance between food intake and digestion (Charles *et al.*, 1992). Therefore, the affect primarily produced by photoperiod is on energy intake and energy expenditure. The interaction between these two parameters as a function of photoperiod determines overall body weight gain (Boon *et al.* 2000; Classen *et al.*, 1991).
Boon *et al.* (2000) mentioned that the effect of a reduction in photoperiod on body weight was basically during the first days, whereafter the rate of weight gain was the same as for longer photoperiods. Crop filling is a generally adopted feeding strategy occurring in birds that enables them to tide over prolonged fasting periods (Boon *et al.*, 2000; Jackson *et al.*, 1995). It can be concluded that changes in feeding behaviour and energy expenditure shown under shorter photoperiods are part of a strategy that allows chicks to gain weight continuously.

Feed intake was not affected by photoperiod in this study as the LD and LL groups showed a similar trend. However, the LD group achieved higher final mature body weight and therefore it would seem that productivity would favour the LD group (figure 4.2).

5.2 SEXUAL MATURITY

In quail, sexual development is known to depend on the length of the daylight period as longer photoperiods stimulate sexual maturation, while short photoperiods inhibit or delay sexual maturation (Boon *et al.*, 2000; Mills *et al.*, 1997; Chaturvedi *et al.*, 1993). Although body weights of the male and female quail from the LD group were both significantly higher than those of the LL group at the end of the trial, only a small number of quail in the LD group had reached sexual maturity between 30 and 40 days (figure 4.3 and figure 4.4). The absence of sexual maturity in the LD group by the age of 40 days post hatching was accompanied by a significantly reduced testis weight and egg weight. The growth rate and consequent body weight of the LD group was lower than those for the LL group before 30 days post hatching. Although sexual development finally took place in the LD group, it happened at a much lower rate because of insufficient stimulation for reproductive development by means of longer photoperiods up to 35 days post hatching. The LD group reached their asymptotic body weight later than the LL group, therefore growing for a longer period than the LL group. Physiological processes generally require that priority be given to obtaining critical body weight and then to accumulate body reserves before the onset of reproduction can commence (Oruwari and Brody, 1988). This may also explain the comment of Yannakopoulus, Christaki and Florou-Paneri (1995) that quail which mature earliest enter lay at a heavier body weight compared to those which mature latest.

Binkley, (1988) ascribe these differences to the pineal hormone melatonin which controls reproduction in photoperiodic mammals and is an integral part of the circadian rhythm in birds. Recent findings also indicate an involvement of this hormone in more basic physiological processes, including growth, development, and aging (Zeman *et al.*, 1999). Pineal melatonin production is restricted to night, or the dark phase of the lighting cycle, and the duration of elevated melatonin levels is proportional to the night length (Underwood and Siopes, 1985). Endocrinologically, testicular function in birds appears to be controlled in much the same manner as in mammals with FSH and possibly testosterone regulating spermatogenesis, while LH is the primary steroidgenic hormone (Follett and Maung, 1978). This may explain why the LD group reached sexual maturity significantly later than the LL group as the LD group took longer to reach their critical body weight and fat content. The results therefore demonstrate that chronological age alone is insufficient to initiate sexual maturity. Furthermore, the triggering of sexual maturity by an interaction of chronological age and body weight may be responsible as a favourable correlation exists between age, body weight and egg weight (table 4.6).

5.3 EGG PRODUCTION

Age at sexual maturity has a direct influence on egg production as the quail from the LL group produced 8 % more eggs than the LD group until the end of the trial and it is expected that these advantage in egg production from the LL group will continue (table 4.5). The advantage in egg production was due to the initial earlier age at sexual maturity and subsequent egg production (figure 4.7). Although the literature pertaining to lifelong egg production for quail is scarce, Lewis, Perry and Morris (1997) found that longer photoperiods increase egg production, but also increase mortality rate up to 504 days in laying hens so that eggs per hen housed were unaffected. Due to insufficient results it is uncertain whether the same effect experienced by layer hens will pertain for quail, because in layer hens, it has been found that the optimal photoperiod for youngest age at sexual maturity is approximately 10 hours (Lewis *et al.*, 1998), whereas in quail, longer photoperiods seems to shorten age at sexual maturity. Therefore, making direct comparisons are not justified and more research in the area of the effect of photoperiod on lifetime egg production in quail is required.

5.4 EGG WEIGHT

The results in this study indicate a significant 14 % advantage in initial egg weight in favour of the LL group compared to the LD group (figure 4.8). It may be possible that due to a number of physiological processes and their interaction, that quail receiving longer photoperiods were able to utilize nutrients more efficiently than those from the LD group. Furthermore as stated by Chaturvedi *et al.* (1992), it may be possible that when the asymptotic body weight is reached, the rate of reproductive development is accelerated. The results in this study support the findings by Chaturvedi *et al.* (1992) as the quail from the LL group utilized comparative amounts of feed as those of the LD group and were able to produce eggs of a greater weight at an earlier age.

The results from this study are contrary to those found in Boon *et al.* (2000) as the egg weight for quail receiving comparative photoperiods to those presented in this study, had lighter egg weights compared to the quail exposed to shorter photoperiods. Similarly, Lewis *et al.*, (1997) reported increased egg weights for laying hens exposed to shorter photoperiods compared to those exposed to longer photoperiods. Boon *et al.*, (2000) had substantially lower numbers per photoperiod group compared to this study which could have had a profound influence on his results due to variation in individuals. The above subjective results are therefore difficult to compare to those found in this study.

CHAPTER 6

GENERAL CONCLUSION

In developing countries, quail farming offers a viable and practical solution to the problem of animal protein shortage. Because of their relatively small size, large numbers of quail can be kept in a small area and the necessary preparation can be carried out at relatively low cost. Quail are robust, disease resistant and have a prolific egg production. Yet they are not commercially well known around the world and deserve wider recognition.

The results in this study indicate that the final body weight for the LD group was significant higher than those of the LL group, while the growth rate of the LD group was significant lower that those of the LL group. It appears that the LL group benefited from the longer feeding time during the period of rapid growth which was shown to be the first three weeks of the trial and later when the rate of growth declined, the 13 hours light was sufficient time for feeding. Furthermore, the LD group benefited from the rest period after dark resulting in conservation of energy. Similarly, the final body weight for the female quail was higher than those of the males in both the LD and LL groups while the growth rate for the males was higher than those of the female quail.

Quail from the LL group reached sexual maturity at an earlier age than the LD group and males reached sexual maturity earlier than female quail. An explanation for this phenomenon may be with regard to increase in day length occurring during the period the trial was in progress. It is a possibility that the birds on the LL treatment could sense cues from the environment, mostly audible from outside, while the LD birds were subjected to a very strong signal of onset of darkness and onset of day. This would retard the sexual development of the birds on the LD treatment in relation to the LL group which could be stimulated by outside cues. A significant correlation exists between testis weight and body weight. The results on the relationship between testis weight and age also shows a similar trend to that observed for body weight and age of quail subjected to the intermediate and continuous lighting schedules.

Female quail of the LL group had a higher egg production than those of the LD group at a given time because of the earlier age at sexual maturity and subsequent earlier egg production of the LL group. It is expected that the LL group will maintain the advantage in egg production with associated economical advantages. Further investigation may be needed as information pertaining to the effect of photoperiod on livelong egg production is scarce.

Although no significant difference existed for egg weight, the initial egg weight of the LD group was significant lower than those of the LL group.

Contrary to studies comparing long and intermediate photoperiods and their effect on quail, the effect may be better demonstrated by comparing long periods to short ones since the magnitude of the results would be more significant.

The results of this study could provide significant economic consideration for producers of quail eggs. The study showed highly significant early egg production resulting in higher overall egg numbers and higher egg weights for the LL treatment in comparison to the LD treatment and these figures, converted into monetary values, can assist in making informed decisions.

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