

**THE INFLUENCE OF BODY MASS ON  
PRODUCTION CHARACTERISTICS OF  
BROILER BREEDERS**

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BREEDERS**

by

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## **DECLARATION**

I declare that the dissertation/thesis hereby submitted by me for the **MAGISTER SCIENTIAE (Animal Science)** degree at the University of the Free State is my own independent work and has not previously been submitted by me to another university/faculty. I further more cede copyright of the dissertation/thesis in favour of the University of the Free State.

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PHITSANE PULANE MIRRIAM

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# CHAPTER 1

## GENERAL INTRODUCTION

Broiler breeder flock body weight (BW) uniformity is constantly controlled and monitored to ensure that the hens are within a limit of  $\pm 15\%$  of the average BW (Hudson *et al.*, 2001). BW uniformity provides an estimate of variability in a flock at a given age, and generally the more uniform the flock the better the performance of that flock. Breeding companies normally provides target profiles for BW and close adherence to these standards is very important in preparation for subsequent laying performance. Uniformity in BW of broiler breeders is desirable so that all birds reach puberty at the same time and have similar rates of lay and egg size (Robinson & Robinson, 1991). The profitability of a poultry breeding operation is dependent upon the maximal production of eggs that are settable, hatchable and of good eggshell quality as well as of optimal egg weight within a given laying cycle.

Body weight is regarded as a function of frame size of the animal and its body condition (Oke *et al.*, 2004). From day one BW gain of broiler breeder is regulated and maintained in order to attain target BW at the onset of production. This is done through restricted feeding regime. The hen cannot be allowed to exhibit her genetic potential because large hens have a compromised reproductive ability.

Variability is one of the great phenomenons of any biological population. Variability in BW within a flock is attributed to genetic variability in the parent stock (Robinson & Robinson, 1991), social dominance (North *et al.*, 1980), nutrition (Costa, 1981), environment, hatching egg size, diseases, temperature and ventilation of the poultry house (Hudson *et al.*, 2001). The poultry producer wants hens of minimum possible size and uniform BW's that will maximize production of standard sized egg at an economic rate (Oke *et al.*, 2004).

There is an expectation for broiler breeder hens to produce like their counterparts commercial laying hens, while on the other hand selection is aimed at improving (increasing) the growth rate of their progeny (Robinson *et al.*, 1993; Robinson & Wilson, 1996; Sandilands *et al.*, 2004). Genetic selection over the years has been placed mainly on fast growth and improved feed conversion. However according to Ciacciariello & Gous (2002), the ability of meat-type parent stock to reproduce has been severely reduced by the selection pressure for mass gain. A certain amount of fat deposited in essential body structure is required for yolk formation and egg production and a minimum amount is critical for the sexual maturity in breeding hens. However excess fat in broiler breeders is undesirable for egg production of breeder hens (Hocking & Whitehead, 1990; Kwakkel, 1997). The broiler breeders' feed intake and BW are constantly regulated from early age in order to reduce the incidence of health and reproductive problem (Leeson & Summers, 2000; Mench, 2002; Gous & Cherry, 2004).

It is critical that the pullets obtain a specific target BW and age prior to maturity. If one of these parameters is not realized problems such as low egg output and delayed sexual maturity are often encountered (Leeson & Summers, 2000). A flock with a highly uniform BW will reach peak egg production earlier and will peak higher and come closest to expressing their full genetic potential than a nonuniform flock (Hudson *et al.*, 2001). A flock with hens that vary in BW will not attain high peak egg production due to varying degrees of maturity among the individual hens; due to delayed onset of production in light hens and accelerated production in heavy hens (Hudson *et al.*, 2001).

Different levels of maturity in BW at sexual maturity have been associated with changes in hen-day production and egg weight (Triyuwanta *et al.*, 1992). This is demonstrated in the report by Robinson & Robinson (1991) where low-weight hens laid significantly fewer eggs than the medium-weight and the high-weight hens (low:  $140.5 \pm 11.1$  eggs; medium  $176.2 \pm 4.9$  eggs and high  $169.2 \pm 6.5$  eggs). Hudson *et al.* (2001), reported that hens with the lowest mean BW had the highest overall egg weight and greater initial egg weights as a result of delayed onset of lay. On the other hand hens with the higher mean BW had the lowest overall egg weight because of decreased initial egg weight.



It is also observed that when hens become too fat, egg laying is likely to become erratic and production decrease at a more rapid rate and stops at an earlier age. Accordingly eggshell quality is reduced due to loss of coordination of ovulation, oviposition and shell deposition. Therefore the quality of the eggshell is compromised (Robinson *et al.*, 1993; Robinson & Wilson, 1996; Poole, 2003). However if hens are too lean they may not carry sufficient energy reserves to sustain peak production consequently have a numerically lower egg production and thus few egg are hatched (Gous & Cherry, 2004).

Fisher (1998) stressed the importance of target BW at the onset of lay and mentioned that it has not increased with genetic progress in broiler growth rate. The modern broiler breeder hen is continually changing in response to selection pressure for desirable reproduction and growth traits. Research with modern broiler breeder hen is needed in order for management practices to be improved and to develop more efficient systems, as well as to determine whether performance of broiler breeder hen could be improved (Renema *et al.*, 2001; Gous & Cherry, 2004). Although substantial amount of information is available on the effect of BW on productive performance, many studies have been done to compare variation in BW on productive performance of broiler breeder hens that were reared under different feeding regimes, not in as a result of 'normal' variation in BW at the onset of lay (Robinson & Robinson, 1991).

Moreki (2005), investigated the influence of calcium intake by broiler breeder hens during the rearing and laying periods on bone development and egg characteristics. The author of the current dissertation was intensively involved with the technical execution of the experiment. Therefore the results of this study (Moreki, 2005) afforded the opportunity to investigate the effect of BW at the onset of lay on subsequent laying performance, eggshell quality and calcium metabolism. In Chapter 4 the effect of BW at onset of lay on the subsequent laying performance and eggshell quality of Ross broiler breeder hens was investigated. The influence of BW at the onset of lay on calcium retention and excretion of broiler breeder hens was investigated in Chapter 5.

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## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1 INTRODUCTION**

This chapter reviews extensively the available literature on the relationship between body mass (BW) and production parameters, which includes egg production, egg weight, eggshell quality and calcium metabolism of broiler breeder hens during the laying period. This involves the examination of previous and current work on the effect of body mass (BW) at the onset of lay on performance of laying broiler breeder hens.

#### **2.2 FEED INTAKE**

A major challenge in feeding broiler breeders is encountered when the growth potential of the hen is tempered with in order to realise optimum productive performance, as a negative correlation exists between reproduction and BW. The hen cannot be allowed to exhibit her genetic growth potential because large hens are uneconomical and broiler breeder females are very reproductively unfit when they are allowed to full-feed. (Leeson & Summers, 2000). Overweight broiler breeder hens have been identified as a major problem in the broiler industry; hence feed restriction methods are practiced in order to maintain BW (Robinson *et al.*, 1993). The one problem that is encountered in broiler breeder management is maintaining a desirable BW by reducing feed consumption without affecting egg production.

Restricted feeding provides an opportunity for total control over the nutrient intake of the hen, though it delays sexual maturity (Fattori *et al.*, 1991; Triyuwanta *et al.*, 1992) and there is a natural tendency of the flock to be non-uniform under a controlled feeding regime (Fisher & Willemsen, 1999). The primary objectives for using feed restriction

programs during both the rearing and laying period are to prevent the females from becoming obese and to allow a steady and slow weight gain to reduce the reproductive problems related to selection for fast growth in broiler breeders (McDaniel, 1983; Renema *et al.*, 1999). Summers & Leeson (1983), reported that BW is correlated to energy consumption. A hen's BW increased linearly with daily feed intake while feed efficiency showed a linearly inverse trend (Harms *et al.*, 1982). Reproduction inefficiency is apparent in reduced egg production and shell quality, in addition to the development of more large follicles and an increased incidence of multiple-yolk eggs, obesity-related mortality, infertility and embryonic loss (Yu *et al.*, 1992; Robinson & Wilson, 1996).

Yu *et al.* (1992) identified at least two mechanisms that contribute to the low production of settable eggs in *ad lib.* fed hens: firstly broiler breeder hens have an increased incidence of multiple hierarchies of follicles, which leads to multiple ovulations and production of defective eggs. Secondly broiler breeder hens have an increased incidence of ovarian regression, which results in cessation of egg production and little persistency of peak production.

When boiler breeder hens are allowed to full feed this can cause abnormal ovary development by as early as 14 weeks of age when they commence lay (Robinson *et al.*, 1999). Therefore the hens that are fed *ad lib* are depend upon reaching critical age to start laying while on the other hand feed restricted hens depend upon attaining critical BW and carcass fat storage to commence laying (Robinson *et al.*, 1993). McDaniel *et al.* (1981), found that broiler breeder hens that were provided with high feeding levels resulted in heavier BW and produced large eggs but had a low egg production, fertility, hatchability and poor shell quality.

Robinson & Robinson (1991), showed that feed restricted hens have a significantly improved production of total and settable eggs with a persistent peak production up to 42 weeks of age along with increased fertility and hatchability. At the same time severe feed restriction in broiler breeders may causes similar production problems as in full feeding

like failure to attain peak egg numbers, and significantly impaired egg production due to delayed sexual maturity, whilst overfeeding is more commonly associated with very rapid decline in egg numbers following a brief period of peak output (Triyuwanta *et al.*, 1992; Robinson *et al.*, 1993).

In a study conducted by Wilson *et al.*, (1995) restricted fed hens were approximately 700 grams lighter than breeder hens that were full fed, with a higher mean egg output (176.6 eggs) than full-fed hens (132.5 eggs). Robinson *et al.*, (1991), also reported 40.4 more eggs laid by restricted hens based on mean data for all hens housed, and 28.4 more eggs based on the surviving hens. Fattori *et al.*, (1991) observed that an increment in consumption was linked to a proportional decline in the number of laying days and a high incidence of double-yolked eggs.

### **2.3 BODY WEIGHT**

Modern broiler strains have the ability to grow fast and therefore consume more feed and mature at a much younger age, without a parallel improvement in their ability to convert feed into lean tissue. The progress made in improving the growth rate of broiler chickens during the past decades has been remarkable, albeit at the expense of production and reproductive efficiency of broiler parents. Consequently it is now standard practice to limit feed intake of broiler breeder hens during both the rearing and laying periods in order to prevent obesity and increase production efficiency (Triyuwanta *et al.*, 1992; Yuan *et al.*, 1994; Gous & Cherry, 2004). Body weight is regarded as a function of frame size of the animal and its condition. The poultry breeder wants hens of minimum possible size and uniform BW's that will maximize production of standard sized eggs at an economic rate (Oke *et al.*, 2004). Reproductive anomalies such as internal ovulation, internal laying, production of soft-shelled or membranous eggs, reduced duration of fertility have been associated with heavier than target BW at the onset of laying (Robinson *et al.*, 1991).

Body weight (Brody *et al.*, 1980; 1984; Robinson & Robinson, 1991), body fat (Bornstein *et al.*, 1984), lean body mass and lighting greatly influence age of sexual maturation (Robinson *et al.*, 1993; Yuan *et al.*, 1994). Hens that are more than 5% below target BW at onset of lay tend to have impaired ovarian development giving rise to delayed onset of lay, poor initial egg size, heightened percentage of rejected/ misshaped eggs and reduced fertility. Equally hens that are 5% above target BW at the onset of lay will have early onset of lay, increased egg size and double yolks, reduced hatching egg yield, increased feed requirement through lay, reduced peak and total eggs, increased levels of mortality possibly due to prolapse (Ross Breeders, 1998). One of the reasons for poor production by broiler breeders with increased BW during rearing is that it can be associated with increased fat deposition, which has a negative influence on production, especially after peak production. Therefore it appears that a balance between BW and body fat composition is critical at the onset of lay and later for desired productive performance of the breeder hen.

Breeding companies normally provides target profiles for BW and close adherence to these standards is very important in order to achieve uniformity in BW, generally the more uniform the flock the better the performance of that flock. A highly uniform flock is more efficient, have an earlier higher peak egg production, and come closest to expressing their full genetic potential. Non-uniform flocks generally do not attain high egg production peak because of the varying degrees of maturity among individual hens. Underweight hens produces eggs that vary greatly in size, while hens above target BW produce a high percentage of double yolked eggs (Hudson *et al.*, 2001). According to Robinson & Robinson (1991), for all hens to reach puberty together and attain similar rates of lay and egg size BW uniformity of broiler breeder pullets is imperative. The low-weight hens in their experiment laid significantly fewer eggs than the medium- and high-weight hens (low:  $140.5 \pm 11.1$  eggs; medium:  $176.2 \pm 4.9$ ; and high  $169.2 \pm 6.5$  eggs). It is critical that the pullets obtain a given weight and age prior to maturity, if one of these parameters is not realized problems are often encountered later during the laying period (Leeson & Summers, 2000).



McDaniel (1983), Robinson *et al.* (1993), Yuan *et al.* (1994), Leeson & Summers, (2000), and Poole (2003) reported several reproductive problems associated with hens becoming overweight *i.e.* reduced fertility and hatchability, decreased egg production and mean egg weights though they come sooner into production. Whereas underweight hens reach sexual maturity significantly later than the medium and heavy weight hens, they also tend to have a low total egg output (Robinson & Robinson, 1991; Hudson *et al.*, 2001). As they may be too lean hens may not carry sufficient energy reserves to sustain peak production (Leeson & Summers, 2000).

Leeson & Summers (2000), also stressed that BW of broiler breeder hens should constantly be controlled from early age in order to reduce the incidence of reproductive problems. The major goal in broiler breeders management is to maintain the health status of the flock, while allowing for continued, but slow increase in body weight. Since a strong negative relationship exists between BW and reproductive efficiency in domestic poultry, that severely limits the ability of broiler breeder to reproduce and perform during the laying period (Robinson *et al.*, 1993; Robinson & Wilson, 1996; Poole, 2003). Broiler breeders are generally reared on a feed restriction regime in order to reduce BW, to prevent leg disorder (Decuyper *et al.*, 1996), high mortality rates and excessive fattening (Kwakkel, 1997). In addition to reduced BW gain it is important to improve egg production and to reduce chick mortality (Robinson & Wilson, 1996), as well as to delay sexual maturity and, consequently improve subsequent performance (Triyuwanta *et al.* 1992). An excessive gain in BW by broiler breeders has a negative influence on production of fertile hatching eggs (Lilburn & Myers-Miller, 1990).

### **2.3.1 EFFECT OF BODY WEIGHT ON EGG PRODUCTION**

Egg production of laying hens is normally divided into the three main periods. **Period 1** is quite short and include the time between when the first eggs are laid and when nearly all the birds are laying continuously. **Period 2** is the main laying period (peak period). The length varies depending on the strain or species and the environment. **Period 3**

corresponds with the reduction in the rate of lay. The decline in egg production is explained by the lowered follicular activity (Larbier & Leclercq, 1992; Rose, 1997).

Reproduction efficiency in broiler breeders is classified by changes to egg production (increased age at sexual maturity, poor rate of lay and termination of laying period) and by changes to chick production (production of unsettingtable eggs, infertility and embryonic death). The objective of a breeding operation is to produce as many eggs as possible of the average size for incubation; this is dependent upon the performance of the breeder hen. Increased BW may result in low fertility, egg production and hatchability indirectly by reducing sequence length (Robinson *et al.*, 1993).

The broiler breeder hen produces about 165 eggs and 130 chicks in a production cycle of 60 weeks achieving a peak production of about 85% (Larbier & Leclercq, 1992). The difference between total eggs produced and chicks hatched is due to the production of eggs at the beginning of the laying period that are either double-yolked, or too small to be hatched, to low fertility in the early laying period, and to reduced hatchability at the end of the laying period (Ciacciariello & Gous, 2002). At the same time the commercial layer hen is expected to produce about 240 eggs, with a peak production of 95%. This gives a difference of 75 eggs compared with the number of eggs laid by a broiler breeder hen. BW has been identified as one of the major factors influencing the rate of lay. Huge disparity in BW at the onset of lay has detrimental effect on the overall production of eggs.

Different levels of BW at sexual maturity have been associated with changes in hen-day production (Triyuwanta *et al.*, 1992). Overweight breeder hens are prone to fatty liver syndrome, and prolapse due to general cloacal muscle weakness due to their tendency to lay large eggs. Too much fat around the reproductive organs usually leads to prolapse (Robinson & Wilson, 1996; Martin, 2000). Similarly underweight hens during the commencement of lay are also likely to experience prolapse as they may begin lay before the reproductive tract has completely matured, this in turn lowers the number of eggs produced in a production cycle. Overweight broiler breeders at the point of lay is

associated with factors that reduce the production of viable eggs such as development of hypertrophic ovaries of yellow follicles, which leads to double-yolked eggs, internal laying that leads to peritonitis, misshapen and poorly shelled eggs, all these factors in turn affect the hatchability of the eggs (Fisher & Willemsen, 1999). Robinson & Wilson (1996), reported a difference of 40 more eggs produced by light hens than heavier hens in production cycle of 62 weeks, attributed to shorter laying sequence and increased fat deposition in heavier hens since 68% of BW difference was fat. Despite coming into production sooner the overweight hens lay fewer collectable eggs than the underweight hens, the most productive hens were those that had the lowest BW gains since they maintained longer peak production (Yu *et al.*, 1992; Robinson *et al.*, 1993).

However Renema *et al.* (2001), reported contradicting results where they found that additional BW did not negatively influence both total and settable egg production. Instead high BW hens had better production than the hens of standard BW. Total egg production recorded for standard BW hens, low BW hens and the high BW hens were 171.4, 180.4 and 182.3 respectively. On the contrary Triyuwanta *et al.* (1992), also observed that individual rate of egg production was not significantly affected by BW, which is also in agreement with the findings of Harms *et al.* (1982), on layer-type hens.

Hens that are below target BW are undesirable since underweight hens produce low total egg output with varying egg size, while overweight birds produce more double-yolk eggs (Robinson & Robinson, 1991; Hudson *et al.*, 2001). Robinson *et al.* (1993), concluded that some hens do not become overweight as they are laying well or, alternatively some hens may lay fewer eggs because they are overweight. It seems as soon as the hen commences lay, less nutrients are diverted into carcass growth.

### **2.3.2 EFFECT OF BODY WEIGHT ON EGG WEIGHT**

Egg weight incorporates of three components *i.e.* the shell, albumen and yolk. Under normal operations egg weight increase as the hen ages. Narushin & Romanov (2002) reported that the physical characteristics of the egg are very important during embryo

development and hatching. These important characteristics of the egg are weight, shell thickness, porosity, shape index, and the consistency of the contents. According to Larbier & Leclercq (1992), the increase in egg weight along with age is particularly rapid during the first few months of lay. The primary factors that influence egg weight and egg mass are BW, feed allowance and age of the hen. All these factors are positively correlated (Harms *et al.*, 1982 Triyuwanta *et al.*, 1992; Yuan *et al.*, 1994).

McDaniel *et al.* (1981), reported that broiler breeders BW and feed intake have influence egg weight and eggshell quality and that there is a high positive correlation between egg weight and chicken weight at hatching (Triyuwanta *et al.*, 1992). Increment of feeding levels aimed at attaining greater BW during lay result in increased egg weights and the incidence of double-yolk eggs, accompanied by a proportional decrease in the number of laying days (Robinson *et al.*, 1993; Yuan *et al.*, 1994). Yuan *et al.* (1994) further reported that the egg weight and egg size of the first egg for lower BW birds correlated with BW, while the opposite was observed in heavier hens. The hens with the high BW had depressed mean egg weight, early settable (>50 g), and total settable eggs than the light hens. Based on the findings by Yuan *et al.* (1994), none of the abovementioned egg size variables are increased by simply allowing increased BW during rearing. These is further demonstrated when early settable egg production by light hens was more than double that of heavier BW hens. This suggests that the BW for heavier hens may be associated with fatter pullets rather than lean body mass and increased maintenance energy requirements.

Hudson *et al.* (2001), found that the hens with the lowest mean BW had the highest overall egg weight probably because of their delayed onset of lay and greater initial egg weights, whereas the other hens in the highest BW group had the lowest overall egg weight, possibly because of the decreased egg weight laid initially by heavy hens. On the contrary Renema *et al.* (2001), reported similar initial egg weights among the high, average and low BW groups, but by week 27-30 the high BW group egg weight was on average 1.1 g more than the low BW group. Therefore the variation in BW profile between the high and low group was evident enough to significantly increased egg weight. However Fattori *et al.* (1991), found no significant difference in weekly average

egg weight among the BW targets of 8% below the standard target BW, standard target BW and 8% above standard target BW.

### **2.3.3 EFFECT OF BODY WEIGHT ON EGGSHELL QUALITY**

The complex structure of the egg is characterized by consisting of four different parts *i.e.* the yolk, albumen, shell membrane and shell. Generally the shell membranes, which are 0.75% of the total egg weight, are included within the shell weight (Rose, 1997).

Eggshell quality is basically governed by the quantity of shell per unit surface area of the egg (Ousterhout, 1980). Eggshell quality is defined in terms of its shape, color and strength, and is dependent upon morphological and physical characteristics. The shell consists entirely of calcium carbonate that is about 94 to 97% calcium carbonate (Larbier & Leclercq, 1992; Koelkebeck, 2001). According to Leeson & Summers (2000), and Roberts (2000), there are numerous factors that influence the general quality of the eggshell, which include environmental temperature, nutrition (calcium), flock age (BW) and disease.

Eggshell quality is best quantified by simply measuring the thickness of the shell directly, or by an indirect method such as specific gravity. The shell should be around 0.3 mm in thickness or 0.4 mm with the cuticle and shell membranes (Leeson & Summers, 2000). Shell thickness and porosity help in the regulation of carbon dioxide and oxygen between the developing embryo and the air during incubation (Larbier & Leclercq, 1992). Eggshells have to be strong and rigid as they have a significant effect on moisture loss during incubation, and to protect the developing embryo against bacterial invasion. The shell has to be strong enough to support the adult hen, but at the same time allow the chick to hatch. It must be porous enough to permit gaseous exchange with the outside air (Rose, 1997; Narushin & Romanov, 2002). Thin-shelled eggs lose more moisture than do thick-shelled eggs, causing the chick to have difficulty in hatching. Shell quality is one of the most important factors that influence hatchability (Leeson & Summers, 2000).

Physiologically, eggshell weight diminishes slightly as the hen ages whilst the total egg weight increases, resulting in thinner shells that are weak (Larbier & Leclercq, 1992; Al-Batshan *et al.*, 1994). Eggs that are larger than normal require more shell but the hen is unable to increase the amount of shell produced as the hen loses her ability to mobilize calcium from the bones resulting in thinner shells (Al-Batshan, 1994). The hen has a tendency to secrete constant amount of calcium to cover an egg without regard to its size (Naber, 1980). This can be an obstacle for normal gas exchange for the embryo (Narushin & Romanov, 2002). McDaniel & Brake (1981), reported that the overweight hens exhibited the lowest hatchability at week 31, 39 and 52 of egg production. A portion of the difference in hatchability, as well as the decline in hatch over time could, be attributed to the decline in eggshell quality. Therefore poor shell quality may be a significant factor in declining hatchability and is there a high association between the two traits. It is further reported that as feed intake increased along with BW, shell quality decreased, while egg weight and chick weight increased.

When hens become too fat eggshell quality is reduced (soft-shell, multiple-yolk and multiple-egg days) as a result of a loss of coordination of ovulation, oviposition, and the shell calcification process. There is a tendency to lay more eggs during the night and laying becomes erratic (Robinson *et al.*, 1993; Robinson & Wilson, 1996). Overweight hens often produce poorly calcified eggs consequently increasing shell porosity and egg weight loss and incidences of embryonic mortality (Robinson *et al.*, 1993). Erratic lay is significantly correlated to laying of soft-shelled and membranous eggs, multiple-yolked eggs and multiple-egg per day, and was negatively correlated with the number of settable eggs laid per hen (Robinson & Wilson, 1996).

A high production of double-yolk eggs is a characteristic of overweight hens. Eggshells from double-yolk eggs were found to be significantly heavier than eggshells from eggs with single-yolk. The single-yolk eggs had a significantly higher percentage shell than the double-yolk eggs. This indicates that the laying hen is capable of putting more shell on the egg when forming a larger egg with a double-yolk. However the percentage of the

shell is less with the double-yolk eggs resulting in significantly thinner shells on the double-yolk eggs (Harms & Abdallah, 1995).

Lower than target BW hens had a higher proportion of soft-shelled eggs and increased embryonic losses, which is indicative of the poor shell quality (Renema *et al.*, 2001). The production of defective eggs (soft shell, shell less, double-yolked and abnormal shell) by both lower than target BW and above target BW hens is negatively correlated to total egg production, chick numbers, hatchability of settable eggs and hatchability of fertile eggs set (Robinson *et al.*, 1993; Renema *et al.*, 2001). Shell quality appears to be a significant part of this negative relationship. This implies that the hens that produce a majority of defective eggs (poor eggshell quality) are reducing their production efficiency through reduced fertility and production of settable eggs that hatch (Renema *et al.*, 2001).

#### **2.3.4 EFFECT OF BODY WEIGHT ON CALCIUM METABOLISM**

Many studies have been carried out to highlight the importance of calcium metabolism during the laying period of both broiler breeder hens and commercial layers. Particular attention was paid to the role of calcium on egg production, eggshell quality; egg weight feed intake and feed conversion (Watkins *et al.*, 1977; Chen & Chen, 2004). The relationship between BW and calcium metabolism in broiler breeder hen requires attention.

Calcium is most prevalent in the body and is required in diet in larger quantities than other minerals (Siebrits, 1993; Elaroussi *et al.*, 1994). It is one of the key elements required for maintenance and egg production (Elaroussi *et al.*, 1994). In poultry the main proportion calcium in the diet is used for bone formation in chicks and shell formation in mature hens (Calnek *et al.*, 1991; Klasing, 1998). About 60-65% of the calcium in the eggshell is derived from dietary sources and the remainder 35-40% from medullary bones (Sugiyama & Kasuhara, 2001). An eggshell contain on average 2.2 g calcium in the form of calcium carbonate and phosphorus (Hopkins *et al.*, 1987).

Calcium homeostasis is maintained in hen by the mobilization of bone calcium and the hen can still supply calcium for the formation of the eggshells during the periods of low calcium intake. Much of the eggshell is formed during the night when calcium intake from the feed is expected to be low (Whitehead, 1991). Under normal conditions when a high calcium diet is being fed dietary calcium is absorbed and utilized for eggshell formation; however the medullary bone is resorbed whenever the supplies of calcium in the gut are not sufficient to provide for the demands of the shell gland (Taylor & Drake, 1984).

According to Gilbert (1983), calcium equivalent to almost 10% of the total bone calcium content is secreted daily to support shell calcium deposition. Thus in one year of production a high producing layer losses 30 to 40 times the hen's body calcium into the eggshells. An equivalent of 2 g calcium is deposited in an eggshell that weighs 5 to 6 g. In order to make this enormous daily output of calcium possible the laying has developed a most efficient calcium homeostasis mechanism. This emphasise the importance of calcium absorption, retention and excretion by breeder hens during laying period. There is however a lack of information with regard to the influence of BW on calcium metabolism and calcium turnover.

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# Chapter 3

## General Materials and Methods

### 3.1 Introduction

The current chapter outlines the different materials and methods followed by Moreki (2005), in the rearing of the hens, collection, preparation and analysis of data.

### 3.2. Animal Husbandry

#### 3.2.1 Rearing

Six hundred and forty day-old Ross broiler breeder female chicks were randomly assigned into three treatments groups, each having four replicates. The three treatments were 1.0% calcium (0.45% available phosphorus), 1.5% calcium (0.7% available phosphorus) and 2.0% calcium (0.9% available phosphorus). Pullets were fed different diets during the experimental period *i.e.* pre-starter (0 to 2 weeks), starter (2 to 4 weeks) and grower (4 to 18 weeks). The physical and nutrient composition of the diets is indicated in Table 3.1 and 3.2, respectively. The pullets had *ad libitum* (ad lib) access to starter diet up to three weeks of age. From three weeks of age the pullets were subjected to quantitative restriction feeding in accordance with the breeder's guide, in order to obtain targeted BW. Individual as well as group BW of all pullets were recorded on weekly basis up to the age of 18 weeks. Group (replicates) feed intake was also recorded on a weekly interval.

The day-old chicks were reared in pens with 40 birds per pen and four pens per treatment in a closed house with windows for ventilation. The replicates were housed in 4 m<sup>2</sup> floor pens, with shavings and/or grass as litter material, at a stocking density of 0.11 and 0.13 m<sup>2</sup> at 12 and 18 weeks of age respectively. Each pen was equipped with an electric brooder (infra-red lamps were used for spot brooding), two tube-type feeders and two automatic drinkers. The pullets received 24 hours of light for the first day and then continued on the natural day length pattern, which was decreasing for that particular time of the year May to July. The pullets were reared as in-season flock as they were subjected to increasing day length season as they were reaching sexual maturity.



**Table 3. 1 Physical composition of the experimental diet on an air-dry basis**

	Pre-starter diet		Starter		Grower	
	1.0%Ca	2.0%Ca	1.0%Ca	2.0%Ca	1.0%Ca	2.0%Ca
Maize	58.62	58.15	58.15	58.37	67.12	64.82
Maize gluten	1.85	-	-	-	-	-
Wheat bran	6.50	12.00	12.00	5.45	12.00	9.30
Full fat soya	-	-	-	1.30	-	-
Soybean oil cake	17.85	17.85	17.85	18.95	6.70	11.60
Sunflower oil cake	8.00	8.00	8.00	8.00	10.0	6.40
Fishmeal	1.00	-	-	-	-	-
Calcium carbonate	1.30	1.45	1.45	3.00	1.70	2.95
Calcium monophosphate	1.27	1.31	1.31	3.37	1.47	4.08
Salt	0.17	0.23	0.23	0.24	0.23	0.26
Sodium bicarbonate	0.30	0.28	0.28	0.25	0.26	0.14
Choline liquid	0.03	0.021	0.02	0.03	0.052	0.05
Lysine	0.33	0.18	0.18	0.15	0.91	0.01
Threonine	0.33	-	-	-	-	-
Methionine	0.24	0.18	0.18	0.18	0.32	0.03
Trace mineral/ vitamin premix	0.35	0.35	0.35	0.35	0.35	0.35

Pre-starter diet fed 0-2 weeks of age.

Starter diet fed 2-4 weeks of age.

Grower diet fed 4-18 weeks of age.

**Table 3.2 Nutrients composition of experimental diets on air-dry basis (%)**

	Pre-starter diet		Starter		Grower	
	1.0% Ca	2.0% Ca	1.0% Ca	2.0% Ca	1.0% Ca	2.0% Ca
Moisture	11.19	11.31	11.31	10.93	11.20	10.96
ME (MJ/Kg)	12.10	11.80	11.80	11.60	12.10	11.70
Protein	20.36	17.99	17.99	17.99	14.00	14.32
Crude fat	3.01	3.05	3.05	3.05	3.26	3.12
Crude fibre	5.35	6.13	6.13	6.13	6.45	5.41
Calcium	0.99	1.01	1.01	2.00	1.10	2.01
Phosphorus	0.79	0.81	0.81	1.28	0.82	1.36
Available phosphorus	0.45	0.90	0.45	0.90	0.45	0.90
Arginine	1.25	1.15	1.15	1.16	0.88	0.90
Isoleucine	0.84	0.74	0.74	0.76	0.55	0.58
Methionine	0.59	0.49	0.48	0.48	0.30	0.29
TSAA <sup>1</sup>	0.95	0.81	0.81	0.81	0.58	0.57
Threonine	0.78	0.66	0.66	0.67	0.51	0.53
Tryptophan	0.23	0.21	0.21	0.21	0.16	0.16
TA <sup>2</sup> arginine	1.16	1.07	1.06	1.07	0.81	0.83
TA <sup>2</sup> isoleucine	0.76	0.67	0.67	0.69	0.49	0.55
TA <sup>2</sup> lysine	1.05	0.85	0.85	0.85	0.55	0.55
TA <sup>2</sup> methionine	0.56	0.45	0.45	0.45	0.27	0.51
TA <sup>2</sup> TSAA	0.87	0.73	0.73	0.73	0.51	0.46
TA <sup>2</sup> threonine	0.69	0.58	0.58	0.59	0.45	0.46
TA <sup>2</sup> tryptophan	0.21	0.19	0.19	0.19	0.14	0.15
AC:Linoleic	1.59	1.68	1.68	1.65	1.82	1.72
Salt	0.21	0.23	0.23	0.25	0.24	0.27
Choline	1410.68	1288.83	1288.83	1308.81	1311.38	1307.09
Sodium	0.18	0.18	0.18	0.18	0.18	0.16
Chlorine	0.24	0.22	0.66	0.66	0.22	0.22
Potassium	0.71	0.70	0.70	0.70	0.57	0.59

<sup>1</sup>Total sulphur amino acids, <sup>2</sup>Chemically determined

Pre-starter diet fed 0-2 weeks of age, Starter diet fed 2-4 weeks of age, Grower diet fed 4-18 weeks of age.

The flock was vaccinated against all the prevalent diseases in the area in consultation with the local parent stock company. Some of the pullets were sacrificed during the different stages of rearing (6, 12 and 18 weeks of age) for bone analysis as required by Moreki (2005) study.

### **3.2.2 Laying**

At 22 weeks of age 66 birds from each of the three rearing treatments were transferred to individual cages within a room common to all treatments. Hence the data set for this study comprise of a total of 198 individually housed birds assigned to one of the three laying treatments. The single cages were equipped with individual feed troughs, water nipples and perches. The above mentioned group of 198 birds consisted of three groups of 66 birds, which were further divided into three subgroups consisting of 22 birds to which, the following laying calcium levels were provided (1.5%, 2.5%, and 3.5%) resulting in a combination of nine treatments. Data were collected on an individual bird as each bird was considered an experimental unit. The birds were photostimulated at 22 weeks in accordance with Ross breeders' recommendation (Ross Breeders, 1998). The photoperiod was extended with artificial light to 14 and 15 hours at 22-23 weeks respectively, then to 16 hours at 26 weeks of age. The 16 hours of light was held constant until the birds were depopulated at 60 weeks of age.

### **3.2.3 Feeding**

Daily feed allotment per hen was done in accordance with the Ross Breeder's (2001), feed allocation schedule during both the rearing and laying period, while water was provided ad lib. The birds were fed a pre-breeder diet from 19 to 22 weeks of age. The pre-breeder diet containing 1.0%, 1.5% and 2.0% calcium was fed from 19-22 weeks of age. From 23 to 60 weeks of age breeder diets containing 1.0%, 2.5%, and 3.5% calcium were fed in three different phases as seen in Tables 3.3 and 3.4. The 2.5% calcium diet was obtained by mixing the 1.5% and 3.5% calcium diets. The diet of 1.5% calcium was obtained by mixing of 1.0% with 2.0% calcium diets.

**Table 3. 3 Physical composition of the laying diets on air-dry basis**

	Pre-breeder diet		Breeder Phase1		Breeder Phase2		Breeder Phase3	
	1.0%Ca	2.0%Ca	1.5%Ca	3.5%Ca	1.5%Ca	3.5%Ca	1.5%Ca	3.5%Ca
Maize	63.53	63.51	61.92	59.66	63.11	60.81	56.43	62.23
Pollard gluten	-	-	4.45	2.3	1.8	1.0	-	-
Wheat bran	12.65	6.65	5.15	-	6.55	-	14.90	1.00
Full fat soya	-	-	-	10.0	-	9.95	-	1.70
Soybean oil cake	7.75	11.4	8.6	10.3	8.4	7.55	8.75	9.50
Sunflower oil cake	12.45	11.1	15.0	7.75	15.0	10.0	15.0	15.0
Calcium carbonate (grit)	-	-	2.0	6.15	2.3	6.75	2.25	6.60
Calcium carbonate (fine)	1.15	2.2	0.5	1.5	0.6	1.65	0.6	1.65
Calcium monophosphate	1.49	4.25	1.29	1.36	1.40	1.50	1.28	1.53
Salt	0.24	0.26	0.41	0.40	0.43	0.44	0.44	0.44
Bicarbonate	0.20	0.15	-	-	-	-	-	-
Choline liquid	0.04	0.04	0.03	0.03	-	0.03	-	-
Lysine	0.10	0.04	0.15	-	0.10	-	0.03	0.03
Methionine	0.05	0.05	0.005	0.06	0.01	0.05	0.01	0.02
Trace mineral/ vitamin premix	0.35	0.35	0.50	0.50	0.30	0.30	0.30	0.30

Pre-breeder diet fed 19-22 weeks of age

Breeder phase 1 fed 23-34 weeks of age

Breeder phase 2 fed 35-42 weeks of age

Breeder phase 3 fed 43-60 weeks of age

**Table 3.4 Nutrients composition of experimental laying diets on air-dry basis (%)**

	Pre-breeder diet		Breeder Phase1		Breeder Phase 2		Breeder Phase3	
	1.0% Ca	2.0%Ca	1.5%Ca	3.5%Ca	1.5%Ca	3.5%Ca	1.5%Ca	3.5%Ca
Moisture	11.07	10.37	10.58	9.96	9.77	9.10	9.85	9.19
ME (MJ/Kg)	11.96	11.70	12.09	12.00	11.94	11.87	11.46	11.43
Protein	15.22	15.50	18.33	17.72	17.03	16.77	16.68	16.06
Crude fat	3.30	3.06	3.00	4.20	2.97	4.07	3.09	2.98
Crude fibre	7.01	5.99	0.00	0.00	6.65	5.08	8.28	6.64
Ash			6.21	11.23	6.74	12.05	6.90	11.98
Calcium	1.00	2.01	1.51	3.50	1.52	3.50	1.59	3.46
Phosphorus	0.84	1.37	0.78	0.71	0.80	0.74	0.84	0.78
Available phosphorus	0.45	0.90	0.41	0.40	0.43	0.43	0.43	0.54
Arginine	0.98	1.01	1.11	1.12	1.08	1.09	1.10	1.07
Isoleucine	0.60	0.64	0.74	0.76	0.43	0.71	0.67	0.67
Lysine			0.81	0.83	1.08	0.78	0.73	0.72
Methionine	0.35	0.34	0.38	0.38	0.69	0.36	0.33	0.33
TSAA <sup>1</sup>	0.06	0.64	0.73	0.70	0.76	0.67	0.66	0.64
Threonine	0.55	0.57	0.66	0.66	0.35	0.63	0.61	0.60
Tryptophan	0.17	0.18	0.19	0.20	0.68	0.19	0.19	0.18
TA arginine	0.91	0.93	1.04	1.04	0.62	1.01	1.01	0.99
TA isoleucine	0.54	0.57	0.67	0.69	0.18	0.65	0.59	0.60
TAllysine	0.60	0.60	0.70	0.71	0.99	0.67	0.61	0.61
TAmethionine	0.31	0.31	0.34	0.35	0.62	0.33	0.29	0.30
TATSAA	0.57	0.57	0.64	0.63	0.64	0.60	0.57	0.56
TAthreonine	0.48	0.50	0.59	0.59	0.31	0.56	0.26	0.53
TATryptophan	0.15	0.16	0.17	0.18	0.17	0.17	0.17	0.17
AC:Linoleic	1.83	1.68	1.65	2.32	1.65	2.26	1.71	1.64
Xanthophylls			23.51	17.68	17.12	14.66	11.29	12.45
Salt	0.24	0.27	0.42	0.41	0.44	0.44	0.45	0.45
Choline	1300.01	1309.56	1205.18	1204.08	1008.79	1003.18	1087.10	993.06
Sodium	0.16	0.16	0.18	0.18	0.19	0.20	0.20	0.20
Chlorine	0.22	0.57	0.33	0.29	0.33	0.31	0.32	0.32
Potassium	0.60	0.60	0.60	0.63	0.63	0.63	0.71	0.61
Magnesium			0.22	0.20	0.23	0.21	0.25	0.23
Manganese			46.82	63.94	50.82	68.71	61.84	71.60

<sup>1</sup>Total sulphur amino acids

The experimental diets were formulated to be isocaloric and isonitrogenous with varying levels of calcium. Feed intake per hen was recorded on a weekly basis while individual bodyweight measurements were recorded on a three weekly interval (27 through 60 weeks of age).

### **3.3 Performance variables**

#### **3.3.1 Egg production parameters**

Egg production was recorded daily and summarized on a weekly basis throughout the experimental period. The egg abnormalities *i.e.* misshapen, cracked, soft-shelled and shell-less eggs were also recorded and calculated for production. Each hen was considered an experimental unit therefore cumulative egg production was calculated on per hen basis. Commencement of lay was regarded as the day when the first egg was laid, while peak production was the day/week when maximum percentage of lay was recorded. Weekly percentage egg production was calculated for the specified weeks from 27 to 60 weeks of age (Ali *et al.*, 2003).

Individual egg weights were recorded on a daily basis throughout the production period. Those eggs with multiple yolk and defective shells were also included in the daily egg weight measurement recordings. The average egg weights were summarized on a weekly basis. Average egg output (mass) was determined on a three-week interval at the following ages (*i.e.* 27, 30, 33, and 36 weeks). Average egg output (percent egg production multiply by egg weight) was calculated (Harms 1991; Ross Breeders, 1998).

#### **3.3.2 Eggshell quality**

A sample of three eggs per bird was randomly taken from the five-day collection period during the three-week intervals (*i.e.* 27, 30, 33, 36 weeks of age), to determine eggshell thickness and eggshell weight. The sample of three eggs was stored in a cool room following the recording of egg weights. For the determination of eggshell thickness with membranes, eggs were broken and their contents were removed. Eggshells with membranes were rinsed with cold water to clean adhering albumin and yolk and then dried with a paper towel. Two small pieces of the eggshell were taken along with

membranes from three locations on the egg (sharp end, equator and broad end), to measure eggshell thickness using an eggshell thickness meter (0.01 mm). The whole eggshell was then placed in a crucible and oven dried at 60°C overnight, then cooled and weighed. Percentage eggshell was calculated by dividing dry shell weight by fresh egg weight and multiplying by 100 (Peebles & Mark, 1991; Chowdhury & Smith, 2001).

### **3.3.3 Calcium retention**

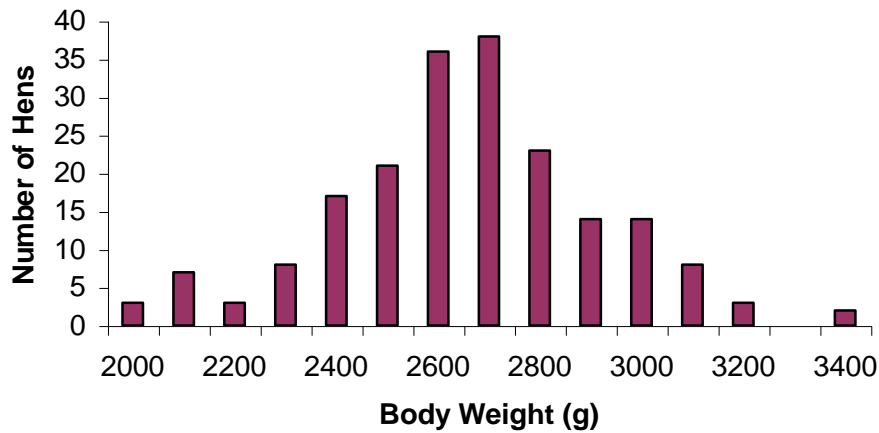
The experiment was conducted for a period of 15 weeks (27 to 42 weeks of age). The hens were housed in individual cages with separate feeders, and metal trays placed below the cages for the collection of excreta. The excreta from 90 hens were collected during a 7-day period at a 3-weekly interval (27, 33, 36 and 42 weeks of age). Excreta samples were collected on metal trays, and transferred into paper bags and dried in the oven at 100 °C for 24 to 48 hours and then air-cooled. Thereafter, dried excreta were weighed and pulverized using a hammer mill with a 1 mm sieve. The pulverized samples were homogenized before taking a representative sample for the determination of calcium by atomic absorption spectrophotometry (Hocking *et al.*, 2002).

Approximately 1-gram sample of excreta were ashed in a muffle furnace at 550 °C for 16 hours and digested in 10 ml nitric acid (Keshavarz, 1986). Calcium retention was calculated by subtracting shell Ca, egg contents Ca, and faecal Ca from the hen's Ca intake in accordance to the procedure of MacFarlane & Gous (1993). In order to cancel differences in Ca intake as a factor, Ca retention was also expressed as a percentage of the Ca intake. Ca content of the egg (g Ca/bird/day) was calculated by multiplying eggs weighing 50 or 60 g by 0.025 and 0.030, respectively (Simons, 1986). Shell Ca (mg/g) was obtained by multiplying average eggshell weight (g) by 373 mg/g.

### **3.4 Body weight distribution**

Figure 1 demonstrates BW distribution of the broiler breeder hens at the onset of lay. This formed a point of reference for the separation of hens into three distinctive BW groups. The hens were separated into three BW groups at 23 weeks of age based on their

individual BW i.e. (high, medium and low BW group). The mean BW and standard deviation of the experimental hens was calculated. The low BW group consisted of hens with BW less than  $-1.0$  standard deviation from the mean; the medium group were hens with BW between  $-0.25$  and  $+0.25$  standard deviation from the mean; the high BW group were hens with more than  $+1$  standard deviation from the mean BW.



**Figure 3.1** Frequency distribution of BW (100-g increments) of 198 broiler breeder hens at the onset of lay (week 23 of age).

### 3.5 Statistical analysis

Data collected from one hundred and eighty laying broiler breeder hens placed in single cages from week 27 to 60 were statistically analysed. Multiple measurements of a response on the same bird were taken during the above-mentioned weeks. Prior to the statistical analysis the data were corrected for the levels of calcium intake as described in Chapter 4. The data were analysed using Proc ANOVA of SAS (1999) to determine the effect of different BW groups on performance traits. Tukey's honest significant difference test was used to determine which BW groups differ significantly.



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## CHAPTER 4

### THE INFLUENCE OF BODY WEIGHT OF BROILER BREEDER HENS ON EGG PRODUCTION PARAMETERS AND EGGSHELL QUALITY

#### 4.1 Introduction

The performance of broiler breeder hens during the laying period is very critical. In this regard the number of eggs laid as well as the quality of the eggshell are important, as they determine the total number of day-old chicks produced in a breeding operation. Shell quality is of major concern in broiler hatching eggs because of breakage and overall hatchability. There are a number of factors that affect egg production and eggshell quality. Body weight (BW) at onset of lay has been identified as among the most influential factors affecting the performance of broiler breeder hens (Ciacciariello & Gous, 2005). In order to improve reproduction efficiency and reduce weight gain, broiler breeder hens are normally placed under restricted feeding practice (Bowmaker & Gous, 1989). Breeding companies have over the years provided guidelines to be adhered to in order to attain specific target BW's.

Studies have been conducted (Gous & Cherry, 2004; Robinson & Robinson, 1991; Yuan *et al.*, 1994; Hudson *et al.*, 2001) to establish the relationship between (BW) and subsequent laying performance of broiler breeder hens. Contradicting observations and differing views have been reported over the years. One view is that BW has no effect on the egg production performance of broiler breeder hens (Triyuwanta *et al.*, 1992; Renema *et al.*, 2001; Gous & Cherry, 2004). Other authors (Harms *et al.*, 1982) reported that BW had an effect on performance at certain stages of lay. According to Fleming (2005) higher than target BW's are generally associated with heavier egg weights that have poor eggshell quality. Robinson & Robinson (1991) and Hudson *et al.* (2001), reported that underweight hens tend to have a low egg output. Although the relationship between BW and production performance of broiler breeder hens has been covered extensively, the effect of BW at the onset of laying has received limited attention. Therefore further

investigation is required to better understand the influence of BW at commencement of lay on the subsequent laying performance of broiler breeder hens.

The current trial was undertaken to ascertain the extent to which variation in BW at the onset of lay has an influence on the subsequent performance and eggshell quality of broiler breeder hens.

## **4.2 Materials and Methods**

One hundred and ninety eight broiler breeder hens were placed in individual cages equipped with feed troughs, water nipples and perches at the onset of lay (23 weeks of age). The hens were subjected to quantitative restricted feeding during both the rearing and the laying period. The birds were photostimulated at 22 weeks in accordance with Ross breeders' recommendation (Ross Breeders, 1998). The photoperiod was extended with artificial light to 14 and 15 hours at 22-23 weeks respectively, then to 16 hours at 26 weeks of age. The 16 hours of light was held constant until the birds were depopulated at 60 weeks of age. The husbandry and the methods followed during the rearing and collection of data have been described in Chapter 3. Data on egg production parameters; egg weights, egg output, egg content and eggshell quality were collected from 27 to 60 weeks of age. The procedures followed in the collection of data are detailed below.

### **4.2.1 Bodyweight distribution**

The separation of hens into three BW groups is detailed and demonstrated in Chapter 3. The hens were assigned into three distinct groups based on their BW at the onset of lay. The Low BW hens had a minimum BW of 2007 g and a maximum BW of 2447 g with a standard deviation of -264 g. The Medium BW hens had a minimum BW of 2645 g and a maximum BW of 2777 g with a standard deviation of 66 g. The High BW hens had a minimum of 2975 g and a maximum BW of 3445 g with a standard deviation of +264 g.

#### **4.2.2 Performance variables**

Egg production was recorded daily and summarized on a weekly basis throughout the experimental period. The egg abnormalities *i.e.* misshapen, cracked, soft-shelled and shellless eggs were also recorded and calculated for production. Each hen was considered an experimental unit therefore cumulative egg production was calculated on per hen basis. Commencement of lay was regarded as the day when the first egg was laid, while peak production was the day/week when maximum percentage of lay was recorded for a period of one week. Weekly percentage egg production was calculated using the formula given by North & Bell (1990), for the specified weeks from 27 to 60 weeks of age.

Individual egg weights were recorded on a daily basis throughout the production period. Those eggs with multiple yolk and defective shells were also included in the daily egg weight measurement recordings. The average egg weights were summarized on a weekly basis. Average egg output (mass) was determined on a three-week interval at the following ages (*i.e.* 27, 30, 33, and 36 weeks). Average egg output (percent egg production multiply by egg weight) was also calculated (Harms, 1991; Ross Breeders, 1998).

#### **4.2.3 Eggshell quality**

A sample of three eggs per bird was randomly taken from the five-day collection period during the three-week intervals (*i.e.* 27, 30, 33, 36 weeks of age), to determine eggshell thickness and eggshell weight. The sample of three eggs was stored in a cool room following the recording of egg weights for all eggs. For the determination of eggshell thickness with membranes, eggs were broken and their contents were removed. Eggshells with membranes were rinsed with cold water to clean adhering albumin and yolk and then dried with a paper towel (Kul & Seker, 2004). Two small pieces of the eggshell were taken along with membranes from three locations on the egg (sharp end, equator and broad end). Eggshell thickness was measured using an Eggshell Thickness Meter sensitive to 0.01 mm (Soliman, *et al.*, 1994; Ehtesham & Chowdhury, 2002; Kul &

Seker, 2004). The two measurements from each of the three regions were averaged to obtain three eggshell thickness values (sharp, equator and broad end).

The whole eggshell was then placed in a crucible and oven dried at 60°C overnight, then cooled and weighed. Percentage eggshell was calculated by dividing dry shell weight by fresh egg weight and multiplying by 100 (Peebles & Mark, 1991; Chowdhury & Smith, 2001). Other external quality traits (egg surface area (ESA), shell weight per unit surface area (SWUSA)) of the egg were estimated using a published formulae (Carter, 1975). Egg surface area ( $\text{cm}^2$ ) =  $3.9782W^{0.7056}$  where W is the egg weight in grams. Shell weight per unit surface area ( $\text{mg}/\text{cm}^2$ ) = egg weight/egg surface area. Egg content weight was obtained by subtracting eggshell weight from the egg weight.

### **4.3 Statistical analysis**

Prior to subjection to analysis the data was corrected for the possible effects of the three levels of calcium during both the rearing and laying periods. The data during the laying period (27 to 60 weeks of age) were analysed, where each hen served as a replicate. The data were analysed using Proc ANOVA of SAS (1999) to determine the effect of BW groups on egg production parameters and eggshell quality. Tukey's honest significance test at a significance level of 5% was used to determine which BW groups differ significantly.

## 4.4 Results and Discussion

### 4.4.1 Egg production

The influence of BW of broiler breeder hens at the onset of lay (week 23 of age) on egg production is presented in Tables 4.1, 4.2 and 4.3 as well as Figure 4.1. Egg production for the different BW groups did not differ significantly ( $P>0.05$ ). These results are in agreement with the findings of Harms *et al.*, (1982), Triyuwanta *et al.*, (1992) Yuan *et al.*, (1994); Renema *et al.*, (2001) and Gous & Cherry, (2004) who recorded similar egg production rates which were not affected by BW. The same results were also observed in layer hens by Harms *et al.*, (1982). These findings suggest that BW at the onset of lay may not be the correct point of reference to measure/predict the subsequent laying performance of broiler breeder hens. The extra BW on the heavier hens did not negatively affect egg production. It seems that as soon as the hens started laying the nutrients were diverted to production, hence similar rates of production. It seems that the heavier BW of hens and their higher maintenance requirements did not negatively affect egg production.

On the contrary Lilburn & Myers-Miller (1990), reported that the high BW hens significantly ( $P<0.06$ ) produced more total and settable eggs than the hens in the low BW group during 24 to 28 and 28 to 32 weeks of age. The hens in their study were separated into BW groups based on their weight at 16 weeks of age compared to 23 weeks of age of the present study. This could be a source of contradicting results. Ciacciariello & Gous (2005), reported that hens on target BW and those above target BW had a significantly higher peak lay rate and laid more eggs to 56 weeks of age compared to the hens that were below target BW. However the number of settable eggs was similar between the different BW groups, as the number of double-yolked eggs drastically reduced the number of settable eggs laid by the hens in the average and high BW group (Ciacciariello & Gous, 2005). Robinson & Robinson (1991) also recorded that low-weight hens laid significantly fewer eggs than the medium and high BW hens. In the present study there was only a tendency albeit not significant ( $P<0.1376$ ) of a mean lower egg production by the light hens (Table 4.2) from the commencement of lay up to 36 weeks of age.

**Table 4.1 The influence of body weight on egg production parameters of broiler breeder hens during 27-60 weeks of age**

Variable	BW	Age in Weeks											
		27	30	33	36	39	42	45	48	51	54	57	60
<b>Egg Production (%)</b>	<b>Low</b>	52.59±27.3	81.63±17.6	62.99±16.9	70.63±28.4	76.73±11.9	78.02±11.1	67.03±15.9	54.95±15.3	53.85±15.6 <sup>a</sup>	57.14±17.2	60.71±18	48.81±14.2
	<b>Medium</b>	55.80±29.6	86.16±14.3	69.12±15.7	73.63±24.8	66.88±17.3	74.03±20.5	63.64±21.5	55.84±21.1	57.85±15.0 <sup>a</sup>	55.71±17.9	51.88±19.2	46.62±18.9
	<b>High</b>	65.38±20.3	80.77±18.9	65.38±16.7	77.92±16.9	72.11±17.2	80.95±13.8	72.79±11.9	56.46±15.9	68.57±12.8 <sup>b</sup>	60.90±16.4	59.29±15.6	56.46±14.6
	<b>Significance (P)</b>	0.2072	0.4272	0.3913	0.6168	0.3426	0.3840	0.2203	0.9720	0.0116	0.6324	0.2606	0.1488
<b>CV</b>	45.21	20.19	24.74	31.77	22.90	21.04	25.22	32.28	23.59	29.64	29.29	31.839	
<b>Egg Weight (g)</b>	<b>Low</b>	51.71±3.6 <sup>a</sup>	58.48±3.1 <sup>a</sup>	60.31±3.1	61.59±3.3	62.93±2.8	65.49±2.7 <sup>a</sup>	68.07±2.9	69.48±2.4	70.64±3.9	71.38±3.39	71.98±4.48	72.71±4.12
	<b>Medium</b>	53.19±4.3 <sup>a</sup>	59.86±3.3 <sup>ab</sup>	61.59±4.5	61.24±13.6	64.19±4.4	68.75±4.4 <sup>ab</sup>	70.99±4.1	72.05±5.37	72.11±5.04	73.92±4.76	72.98±6.56	74.02±5.08
	<b>High</b>	57.06±5.6 <sup>b</sup>	61.21±4.3 <sup>b</sup>	62.68±5.0	64.47±4.2	65.14±4.6	68.98±4.6 <sup>b</sup>	70.83±4.8	71.64±5.36	71.64±5.36	73.93±4.55	74.31±4.7	75.13±5.64
	<b>Significance (P)</b>	0.0003	0.0403	0.1772	0.4306	0.3274	0.0440	0.1034	0.3020	0.3504	0.2256	0.4846	0.4286
<b>CV</b>	8.52	6.02	7.057	14.53	6.47	6.09	5.88	6.81	6.83	6.0008	7.4170	6.9127	
<b>Egg Output (g)</b>	<b>Low</b>	27.70±15.4	47.85±10.9	38.01±10.4	43.28±17.8	47.13±8.5	51.08±7.5	45.86±11.8	38.35±11.2	38.15±11.9 <sup>a</sup>	40.80±12.7	43.85±10.9	35.66±11.2
	<b>Medium</b>	30.04±16.4	51.68±9.7	42.77±10.5	47.09±16.9	42.76±11.3	50.69±13.7	44.86±14.7	40.40±15.9	41.74±11.3 <sup>a</sup>	41.29±14.3	37.91±13.9	34.57±14.2
	<b>High</b>	37.60±12.9	49.54±12.4	40.82±10.4	50.14±11.0	47.37±7.6	55.80±9.9	51.59±9.1	40.65±12.2	50.10±9.5 <sup>b</sup>	45.01±12.5	43.95±11.7	42.76±12.3
	<b>Significance (P)</b>	0.0575	0.4534	0.2687	0.3840	0.3530	0.2802	0.1716	0.3020	0.0069	0.5962	0.2577	0.1082
<b>CV</b>	47.29	21.96	25.58	32.89	24.90	21.18	25.56	34.12	24.58	31.1496	29.76	33.6129	
<b>Egg Content (g)</b>	<b>Low</b>	47.69±3.4 <sup>a</sup>	54.23±3.1	56.80±3.1	57.66±3.62	59.06±3.8	61.14±3.6	64.06±3.9	65.26±3.9	67.03±4.9	66.86±4.4	66.60±3.9	67.36±4.6
	<b>Medium</b>	49.62±4.0 <sup>b</sup>	54.82±6.6	57.18±5.8	58.17±4.85	58.54±4.1	61.89±4.6	63.73±3.7	65.18±3.8	66.25±3.8	66.68±3.8	66.11±4.9	68.03±4.6
	<b>High</b>	52.91±6.6 <sup>b</sup>	56.21±5.9	58.16±5.4	58.99±3.61	59.91±3.5	62.30±3.8	65.20±3.9	65.99±3.69	66.39±3.5	67.61±4.1	67.15±4.0	69.73±4.36
	<b>Significance (P)</b>	0.0001	0.0784	0.2517	0.1723	0.0972	0.3007	0.0706	0.4029	0.5979	0.4299	0.4819	0.0559
<b>CV</b>	10.21	10.37	8.89	7.13	6.45	6.65	5.97	5.77	6.06	6.05	6.47	6.61	

Means (mean±SD) calculated for each BW group, means within a column with no common superscript differ significantly at (P<0.05).

CV=Coefficient of variation.



**Table 4.2 The influence of body weight on the mean egg production performance of broiler breeders from the commencement of lay up to 36 weeks of age.**

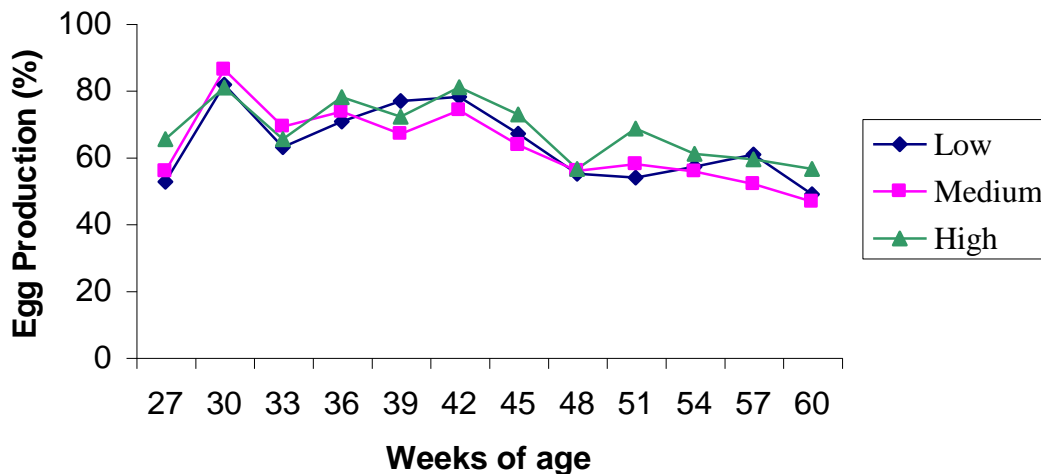
Variable	BW	Mean±SD	Significance (P)	CV
<b>Egg Production (%)</b>	<b>Low</b>	70.44±9.9	0.1376	11.29
	<b>Medium</b>	74.12±8.2		
	<b>High</b>	74.06±6.5		
<b>Egg Weight (g)</b>	<b>Low</b>	59.41±3.2	0.1091	6.19
	<b>Medium</b>	59.16±3.4		
	<b>High</b>	60.92±4.4		
<b>Egg Output (g)</b>	<b>Low</b>	42.95±6.9 <sup>a</sup>	0.0071	12.99
	<b>Medium</b>	46.09±5.7 <sup>ab</sup>		
	<b>High</b>	47.90±5.4 <sup>b</sup>		
<b>Egg Content (g)</b>	<b>Low</b>	55.54±3.17	0.2750	6.15
	<b>Medium</b>	55.57±3.49		
	<b>High</b>	56.78±3.59		

Means (mean±SD) are calculated for each BW group; means within a column with no common superscript differ significantly at (P<0.05).  
CV= Coefficient of variation.

**Table 4.3 The influence of body weight on the mean egg production performance of broiler breeders from the commencement of lay up to 60 weeks of age.**

Variable	BW	Mean±SD	Significance (P)	CV
<b>Egg Production (%)</b>	<b>Low</b>	68.98±8.08	0.5618	12.29
	<b>Medium</b>	66.51±9.36		
	<b>High</b>	66.71±6.58		
<b>Egg Weight (g)</b>	<b>Low</b>	70.07±3.97	0.3133	5.95
	<b>Medium</b>	69.94±4.17		
	<b>High</b>	71.55±4.38		
<b>Egg Output (g)</b>	<b>Low</b>	48.09±6.07	0.5499	13.52
	<b>Medium</b>	46.27±7.09		
	<b>High</b>	47.66±5.48		
<b>Egg Content (g)</b>	<b>Low</b>	63.75±3.53	0.2938	5.04
	<b>Medium</b>	64.03±3.29		
	<b>High</b>	65.15±2.93		

Means (mean±SD) are calculated for each BW group; means within a column with no common superscript differ significantly at (P<0.05).  
CV= Coefficient of variation.



**Figure 4.1** The influence of bodyweight of broiler breeder hens on egg production during the laying period.

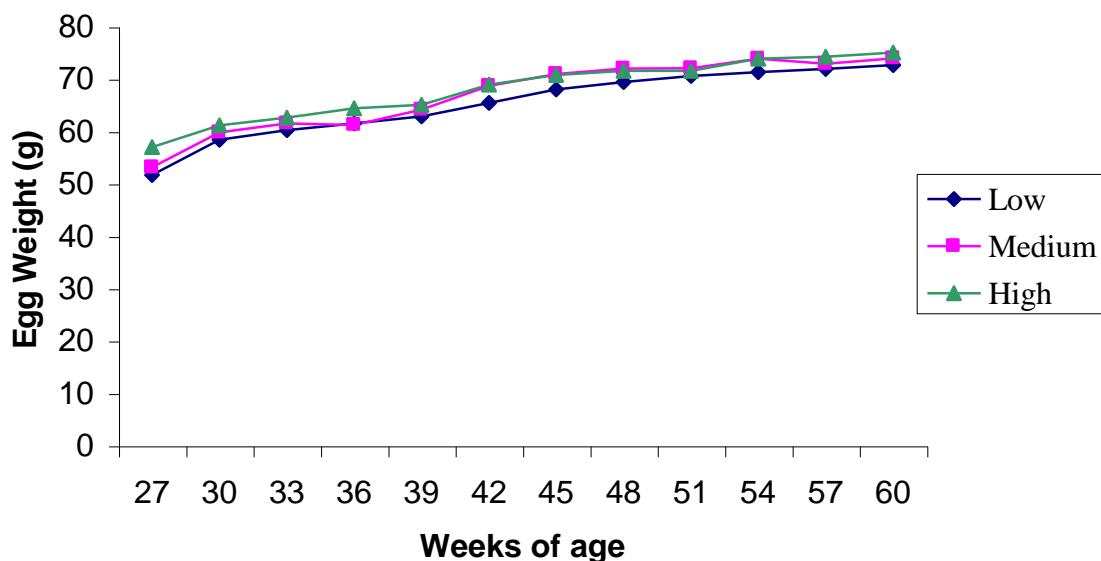
Leeson *et al.*, (1997) in their study on layer hens reported that the smaller hens reached sexual maturity (matured) slower than the heavy hens. Furthermore the heavier hens laid significantly more eggs than the light hens at week 22 of age only. After week 22 there were no real differences in the egg numbers between the heavy and the light hens. The hens in the low BW subsequently eat less feed and therefore produce fewer and smaller eggs (Leeson *et al.*, 1997). In the current study restricted feeding was practiced, and this could be the reason for inconsistent results to those obtained by Leeson *et al.*, (1997).

#### 4.4.2 Egg weight

Table 4.1 as well as Figure 4.2 indicates that BW at onset of lay significantly ( $P < 0.05$ ) influenced egg weight only during the initial stages (week 27 and 30 of age) of lay, as well as week 42 of age. During these weeks a high BW resulted in significantly ( $P < 0.05$ ) heavier eggs weights compared to the low BW groups. These findings demonstrate that the additional BW at the onset of lay had a beneficial effect on early egg weights. Egg weights were not significantly ( $P < 0.05$ ) different among the BW groups for the remainder of the laying period up to 60 weeks of age, except for week 42 of age. Similar results were reported by Summers *et al.* (1991), on layer-type hens were BW had an effect on egg weights during the first two weeks into production. These results are

however in contrast to those reported by Renema *et al.* (2001), where similar initial (27 to 30 week) egg weights were recorded among the different BW groups.

In their study Renema *et al.* (2001), reported that the egg weights for the different BW groups were however not similar for the remainder of the laying period through to week 58 of age. The egg weights differed to a maximum of 1.9 g during the period of weeks 55 to 58 of age. The 300 g higher BW profile of high compared to low-weight hens was enough to significantly increase egg weights. However Fattori *et al.* (1991) reported that there were no significant differences in weekly egg weights among the BW targets of 8% below standard BW target, standard BW target and 8% above standard BW target throughout the laying period. Similarly Yuan *et al.* (1994) reported that no statistical differences were observed in mean egg weights among the light and the heavy hens. The egg weight results of the present study, shown in Tables 4.2 and 4.3 are consistent with the findings of both Fattori *et al.* (1991) and Yuan *et al.* (1994). In contrast Ciacciariello & Gous (2005), reported that hens in low BW group laid eggs with a significantly ( $P<0.05$ ) low mean egg weights than the hens in the average and high BW group for 23-56 weeks of age. These results suggested that lower than target BW could have a negative effect on the laying performance of broiler breeder hens.



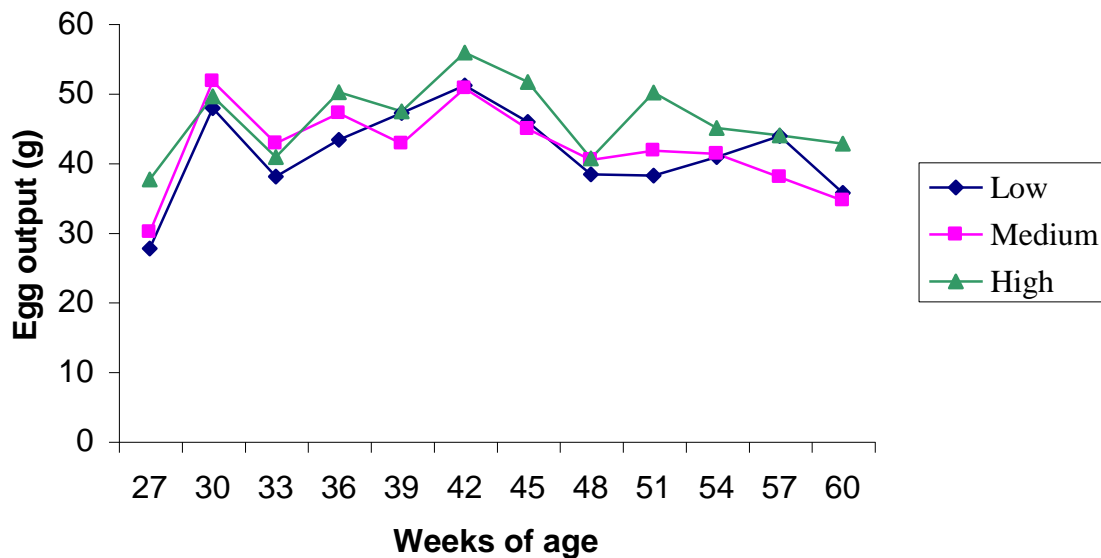
**Figure 4.2** The influence of bodyweight of broiler breeder hens on egg weight during the laying period.

### 4.4.3 Egg output

Egg output (mass) is a measure of the performance of laying hens, as it is the product of egg production and egg weight. Egg output (mass) is computed by multiplying mean percentage egg production by mean egg weight (Harms, 1991; Ross Breeders, 1998).

There were no significant ( $P>0.05$ ) differences found between the different BW groups regarding egg output for the duration of the experiment (Tables 4.1 and 4.3 as well as Figure 4.3). The high BW hens continued (Table 4.1) to have a numerically higher egg output, though it was found not to be significantly ( $P>0.05$ ) different on a weekly basis. Comparing these results with studies previously conducted revealed contrasting results. In their studies Harms *et al.* (1982), and Leeson *et al.* (1997), reported significant ( $P<0.05$ ) differences in egg output between the different BW groups, where the high BW hens showed a higher egg output than both the low and medium BW groups. Harms *et al.* (1982), concluded that there is a relationship between egg output and BW, as egg output numerically increased with BW. Accordingly egg output is more a function of egg weight than that of egg production.

The results of the current study for the total laying period (Tables 4.1 and 4.3) did not confirm these findings. A summary of egg output from commencement of lay up to 36 weeks of age (Table 4.2) however supports the findings of Harms *et al.* (1982). The heavy hens had a significantly ( $P=0.0071$ ) higher egg output of 4.95 g and 1.81 g than the hens in the low and medium BW group respectively. These results suggest that the mean egg output was positively related to BW during the earlier stages of lay (up to 36 weeks of age). It further seems from Table 4.2 that egg output was a function of both egg production and egg weight. The additional 3.62 % egg production and 1.51 g egg weight by the heavy hens compared to light hens was sufficient to effect a 4.95 g higher egg output during early lay. Comparing the high and medium BW groups revealed however no significant ( $P>0.05$ ) differences in egg output during early lay.



**Figure 4.3** The influence of bodyweight of broiler breeder hens on egg output during the laying period.

#### 4.4.4 Egg content

Egg content was found to be only significantly ( $P < 0.05$ ) different between the BW groups during week 27 (Table 4.1). The high BW group hens yielded the highest egg content (52.91 g), followed by medium BW (49.62 g), and lastly the lightest hens (47.69 g). The high BW group hens continued to have a numerically higher yield of egg content throughout the laying period. It was however not statistically different between the BW groups throughout the laying period. No literature regarding the influence of BW on egg content could be found in the available literature.

#### 4.5 Eggshell quality

Eggshell quality is frequently used as a synonym for shell strength and denotes the ability of the eggshell to withstand externally applied forces without breaking or cracking (Hamilton, 1982). Eggshell quality can be defined by variables such as egg specific gravity through its relationship to shell porosity as shown by positive correlation with pore concentration (Peebles & Brake, 1987).

The results for eggshell thickness are presented in Tables 4.4, 4.5 and 4.6. With the exception of weeks 27, 30, 33 and 36 no significant ( $P > 0.05$ ) influence of initial BW of

broiler breeder hens on eggshell thickness could be observed. The significant ( $P < 0.05$ ) differences, which occurred during the early stages of lay, indicate that a high BW could result in thicker eggshells during this period of lay. This was however not supported by the statistical analysis of summarised mean shell thickness up to 36 weeks of age (Table 4.5).

No significant influence of BW on eggshell thickness during the later stages of lay was observed. Similarly BW did not significantly influence the mean eggshell thickness from the commencement of lay up to 60 weeks of age. These findings are in agreement with those reported by Triyuwanta *et al.* (1992), on dwarf broiler breeder hens; though the hens were assigned to different BW groups based on their BW at 21 weeks of age. No significant differences in shell index and shell breaking strength were reported by these researchers between the hen weight groups from 43 to 57 weeks of age. However an interaction between BW and feed restriction was highly significant ( $P < 0.01$ ) on the shell index. A decrease in the shell index was observed in the weighing groups that were subjected to the highest feed intake. The differences in the results could be because the hens in the current study were provided with the same quantity of feed. Leeson *et al.* (1997) reported that BW did not have a significant effect on the production of eggs with shell deformities from 22 to 70 weeks of age in layer hens.

According to Larbier & Leclercq (1992) and Al-Batshan *et al.* (1994), physiologically eggshell weight diminishes slightly with as the hen ages whilst the total egg weight increases resulting in thinner eggshells that are also weak. These authors are of the opinion that larger eggs than normal require more shell but the hen is unable to increase the amount of shell produced as the hen gradually loses her ability to mobilize calcium from the bones resulting in thinner eggshells. Naber (1980), stated that the hen has a tendency to secrete constant amount of calcium to cover an egg without regard to its size. In the present study heavier egg weights were observed for high BW hens during the initial stages of lay. Accordingly thicker eggshells were recorded during the early stages of lay (Table 4.4). Therefore above conclusions were not supported by the results of the present study.

**Table 4.4. The influence of bodyweight on eggshell thickness parameters of broiler breeder hen during weeks 27-60.**

Variable	BW	Age in Weeks											
		27	30	33	36	39	42	45	48	51	54	57	60
<b>Sharp End (mm)</b>	<b>Low</b>	39.54±3.71	40.18±3.06	39.21±2.96	39.40±2.9 <sup>ab</sup>	40.71±2.57	41.32±2.71	41.69±2.70	40.27±3.33	39.94±3.72	39.92±3.02 <sup>a</sup>	40.04±3.04	39.04±3.33 <sup>a</sup>
	<b>Medium</b>	39.24±2.78	39.97±3.35	38.49±2.96	38.77±3.2 <sup>a</sup>	40.18±3.67	41.67±2.68	42.49±2.84	40.61±2.75	39.89±3.14	40.97±2.37 <sup>b</sup>	41.20±2.77	40.75±3.33 <sup>b</sup>
	<b>High</b>	40.06±3.46	40.88±3.79	39.03±4.02	39.94±3.1 <sup>b</sup>	39.96±3.91	41.81±2.96	42.29±2.96	40.84±2.59	40.03±3.21	39.88±2.75 <sup>a</sup>	40.53±2.71	39.96±2.84 <sup>b</sup>
	Significance (P)	0.3084	0.1527	0.3221	0.0564	0.5094	0.6139	0.3202	0.5904	0.9727	0.0475	0.1508	0.0524
CV	8.07	8.48	8.53	7.83	8.71	6.686	6.7400	7.0188	8.318	6.5882	6.9517	6.808	
<b>Equator (mm)</b>	<b>Low</b>	38.97±3.2 <sup>ab</sup>	39.66±3.1 <sup>ab</sup>	38.79±2.9 <sup>a</sup>	38.91±2.6 <sup>ab</sup>	39.71±2.92	40.74±2.72	41.53±2.64	40.11±2.96	39.68±3.16	40.17±2.19	39.69±2.84	38.99±3.03
	<b>Medium</b>	38.19±2.9 <sup>a</sup>	38.93±3.4 <sup>b</sup>	37.64±2.9 <sup>b</sup>	37.99±3.1 <sup>b</sup>	39.42±3.63	40.49±2.89	41.51±2.73	39.39±2.68	38.53±3.10	40.44±2.34	39.97±2.67	40.17±1.97
	<b>High</b>	39.62±3.3 <sup>b</sup>	40.09±3.9 <sup>a</sup>	38.55±3.9 <sup>a</sup>	39.15±3.1 <sup>a</sup>	39.62±3.58	41.23±2.93	41.73±3.18	40.31±2.45	39.59±2.88	40.55±2.46	40.88±2.72	40.08±2.47
	Significance (P)	0.0285	0.0542	0.0415	0.0322	0.8817	0.2545	0.8966	0.1025	0.0812	0.7556	0.0959	0.1453
CV	8.12	8.94	8.47	7.69	8.698	7.0203	6.895	6.7125	7.7566	5.8222	6.8040	5.9826	
<b>Broad End (mm)</b>	<b>Low</b>	38.80±3.1 <sup>ab</sup>	39.61±2.9 <sup>ab</sup>	38.59±2.96	38.56±2.8 <sup>ab</sup>	39.87±2.48	40.77±2.48	41.59±2.75	39.97±2.74	39.74±2.86	40.66±2.10	40.10±3.73	39.75±3.67
	<b>Medium</b>	38.57±2.9 <sup>a</sup>	39.26±3.5 <sup>a</sup>	37.56±2.72	37.98±3.0 <sup>a</sup>	39.19±3.64	40.77±2.51	41.89±2.50	39.75±2.71	39.04±3.52	40.98±2.64	40.54±3.02	40.23±3.16
	<b>High</b>	39.88±3.5 <sup>b</sup>	40.49±4.1 <sup>b</sup>	38.38±3.79	39.09±2.7 <sup>b</sup>	39.46±3.77	41.02±2.04	42.25±2.93	40.15±2.69	39.85±3.03	40.84±2.64	40.95±2.81	40.47±2.08
	Significance (P)	0.0446	0.0428	0.0657	0.0452	0.5459	0.8133	0.4646	0.6729	0.3242	0.8368	0.3788	0.6508
CV	8.02	8.965	8.226	7.374	8.690	6.5759	6.442	6.7896	8.0696	6.2080	7.0685	7.2375	

Means (mean±SD) calculated for each BW group, means within a column with no common superscript differ significantly at (P<0.05).

CV=Coefficient of variation.

**Table 4.5. The influence of bodyweight on mean eggshell thickness parameters of broiler breeder hens from commencement of laying up to 36 weeks of age**

Variable	BW	Mean±SD	Significance (P)	CV
Sharp End (mm)	Low	39.51±2.37	0.5941	6.66
	Medium	39.08±2.22		
	High	39.71±3.26		
Equator (mm)	Low	39.08±2.32	0.2568	6.47
	Medium	38.27±2.25		
	High	39.16±2.95		
Broad End (mm)	Low	38.92±2.35	0.3090	6.32
	Medium	38.41±2.19		
	High	39.31±2.85		

Means (mean±SD) are calculated for each BW group; means within a column with no common superscript differ significantly at (P<0.05).

CV= Coefficient of variation.

**Table 4.6. The influence of bodyweight on mean eggshell thickness parameters of broiler breeder hens from commencement of laying up to 60 weeks of age**

Variable	BW	Mean±SD	Significance (P)	CV
Sharp End (mm)	Low	40.49±1.91	0.7842	4.082
	Medium	40.87±1.91		
	High	40.81±2.07		
Equator (mm)	Low	40.20±1.67	0.5703	4.999
	Medium	39.98±2.22		
	High	40.54±1.93		
Broad End (mm)	Low	40.33±1.53	0.7118	4.963
	Medium	40.21±2.25		
	High	40.64±1.93		

Means (mean±SD) are calculated for each BW group; means within a column with no common superscript differ significantly at (P<0.05).

CV= Coefficient of variation.

In Tables 4.7, 4.8 and 4.9 the results for shell percentage, shell weight, shell weight per unit surface area (SWUSA) and egg surface area are presented. There were no significant differences detected in shell percentage between the BW groups throughout the laying period. Significant (P<0.05) differences were however occasionally observed in shell weight during the initial stages of lay, post peak and at the end of the laying period (Table 4.7).



**Table 4.7. The influence of bodyweight on eggshell percentage (%), shell weight (g) and SWUSA (mg/cm<sup>2</sup>) of broiler breeder hens during 27-60 weeks of age**

Variable	BW	Age in Weeks											
		27	30	33	36	39	42	45	48	51	54	57	60
Shell Percentage (%)	Low	9.06±1.58	9.11±0.68	8.75±0.75	8.70±0.55	8.65±0.51	8.84±0.53	8.87±0.58	8.69±0.66	8.75±0.63	8.83±0.48	8.68±0.63	8.59±0.79
	Medium	9.10±0.76	9.01±1.08	8.53±0.70	8.65±0.86	8.55±0.86	8.83±0.63	8.84±0.66	8.65±0.69	8.72±0.74	8.86±0.61	8.83±0.89	8.79±0.68
	High	9.24±0.93	9.11±0.99	8.69±1.17	8.75±0.68	8.52±0.83	9.04±0.76	8.76±0.67	8.86±0.62	8.89±0.64	8.85±0.61	8.89±0.69	8.81±0.74
	Significance (P)	0.6119	0.6707	0.2162	0.7126	0.6440	0.0772	0.6552	0.1428	0.3804	0.9836	0.4147	0.5087
CV		10.58	10.69	10.18	8.35	9.04	7.38	7.29	7.59	7.71	6.59	8.54	8.30
Shell Weight (g)	Low	4.76±0.89 <sup>a</sup>	5.49±0.49	5.43±0.43 <sup>ab</sup>	5.49±0.56	5.58±0.39	5.92±0.47 <sup>a</sup>	6.24±0.55	6.21±0.59 <sup>ab</sup>	6.42±0.60	6.48±0.59	6.34±0.62	6.34±0.71 <sup>a</sup>
	Medium	4.96±0.45 <sup>a</sup>	5.45±0.52	5.32±0.52 <sup>b</sup>	5.50±0.49	5.46±0.56	5.98±0.53 <sup>a</sup>	6.16±0.49	6.16±0.56 <sup>b</sup>	6.32±0.57	6.47±0.46	6.37±0.45	6.54±0.39 <sup>ab</sup>
	High	5.38±0.80 <sup>b</sup>	5.59±0.79	5.51±0.69 <sup>a</sup>	5.66±0.53	5.59±3.96	6.19±0.64 <sup>b</sup>	6.26±0.60	6.41±0.52 <sup>a</sup>	6.47±0.49	6.56±0.57	6.54±0.48	6.73±0.63 <sup>b</sup>
	Significance (P)	0.0001	0.2678	0.0529	0.0972	0.3058	0.0128	0.5071	0.0251	0.3380	0.6243	0.1125	0.0264
CV		13.26	10.97	10.30	9.47	10.49	9.25	8.71	8.86	8.62	8.16	8.01	8.47
SWUSA (mg/cm <sup>2</sup> )	Low	73.05±12.9	77.19±6.56	74.12±5.91	74.06±5.38	74.12±4.08	76.57±4.6 <sup>ab</sup>	77.99±5.24	76.79±5.94	77.89±5.52	78.59±4.62	77.16±5.85	76.61±7.18
	Medium	74.18±5.68	76.46±9.09	72.31±5.50	73.94±6.86	72.99±7.05	76.73±5.4 <sup>a</sup>	77.39±5.53	76.29±6.08	77.38±6.38	78.71±5.08	78.17±6.76	78.55±5.21
	High	76.76±7.91	76.52±8.74	74.11±9.09	75.11±5.65	73.35±7.65	78.89±6.9 <sup>b</sup>	77.35±6.04	78.55±5.43	78.94±5.51	78.96±5.47	79.22±5.72	79.38±6.51
	Significance (P)	0.0687	0.8267	0.1187	0.4355	0.6394	0.0293	0.8213	0.0655	0.3393	0.9380	0.2874	0.2427
CV		10.43	10.99	9.36	8.19	9.05	7.43	7.27	7.56	7.52	6.52	7.86	7.79
Egg Surface area (cm <sup>2</sup> )	Low	65.01±3.4 <sup>a</sup>	71.26±2.72	73.36±2.66	74.11±3.38	75.34±3.29	77.32±3.15	79.93±3.39	80.88±3.32	82.44±4.25	82.35±3.88	82.04±3.39	82.63±3.98
	Medium	66.84±3.8 <sup>a</sup>	71.65±5.40	73.53±4.88	74.52±4.15	74.80±3.49	77.97±3.99	79.61±3.16	80.77±3.24	81.75±3.17	82.21±3.18	81.67±3.89	83.32±3.71
	High	69.96±6.1 <sup>b</sup>	72.93±5.20	74.51±4.69	75.34±3.23	76.04±3.24	78.48	80.87±3.45	81.62±3.14	81.99±2.89	83.01±3.49	82.64±3.26	84.82±3.64
	Significance (P)	0.0001	0.0659	0.2414	0.1338	0.0863	0.2093	0.0766	0.2626	0.5984	0.4173	0.3813	0.0560
CV		7.09	6.69	5.89	4.91	4.46	4.61	4.13	3.98	4.14	4.18	4.31	4.46

Means (mean±SD) calculated for each BW group, means within a column with no common superscript differ significantly at (P<0.05).

CV=Coefficient of variation.

SWUSA= Shell weight per unit surface area.

**Table 4.8. The influence of body weight on mean eggshell percentage (%), shell weight (g), and SWUSA (mg/cm<sup>2</sup>) of broiler breeder hens from commencement of laying up to 36 weeks of age**

Variable	BW	Mean±SD	Significance (P)	CV
<b>Shell Percentage (%)</b>	Low	8.87±0.48	0.7252	7.05
	Medium	8.76±0.59		
	High	8.86±0.75		
<b>Shell Weight (g)</b>	Low	5.40±0.44	0.2535	8.84
	Medium	5.33±0.41		
	High	5.52±0.59		
<b>SWUSA (mg/cm<sup>2</sup>)</b>	Low	74.71±4.34	0.5365	7.09
	Medium	73.76±4.77		
	High	75.13±6.52		
<b>Egg Surfacearea (cm<sup>2</sup>)</b>	Low	72.27±2.92	0.2425	4.26
	Medium	72.24±3.08		
	High	73.40±3.25		

Means (mean±SD) are calculated for each BW group; means within a column with no common superscript differ significantly at (P<0.05).

CV= Coefficient of variation.

SWUSA= Shell weight per unit surface area.

**Table 4.9. The influence of body weight on mean eggshell percentage (%), shell weight (g), and SWUSA (mg/cm<sup>2</sup>) of broiler breeder hens from commencement of laying up to 60 weeks of age**

Variable	BW	Mean±SD	Significance (P)	CV
<b>Shell Percentage (%)</b>	Low	8.76±0.34	0.5763	5.39
	Medium	8.71±0.52		
	High	8.84±0.49		
<b>Shell Weight (g)</b>	Low	6.12±0.39	0.1132	6.59
	Medium	6.09±0.38		
	High	6.31±0.45		
<b>SWUSA (mg/cm<sup>2</sup>)</b>	Low	76.83±3.10	0.3235	5.31
	Medium	76.44±4.29		
	High	78.04±4.43		
<b>Egg Surfacearea (cm<sup>2</sup>)</b>	Low	79.59±3.07	0.2331	3.47
	Medium	79.81±2.78		
	High	80.88±2.55		

Means (mean±SD) are calculated for each BW group; means within a column with no common superscript differ significantly at (P<0.05).

CV= Coefficient of variation.

SWUSA= Shell weight per unit surface area.

The shell weight of the eggs laid by the hens in the high BW group were significantly ( $P<0.05$ ) heavier than that of hens in the low and medium BW groups during the weeks 27, 33, 42, 48 and 60. A statistical comparison of mean shell weight from the commencement of lay up to week 36 of age (Table 4.8) and up week 60 (Table 4.9) revealed no significant influence of different BW's of broiler breeder hens on shell weight.

During the initial stages of the laying period (Table 4.7) no significant differences were detected in SWUSA among the three BW groups. At week 42 of age the hens in the high BW group laid eggs with a significantly higher ( $78.89 \text{ mg/cm}^2$ ) SWUSA than the hens in the medium ( $76.73 \text{ mg/cm}^2$ ) and low BW groups. These differences were not observed for the remainder of the laying period up to 60 weeks of age. Similar results were obtained for egg surface area where the only significant ( $P<0.05$ ) difference was observed at week 27 of age. The hens in the high BW groups laid eggs that had a significantly ( $P<0.05$ ) higher egg surface area ( $69.96 \text{ cm}^2$ ) than the hens in both the medium ( $66.84 \text{ cm}^2$ ) and the low ( $65.01 \text{ cm}^2$ ) BW groups. No significant differences in the egg surface area of the eggs laid during the remaining period of lay were detected among the BW groups. These findings are contrary to those reported by Mc Daniel (1983). These researchers found that the hens in the heavier treatment laid eggs that had a significantly ( $P<0.05$ ) lower specific gravity, during the initial stages of the laying period. This trend of poor shell quality continued during the laying period except for weeks 46 and 50 of age.

The results of the current study indicate that BW in lay does not affect overall eggshell quality, except for some weeks during the laying period. These findings are in agreement to those reported previously by Leeson *et al.* (1997), on layer hens. However in a study conducted by Renema *et al.* (2001), the hens that were raised on a growth curve of 150 g higher than the standard target breeder curve at 18 weeks of age, had a high incidence of eggs with shell defects and double yolk. Therefore the additional weight gain seems to have a detrimental effect on the eggshell quality.

#### **4.6 Conclusions**

The outcome of the present study showed that BW at the onset of lay does not have a definite and obvious positive nor negative influence on the overall egg production parameters (egg production, egg weight, egg output and egg content) and eggshell quality (shell thickness, shell percentage, shell weight, SWUSA, egg surface area) of broiler breeder hens. However the results suggested that egg weight could be influenced positively during the initial stages of lay (week 27 and 30) by high BW hens at the onset of lay. Accordingly it seems from the results that high BW's of broiler breeder hens at onset of lay could result in a higher mean egg output from commencement of lay up to 36 weeks of age. Results regarding eggshell quality indicated that a high BW of broiler breeder hens could positively influence eggshell thickness during the early and late stages of lay, shell weight occasionally throughout the laying period, and irregularly affect SWUSA at post peak and egg surface area during early production. It seems that BW of hens at the onset of lay as a point of reference for subsequent egg production and eggshell quality is probably not sufficient. Other factors like change in BW grouping over the laying period and energy requirements of the hens may also be important to consider.

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## CHAPTER 5

### THE INFLUENCE OF BODY WEIGHT OF BROILER BREEDER HENS ON CALCIUM RETENTION AND EXCRETION

#### 5.1 Introduction

Calcium plays a major role in a wide variety of biological functions mainly in bone and eggshell formation (Sooncharernying & Edwards, 1989; Elaroussi *et al.*, 1994). In poultry the major portion of the dietary calcium is used for bone formation in growing chicks and during the laying period for eggshell formation in mature hens (Calnek *et al.*, 1991; Klasing, 1998). Calcium is normally retained by the presence of medullary bone in the bone marrow cavities of the long bones two weeks prior to the onset of lay. Calcium is also the main mineral component of eggshells, which are almost entirely calcium carbonate, 40% of which is calcium (Roudybush & Grau, 1987).

The hen's body contains approximately 20 grams calcium while an egg contains two grams. If the hen lays daily an eggshell containing 2.0 to 2.2 grams calcium, approximately 10% of the body store will be turned-over daily to support shell calcium deposition (Gilbert, 1983; Hopkins *et al.*, 1987; Bar *et al.*, 2002). This remarkable turnover of calcium makes the laying hen one of the largest users of calcium (Harms & Roland, 1976; Simons, 1986). According to Hess & Eckman (2002), breeder hens must absorb and have available 73 % of their daily calcium intake on the day that they form an egg. Over the course of the week, they must absorb 47 % of their calcium intake for eggshell formation. Therefore extra calcium is stored in the skeleton on days that an egg is not laid. The large body and skeleton of the breeder hen provide an ample supply of buffer for protein, fat, and calcium deposition in the egg. This emphasizes the importance of calcium intake, absorption and retention during the laying period.

Calcium homeostasis is achieved by balancing the efficiency of intestinal calcium absorption, renal excretion and bone mineral metabolism for the requirements of the hen (McDonald, 1995). Much work has been done on calcium and its relationship to performance of both layers and broiler breeders during lay, but there is a paucity of information about the relationship of BW to calcium metabolism and subsequently performance of broiler breeder hens. The onset of lay involves the production of calcified eggshells increasing the formation and secretion of hormones involved in the calcium homeostasis, and intestinal absorption of calcium (Bar *et al.*, 1998). Calcium homeostasis is maintained in the hen by mobilization of bone calcium. Thus the hen can supply calcium for the formation of eggshells during periods of low calcium intake. There is a lack of information available regarding the influence of BW of broiler breeder hens at the onset of lay on calcium excretion and retention.

The objective of the current study was to determine the effect of BW at the onset of lay on the subsequent calcium intake, calcium excretion and calcium retention of laying broiler breeder hens.

## **5.2 Materials and Methods**

The effect of BW at the onset lay on calcium retention and excretion of broiler breeder hens was investigated using the data of the study described in Chapter 3. The management of the hens during lay was similar to that described in Chapter 3. One hundred and ninety eight Ross broiler breeder hens placed individually in cages fitted with individual feeders and metal trays. From these hens 90 were randomly selected for the collection of excreta for the duration of the experiment. The hens were divided into three groups based on their BW at the onset of lay as described in Chapter 3. The experiment was conducted for a period of 15 weeks (27 to 42 weeks of age).

### 5.2.1 Calcium balance

The excreta of 90 hens were collected during a 7-day period during the following weeks of age (27, 33, 36 and 42). Excreta samples were collected on metal trays, and transferred into paper bags and dried in an oven at 100 °C for 24 to 48 hours and then air-cooled. Thereafter, dried excreta were weighed and pulverized using a laboratory mill with a 1 mm sieve. The pulverized samples were homogenized before taking a representative sample for the determination of calcium by atomic absorption spectrophotometry (Hocking *et al.*, 2002; Ajakaiye *et al.*, 2003). Approximately 1-gram sample of excreta were ashed in a muffle furnace at 550 °C for 16 hours and digested in 10 ml nitric acid for calcium determination.

Calcium retention was calculated by subtracting shell Ca, Ca in egg contents, and faecal Ca from the hen's Ca intake (MacFarlane & Gous, 1993). In order to cancel differences in Ca intake as a factor, Ca retention was also expressed as a percentage of the Ca intake. Ca content of the egg (g Ca/bird/day) was calculated by multiplying eggs weighing 50 or 60 g by 0.025 and 0.030, respectively (Simons, 1986). Shell Ca (mg/g) was obtained by multiplying average eggshell weight (g) by 373 mg/g.

### 5.3 Statistical Analysis

The data were corrected prior to analysis for the effect of different calcium levels during the rearing and laying periods. The data for the selected weeks (27, 33, 36 and 42 weeks of age) during the laying period were analysed, where each hen served as a replicate. Data was analysed using Proc ANOVA of SAS (1999) to determine the effect of BW groups on calcium intake and excretion. Tukey's honest significant difference test at 5% significance level was used to determine which groups differ significantly. Pearson Correlation coefficients were determined (SAS, 1999) to measure the strength of the linear relationship between the calcium intake and retention from commencement of lay up to 42 weeks of age.

## 5.4 Results and Discussion

### 5.4.1 Calcium metabolism

#### 5.4.1.1 Calcium intake

The results for the effect of BW on the daily calcium intake, excretion, and retention during the different weeks in lay are summarized in Tables 5.1, 5.2, 5.3 and 5.4. No significant ( $P>0.05$ ) differences were observed in daily calcium intake among the hens in the different BW groups during the different stages of the laying period. An increasing trend of heavier hens having higher intake of calcium was observed, though no statistical differences were noted. This lack of response by the hens in different BW groups is in concurrent with the report by Clunies & Leeson (1994), where no significant differences in feed intake and consequently in calcium intake were observed between the high BW and low BW strains of layer hens. Though they employed *ad lib.* feeding compared to restricted feeding method in the current study, similar results were still obtained.

#### 5.4.1.2 Eggshell calcium excretion

From the results in Table 5.1 it seems that the heavier hens excreted a significantly ( $P<0.0417$ ) higher amount of eggshell calcium during week 27 than the lower BW hens. Accordingly (Table 5.4) summarised mean eggshell calcium was significantly ( $P<0.0339$ ) higher for the high BW hens during the laying period (27 to 42 weeks of age). These results were supported to some extent (Table 5.3) by the average eggshell calcium excreted for the period 36 to 42. The highest eggshell calcium excretion for this period was recorded for the medium BW hens followed by the high BW hens. Although not always statistical significant the higher eggshell calcium excreted by the high BW hens (Tables 5.3 and 5.4) was supported in Chapter 4 by thicker and heavier eggshell weights than the other BW groups. According to Sugiyama & Kasuhara (2001), an equivalent of 60-65% of the calcium in the eggshell is derived from dietary sources and the remaining 25-40% from medullary bone.

**Table 5.1 The effect of body weight on calcium intake, excretion and retention of broiler breeder hens at different stages of the laying period.**

Variable	BW	27	33	36	42
<b>Ca Intake (g)</b>	<b>Low</b>	3.80±1.32	3.25±0.99	3.05±0.51	3.18±0.43
	<b>Medium</b>	3.63±1.39	3.38±1.19	3.28±0.58	3.27±0.51
	<b>High</b>	4.03±1.30	3.68±1.14	3.49±0.46	3.36±0.48
<b>Significance (P)</b>		0.7032	0.5590	0.1164	0.7043
<b>CV</b>		34.96	32.28	15.38	14.61
<b>Shell Ca Excreted (g)</b>	<b>Low</b>	0.81±0.56 <sup>a</sup>	1.25±0.31	1.26±0.29	1.50±0.22
	<b>Medium</b>	0.75±0.58 <sup>a</sup>	1.41±0.32	1.52±0.37	1.64±0.31
	<b>High</b>	1.18±0.39 <sup>b</sup>	1.33±0.29	1.59±0.36	1.66±0.31
<b>Significance (P)</b>		0.0417	0.3828	0.0592	0.4431
<b>CV</b>		56.27	23.15	23.52	17.83
<b>Faecal Ca Excreted (g)</b>	<b>Low</b>	2.07±0.86	1.31±0.78	1.39±0.73	1.37±0.51
	<b>Medium</b>	1.94±1.11	1.17±0.77	1.14±0.64	1.45±0.56
	<b>High</b>	1.89±0.89	1.46±0.72	1.39±0.64	1.45±0.49
<b>Significance (P)</b>		0.8429	0.5967	0.5995	0.9340
<b>CV</b>		48.76	57.48	50.83	36.26
<b>Total Ca Excreted (g)</b>	<b>Low</b>	2.88±0.89	2.56±0.76	2.65±0.85	2.87±0.39
	<b>Medium</b>	2.69±0.91	2.58±0.78	2.67±0.88	3.09±0.52
	<b>High</b>	3.07±0.86	2.79±0.85	2.98±0.85	3.11±0.65
<b>Significance (P)</b>		0.4736	0.6901	0.5576	0.5999
<b>CV</b>		30.76	30.10	30.92	18.15
<b>Ca Retention (g)</b>	<b>Low</b>	0.86±1.05	0.70±0.88	0.46±0.49	0.29±0.27
	<b>Medium</b>	1.18±1.18	0.79±0.93	0.55±0.58	0.16±0.30
	<b>High</b>	0.99±1.19	0.88±0.68	0.46±0.49	0.23±0.25
<b>Significance (P)</b>		0.7353	0.8573	0.8921	0.6009
<b>CV</b>		113.54	105.79	106.95	125.45
<b>Shell Ca as % Of Ca Intake (g)</b>	<b>Low</b>	24.08±19.16	41.29±14.27	41.93±9.38	48.04±10.44
	<b>Medium</b>	24.33±19.47	45.58±15.71	47.05±11.76	51.36±13.09
	<b>High</b>	36.67±20.22	38.73±11.24	45.62±9.38	49.66±7.04
<b>Significance (P)</b>		0.1180	0.4012	0.4612	0.7939
<b>CV</b>		68.84	33.08	22.67	20.63
<b>Faecal Ca as % Of Ca Intake</b>	<b>Low</b>	59.93±24.12	40.16±21.63	43.55±18.69	42.46±13.65
	<b>Medium</b>	53.77±23.33	34.16±18.95	33.29±14.37	43.31±12.71
	<b>High</b>	47.54±20.42	38.16±14.49	38.49±14.46	42.28±10.62
<b>Significance (P)</b>		0.3003	0.6741	0.3191	0.9793
<b>CV</b>		42.20	49.46	41.38	28.52
<b>Excreted Ca as % of Ca Intake</b>	<b>Low</b>	79.71±20.66	81.46±20.45	85.47±19.02	90.51±8.88
	<b>Medium</b>	77.29±17.69	79.73±18.41	80.35±18.15	94.66±8.34
	<b>High</b>	81.40±23.29	76.89±14.85	84.12±15.85	91.94±7.41
<b>Significance (P)</b>		0.8500	0.7875	0.7742	0.5833
<b>CV</b>		26.08	22.68	21.17	9.36
<b>Calcium Ret as % of Ca intake</b>	<b>Low</b>	18.18±18.81	18.13±20.29	14.98±18.47	8.56±8.96
	<b>Medium</b>	29.53±26.91	19.61±18.42	18.95±18.11	4.31±8.51
	<b>High</b>	19.79±21.41	22.03±15.52	15.85±15.35	7.41±8.66
<b>Significance (P)</b>		0.3142	0.8428	0.8475	0.5542
<b>CV</b>		100.73	90.82	104.72	129.99

Means (mean±SD) are calculated for each BW group; means within a column with no common superscript differ significantly at (P<0.05).

CV= Coefficient of variation.

**Table 5.2 The influence of body weight on the mean daily calcium intake, shell calcium and faecal excretion of broiler breeder hens from 27 to 33 weeks of age.**

Variable	BW	Mean±SD	Significance (P)	CV
<b>Ca Intake (g)</b>	<b>Low</b>	3.38±1.18	0.4579	33.22
	<b>Medium</b>	3.58±1.30		
	<b>High</b>	3.93±1.14		
<b>Shell Ca Excreted (g)</b>	<b>Low</b>	1.05±0.35	0.1511	26.79
	<b>Medium</b>	1.11±0.32		
	<b>High</b>	1.26±0.23		
<b>Faecal Ca Excreted (g)</b>	<b>Low</b>	1.54±0.76	0.8662	49.81
	<b>Medium</b>	1.55±0.86		
	<b>High</b>	1.68±0.75		
<b>Total Ca Excreted (g)</b>	<b>Low</b>	2.58±0.79	0.4381	29.03
	<b>Medium</b>	2.66±0.82		
	<b>High</b>	2.94±0.77		
<b>Ca retention (g)</b>	<b>Low</b>	0.76±0.95	0.6744	10.10
	<b>Medium</b>	1.05±0.99		
	<b>High</b>	0.99±0.89		
<b>Shell Ca as % of Ca Intake</b>	<b>Low</b>	35.10±13.60	0.9244	38.82
	<b>Medium</b>	34.96±13.64		
	<b>High</b>	36.78±14.23		
<b>Faecal Ca as % of Ca Intake</b>	<b>Low</b>	47.41±21.29	0.7229	42.42
	<b>Medium</b>	43.46±19.18		
	<b>High</b>	42.04±15.51		
<b>Excreted Ca as % of Ca Intake</b>	<b>Low</b>	80.23±19.24	0.9244	22.69
	<b>Medium</b>	77.96±17.51		
	<b>High</b>	77.98±16.75		
<b>Ca retained as % of Ca Intake</b>	<b>Low</b>	18.09±18.78	0.5284	81.89
	<b>Medium</b>	25.64±18.56		
	<b>High</b>	21.91±16.13		

Means (mean±SD) are calculated for each BW group; means within a column with no common superscript differ significantly at (P<0.05).

CV= Coefficient of variation.

**Table 5.3 The influence of body weight on the mean daily calcium intake, shell calcium and faecal excretion of broiler breeder hens from 36 to 42 weeks of age.**

Variable	BW	Mean±SD	Significance (P)	CV
<b>Ca Intake (g)</b>	<b>Low</b>	3.08±0.51	0.2398	15.14
	<b>Medium</b>	3.38±0.57		
	<b>High</b>	3.48±0.45		
<b>Shell Ca Excretion (g)</b>	<b>Low</b>	1.41±0.19 <sup>a</sup>	0.0328	14.43
	<b>Medium</b>	1.69±0.19 <sup>b</sup>		
	<b>High</b>	1.66±0.27 <sup>ab</sup>		
<b>Faecal Ca Excretion (g)</b>	<b>Low</b>	1.35±0.57	0.9270	38.97
	<b>Medium</b>	1.39±0.65		
	<b>High</b>	1.45±0.52		
<b>Total Ca Excretion (g)</b>	<b>Low</b>	2.77±0.60	0.4627	21.79
	<b>Medium</b>	3.09±0.63		
	<b>High</b>	3.10±0.69		
<b>Calcium retention (g)</b>	<b>Low</b>	0.34±0.23	0.7832	94.32
	<b>Medium</b>	0.25±0.30		
	<b>High</b>	0.30±0.30		
<b>Shell Ca as % of Ca Intake</b>	<b>Low</b>	46.73±7.17	0.4636	14.87
	<b>Medium</b>	51.09±9.30		
	<b>High</b>	48.28±5.55		
<b>Faecal Ca as % of Ca Intake</b>	<b>Low</b>	42.65±13.03	0.8981	28.54
	<b>Medium</b>	40.06±10.87		
	<b>High</b>	40.95±11.35		
<b>Excreted Ca as % of Ca Intake</b>	<b>Low</b>	89.38±8.19	0.8858	10.20
	<b>Medium</b>	91.17±8.49		
	<b>High</b>	89.23±10.18		
<b>Ca retained as % of Ca Intake</b>	<b>Low</b>	10.61±7.47	0.8080	88.43
	<b>Medium</b>	8.15±8.39		
	<b>High</b>	10.45±9.71		

Means (mean±SD) are calculated for each BW group; means within a column with no common superscript differ significantly at (P<0.05).

CV= Coefficient of variation.

**Table 5.4 The influence of BW on the mean daily calcium intake, shell calcium and faecal excretion of broiler breeder hens from 27 to 42 weeks of age.**

Variable	BW	Mean±SD	Significance (P)	CV
<b>Ca Intake (g)</b>	<b>Low</b>	3.30±0.94	0.4101	27.01
	<b>Medium</b>	3.43±0.99		
	<b>High</b>	3.76±0.89		
<b>Shell Ca Excreted (g)</b>	<b>Low</b>	1.14±0.35 <sup>a</sup>	0.0339	22.38
	<b>Medium</b>	1.27±0.27 <sup>ab</sup>		
	<b>High</b>	1.42±0.22 <sup>b</sup>		
<b>Faecal Ca Excreted (g)</b>	<b>Low</b>	1.44±0.69	0.7994	45.99
	<b>Medium</b>	1.42±0.72		
	<b>High</b>	1.58±0.64		
<b>Total Ca Excreted (g)</b>	<b>Low</b>	2.58±0.73	0.2916	26.88
	<b>Medium</b>	2.70±0.78		
	<b>High</b>	3.00±0.72		
<b>Ca retention (g)</b>	<b>Low</b>	0.69±0.68	0.9172	86.25
	<b>Medium</b>	0.79±0.64		
	<b>High</b>	0.74±0.60		
<b>Shell Ca as % of Ca Intake</b>	<b>Low</b>	39.70±9.44	0.8201	24.69
	<b>Medium</b>	41.67±9.83		
	<b>High</b>	41.79±11.04		
<b>Faecal Ca as % of Ca Intake</b>	<b>Low</b>	44.46±18.32	0.7909	36.12
	<b>Medium</b>	41.15±15.15		
	<b>High</b>	41.11±11.56		
<b>Excreted Ca as % of Ca Intake</b>	<b>Low</b>	80.72±15.86	0.9558	16.64
	<b>Medium</b>	81.01±12.44		
	<b>High</b>	82.13±11.86		
<b>Ca retained as % of Ca Intake</b>	<b>Low</b>	18.12±14.15	0.7655	67.45
	<b>Medium</b>	20.85±12.42		
	<b>High</b>	17.62±11.34		

Means (mean±SD) are calculated for each BW group; means within a column with no common superscript differ significantly at (P<0.05).

CV= Coefficient of variation.

Farmer *et al.* (1986), and Clunies *et al.* (1992), reported that the quantity of calcium absorbed and deposited in the shell is greatly depended upon the level of calcium in the diet and feed intake. With a high intake of calcium most of the shell calcium is derived by



intestinal calcium absorption, while on low calcium intake most of the shell calcium is derived from the bone. As no significant ( $P>0.05$ ) differences in calcium intake by the hens were observed it could be speculated that most of the calcium deposited in the eggshell of eggs laid by high BW hens was derived from the medullary bone. In contrast Robinson *et al.* (1993), is of the opinion that heavy hens presumably lose coordination of ovulation, oviposition and eggshell calcium deposition. However no negative consequences of additional BW related to shell quality (Chapter 4) and calcium deposition were however observed in the current study. Hartel (1987), is of the opinion that eggshell calcification normally improves as the dietary supply of calcium improve therefore a positively linear relationship between the two variables could be expected. The clear expression of this relationship was not observed, though there was a tendency for high BW hens to have a slightly higher calcium intake than the other two BW groups.

#### **5.4.1.3 Faecal calcium excretion**

From Tables 5.1, 5.2, 5.3 and 5.4 it is evident that no statistical significant ( $P>0.05$ ) differences occurred in faecal calcium excretion of hens in the various BW groups. A high coefficient of variation for faecal calcium excretion could contribute to these non-significant differences. In fact a relatively high coefficient of variation was observed overall. Shafey *et al.* (1990), and Macfarlane & Gous (1993), concluded that the greater the calcium intake, the greater the excretion of faecal calcium. From Tables 5.2, 5.3 and 5.4 there was a tendency for hens that consumed more calcium to subsequently have higher faecal calcium excretion.

#### **5.4.1.4 Calcium retention**

The conventional wisdom regarding calcium retention is that the bird retains only 50 % of the calcium consumed. Macfarlane & Gous (1993), however proved that it varies with the amount of calcium consumed. In the current study there was not a clear tendency for the amount of calcium retention to vary according to calcium intake among the various

BW groups. The BW group with higher calcium intake tended only in some instances to have higher calcium retention though there were no significant differences.

Calcium retention was not statistically different between the different BW groups. Hocking *et al.* (2002), reported that though there were significant differences in BW of male turkey hens from week 3 to 18 of age, no significant differences occurred in the amount of calcium retained. Atteh *et al.* (1983), found with male broilers that, additional BW as a result of increased fat content in the diet led to a significant reduction in calcium retention. These contrary results compared to the current study are probably attributed to the interaction between dietary fat and calcium digestion and the sex of the birds.

#### **5.4.2 Calcium retention as a percentage of intake**

No statistical significant ( $P>0.05$ ) differences occurred in daily calcium intake between the laying hens in the different BW groups. There was only a trend for hens in the high BW group to take in more calcium. Therefore calcium intake was probably not a factor that could have influenced the calcium metabolism results. Accordingly the expression of calcium retention results as a percentage of calcium intake was unnecessary. This expectation is supported by the results (with the exception of eggshell calcium excretion) in Tables 5.1, 5.2, 5.3 and 5.4. The different results obtained for eggshell calcium excretion are difficult to explain. It suggested that the non-significant differences in calcium intake of breeder hens in the different BW groups influenced the results regarding eggshell calcium excretion.

In the present study calcium retention was significantly ( $P<0.001$ ) correlated ( $r=0.63$ ) to calcium intake. Similarly Clunies *et al.* (1992) reported that calcium retention is significantly highly correlated to calcium intake. A positive linear relationship ( $r= 0.32$ ) was observed by these researchers with layer hens between calcium intake and grams calcium retained. Shafey *et al.* (1990) reported that calcium retention was curvilinear in relation to intake, suggesting that the ratio of calcium absorbed and retained would probably decrease as the intake of calcium and phosphorus increase in a fixed ratio.

Furthermore Keshavarz (1986), and Keshavarz & Nakajima (1993), reported that percent retention calcium was reduced with increasing calcium intake, indicating an inverse relationship between the two variables. However absolute calcium retention increases due to increasing calcium intake. As already indicated calcium intake did not play a major role in the current study.

## **5.5 Conclusions**

The results from the current study showed that heavier BW's of hens at the onset of lay increase calcium deposited in the eggshell. The high BW hens continued to have a tendency of depositing more calcium in the eggshell, which manifested in higher shell weights and thicker eggshells. This was however not supported by the results of total amount of calcium excreted and retained. In fact the results in the current study indicates in general that calcium homeostasis was maintained equally well by the hens in the different BW groups. The hens in the different BW groups were able to supply calcium needed for the formation of eggshells though there were no significant differences in calcium intake.

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## CHAPTER 6

### GENERAL CONCLUSIONS

Over the years it has become normal practice to manage and control the body weight of broiler breeder hens during rearing and laying period in order to prevent obesity and maximize production performance during the laying cycle. This is done through the control of feed intake by using different restricted feeding methods since BW and feed intake are highly correlated. Uniformity in BW is the desirable outcome especially at the onset of lay in order to achieve similar rates of lay and egg weights. Therefore an understanding of how BW at the onset of lay influence the performance (egg production, egg weight, egg content, egg output) as well as eggshell quality (eggshell thickness, shell weight) of broiler breeder hens during the laying period is of outmost importance.

The results in the current study showed that differing BW's at the onset of lay did not have pronounced influence on egg production during the laying period (23 to 60 weeks of age). Accordingly egg output was clearly not affected by BW since it is a function of egg production. The influence of body weight on production characteristics of broiler breeder hens requires further investigation by planning a different experimental design and having BW groups that are distinctly different from each other and where there are no possible overlaps in groups, as well as an increased number of experimental units. However additional weight in high BW hens did lead to heavier egg weights at the early stages of lay (27 to 30 weeks of age), this confirms the existing knowledge that egg weight is a function of BW. Accordingly high BW of broiler breeder hens at the onset of lay resulted in a higher mean egg output from commencement of lay up to 36 weeks of age. The change in response as laying progresses warrants further investigation into the pattern of BW change over the entire period of lay.

The overall thickness of eggs laid by hens in the high BW group during the early stages of lay was thicker than the other hens in the other BW groups, indicating that a better calcium deposition in the eggshells of these hens. Similarly shell weight was positively

influenced by a high BW occasionally throughout the laying period. These responses were not anticipated as the performance of the heavier hens was expected to be poor and lower than of the other hens. Other parameters (shell percentage, SWUSA) of eggshell quality did not yield any pronounced influence of BW at the onset of lay. Furthermore it seems from the results of the present study that calcium homeostasis was maintained by broiler breeder hens irrespective of the BW status at the onset of lay. It seems that concentrating on the BW at the onset of lay as a point of reference for subsequent egg production and eggshell quality is probably not sufficient, and many other factors like change in BW grouping over the period of lay and energy requirements of the hens could also be important to consider.

## ABSTRACT

A study was conducted to investigate the effect of variation in body weight (BW) of broiler breeder hens at onset of lay (23 weeks of age) on subsequent egg production parameters and eggshell quality (27 to 60 weeks of age). Ross broiler breeder hens (n = 198) reared under restricted feeding were randomly placed in individual cages at 23 weeks of age. Hens were divided into low (LBW), medium (MBW), and high (HBW) body weight groups as follows: 2007 - 2447 g, 2645 - 2777 g and 2975 - 3445 g, respectively. The production parameters were recorded on a three weekly interval during the experimental period.

The hens in the HBW group laid eggs that were significantly ( $P < 0.05$ ) heavier than hens in the other two groups during the initial stages of lay (27 to 30 weeks of age). The HBW hens had a statistically ( $P < 0.05$ ) higher egg content in comparison to the other two groups only during the first production interval (week 27 of age). Egg production was not significantly ( $P > 0.05$ ) affected by BW at the onset of lay. HBW hens at the onset of lay resulted in a higher mean egg output ( $P = 0.0071$ ) from the commencement of lay up to 36 weeks of age. HBW hens laid eggs with thicker broad and equator ends than the MBW and LBW hens during the first 10 weeks of lay. No statistical differences ( $P > 0.05$ ) were observed in shell percentage, shell per unit surface area and egg surface area between the different BW groups. BW variation significantly affected shell weight from 27 to 60 weeks of age, as high BW was associated with heavier shell weight. The results suggest that a high BW at the onset of lay plays a positive role on the performance (egg weight, egg output, egg content and eggshell thickness) of laying broiler breeder hens during the initial stages of lay.

In a second trial the effect of BW at the onset of lay on calcium retention and excretion of broiler breeder hens during the different stages of lay was investigated. Ninety randomly selected hens from the broiler breeder hens as described in the first paragraph were used in the investigation. The experiment was conducted for a period of 15 weeks (27 to 42

weeks of age). Excreta samples were collected during a 7-day collection period at weeks 27, 33, 36, and 42 of age.

The hens in the HBW group excreted a significantly ( $P < 0.05$ ) higher amount of calcium into the eggshells than the LBW and MBW hens with exception of week 27-33 of age; this was related to a higher daily calcium intake by the HBW hens though calcium intake did not differ statistically ( $P > 0.05$ ). No significant differences were observed in calcium retention, faecal calcium excretion and total calcium excretion among the BW groups throughout the 15-week period of the trial. It seems that calcium homeostasis was maintained by the broiler breeder hens irrespective of the BW status at the onset of lay.

It was concluded that BW of the hens at the onset of lay as a point of reference for subsequent egg production and eggshell quality is probably not sufficient. Other factors like change in BW grouping over the laying period and energy requirements of the hens may also be important to consider.

## Opsomming

'n Studie is uitgevoer om die invloed van variasie in liggaamsgewig (LG) van braaikuikenhenne aan die begin van die lêperiode (23 weke ouderdom) op die daaropvolgende eierproduksie parameters en eierdopkwaliteit (27 tot 60 weke ouderdom) te ondersoek. Ross braaikuikenhenne ( $n = 198$ ) wat op innamebeperkte diete grootgemaak is, is ewekansig in individuele hokke op 23 weke ouderdom geplaas. Die henne is onderskeidelik in laag (LLG), gemiddel (MLG) en hoë (HLG) liggaamsgewiggroepe as volg ingedeel: 2007 g- 2447 g, 2645 g- 2777 g and 2975 g – 3445 g. Die produksieparameters is met drieweke intervalle gedurende die eksperimentele periode ingesamel.

Die henne in die HLG groep het betekenisvol ( $P < 0.05$ ) swaarder eiers as die twee ander groepe gedurende die begin stadium van die lêperiode (27 tot 30 weke ouderdom) geproduseer 'n Statisties ( $P < 0.05$ ) hoër eiereinhoud in vergelyking met die ander twee groepe is vir die HLG groep henne gedurende week 27 waargeneem. Eierproduksie is nie statisties betekenisvol ( $P > 0.05$ ) deur LG aan die begin van die lêperiode beïnvloed nie. HLG henne aan die begin van die lêperiode het 'n hoër ( $P = 0.0071$ ) eiermassa vanaf die begin van die lê tot 36 weke ouderdom tot gevolg gehad. HLG henne het gedurende die eerste 10 weke van die lêperiode 'n verhoogde ( $P < 0.05$ ) eierdopdikte tot gevolg gehad. Geen statisties betekenisvolle ( $P > 0.05$ ) verskille in persentasie dop, eierdopgewig per eenheidsoppervlakte en eieroppervlakte is tussen die verskillende LG groepe waargeneem nie. Variasie in LG het eierdopgewig vanaf 27 tot 60 weke ouderdom betekenisvol ( $P < 0.05$ ) beïnvloed en het 'n HLG met n swaarder eierdopgewig gepaard gegaan. Die resultate het aangedui dat 'n HLG aan die begin van die lêperiode 'n positiewe rol speel in die prestasie (eiergewig, eiermassa, eierhoud en eierdopdikte) van braaikuikenhenne gedurende die vroeë stadiums van die lêperiode.

In 'n tweede studie is die invloed van LG van braaikuikenhenne aan die begin van die lêperiode op kalsiumretensie en kalsiumekskresie gedurende verskillende stadia van die

lêperiode ondersoek. Negentig ewekansig geselekteerde henne afkomstig van die braaikuikenhenne beskryf in die eerste paragraaf is in die ondersoek gebruik. Die studie is vir 'n periode van 15 weke (27 tot 42 weke ouderdom) uitgevoer. Mismonsters is gedurende 'n 7 dae kolleksieperiode op 27, 33, 36 en 42 weke ouderdom geneem.

Die henne van die HLG groep het met die uitsondering van weke 27-33 betekenisvol ( $P < 0.05$ ) meer kalsium in eierdoppe as die LLG en MLG henne uitgeskei. Dit was verwant aan die hoër kalsiuminname van die HLG henne, alhoewel kalsiuminname nie statisties betekensvol ( $P > 0.05$ ) verskil het nie. Geen betekenisvolle ( $P > 0.05$ ) verskille in kalsiumretensie, miskalsiumuitskeiding en totale kalsiumuitskeiding is gedurende die 15 weke proefperiode waargeneem nie. Dit blyk dat kalsiumhomeostase deur die braaikuikenhenne gehandhaaf is ongeag die LG status aan die begin van die lêperiode.

Daar is tot die slotsom gekom dat LG van henne aan die begin van die lêperiode as 'n punt van verwysing vir die daaropvolgende eierproduksie en eierdopkwaliteit, waarskynlik nie voldoende is nie. Ander faktore soos 'n verandering in LG groepering gedurende die lêperiode en energiebehoefte van die henne mag moontlik ook belangrik wees om in ag te neem.