BREAST MEAT YIELD IN BROILERS AFFECTED BY LIGHTING AND DIETARY ENERGY LEVELS IN STARTER AND FINISHER PHASES

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PREFACE AND DECLARATION

I, …………………………………….………………………., declare that

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ABSTRACT

The increased demand in poultry products has prompted researchers to investigate opportunities and methods which may streamline the production of valuable commodities. Two experiments were conducted in this study. Both experiments were conducted to determine whether breast meat yield (BMY) would be enhanced in broilers reared under short daylengths of 8 and 16 h if higher levels of dietary metabolisable energy (ME) were fed. In each experiment, 1000 as hatched broilers were reared in four light tight rooms, each room divided into two pens which were populated with 125 chicks in each. Within each room two levels of dietary ME were fed resulting in a 2 × 2 factorial experimental design with the main effects being daylength and dietary ME. The first experiment focused on the starter phase of 1 to 10 d. The dietary treatments consisted of a control starter ration formulated to represent the nutrient levels of a standard commercial ration and a treatment ration which was similar to the control ration however contained 15% higher ME. Live weight and performance parameters of body weight gain (BWG), feed intake (FI) and feed conversion ratio (FCR) were measured at 7 and 10 d. At 10d, three birds from each pen were randomly selected and slaughtered for body part analysis. Lighting and dietary treatment had no effect on live weight, BWG, FI and FCR at 7 or 10d. Body part analysis showed that BMY, thigh yield and drumstick yield were unaffected by lighting and dietary ME as main effects. A significant interaction between dietary ME and daylength occurred where BMY and thigh yield were reduced when broilers were fed a 15% higher ME diet and reared on 8 h daylengths. The second experiment focused on the finisher phase of 25 to 35d. Lighting treatments remained the same as the first experiment but dietary treatments differed slightly as the treatment diet contained only 10% higher ME than the control diet which was formulated to the nutrient levels of a standard broiler finisher. At 35 d performance parameters of live weight, BWG, FI and FCR were measured. It was observed that live weight and FI were reduced in broilers fed a diet containing 10% higher ME from 25 to 35d. At 35d, body part analysis from 3 broilers slaughtered from each pen revealed no significant differences in BMY, thigh yield and drumstick yield from dietary ME and daylength. Breast meat yield in broilers within the starter and finisher phase was not improved on short daylengths of 8 and 16 h through the addition of dietary ME in higher levels than that conventionally used.

CHAPTER 1

GENERAL INTRODUCTION

Production of poultry meat as a protein source for human consumption is ever increasing. Consumers desire a protein source which is leaner and considered healthier than that of red meat. The affordability of poultry products in comparison to other meat sources is aiding in increased consumer demand. In South Africa broiler production is increasing at a positive rate. SAPA reported that for January to April 2015 a 6.23% increase was observed for the number of broilers slaughtered in comparison to the same time frame in 2014 (SAPA, 2015).

The increased demand for chicken meat has prompted the improvement of all facets relating to broiler production. From a genetic point of view, the modern broiler has improved dramatically since the commencement of poultry breeding over 60 years ago. Havenstein *et al.* (2003) illustrated the advancement in broiler performance by comparing the Athens Canadian Randombred Control (ACRBC) strain of 1957 compared to the 2001 Ross 308 strain. It was noted that at 35d Ross 308 broilers were 3.81 and 3.47 times heavier than ACRBC broilers fed diets correlating to those used in 2001 and 1957, respectively. Until recently, success in broiler breeding was primarily viewed in terms of increasing BWG and FCE. However with consumers increasing their demand for lean white meat, geneticists have shifted their attention to producing broilers with a higher BMY (Ewart 1993). In terms of improved performance through genetic selection, success can be attributed to the heritability of production traits (Zerehdaran *et al.,* 2005; Felício *et al.,* 2013), the short generation interval in chickens and the commercial scale of selection programs. Havenstein *et al.* (2003) suggested that at least 85% of improvement in broiler production can be accredited to genetic advancements.

The constant improvement and change in the genotypes of broilers means that studies concerning broilers must continue so that all commercial practices especially management factors can stay relevant to the modern and ever improving bird. For broiler production to continue to improve, the management of environmental and nutritional aspects must simultaneously advance. Scientific studies display quantitative insight into the changes and potential of the modern broiler. This allows nutritionists and producers to adjust practices to reap maximum production potential.

The nature of modern broiler production has facilitated enhanced production and efficiency however broiler welfare has been compromised through intense selection of economic traits and the use of modern rearing techniques. Increased sensitivity to broiler welfare has resulted in the scrutiny of commercial systems and evaluations of areas where broiler welfare can be improved (Knowles *et al.,* 2008). A particular area which has been identified to improve broiler welfare is the adjustment of lighting schedules. Broilers have traditionally been reared under continuous exposure to light. The basis of this practice was that without periods of darkness, broilers have continuous access to feed which will increase FI and therefore maximize growth potential. However, it has been identified that continuous light exposure reduces broiler welfare through increased mortality rates (Rozenboim *et al.,* 1999), higher incidences of leg disorders (Sanotra *et al.,* 2002), metabolic disorders, reduced immune functions (Guo b *et al.,* 2010) and poorer ocular development (Lewis & Gous 2009). Implications of these findings have resulted in welfare regulations preventing the use of continuous lighting regimes. EU welfare regulations stipulate that birds reared for meat production must be reared on a 24 hr cycle which includes no less than 6 hrs of darkness, of which 4 hrs should be uninterrupted (European Commission, 2000). Attention must therefore be shifted to the production implications of rearing birds under lighting regimes containing shorter daylengths.

It has been identified that rearing birds on shorter daylengths does not impair growth rate and overall carcass weight; however, alterations in certain body parts have been observed. Breast meat has been seen to be reduced in relation to other body parts such as thighs, drumsticks and wings (Downs *et al.,* 2006; Lewis *et al.,* 2009a; Li *et al.,* 2010). This has economic implications as breast meat is the most economically relevant portion of the carcass fetching the highest portion price due to consumer demand.

In order to resolve the reduced BMY caused by lighting regimens containing limited light exposure, certain management and nutritional approaches have been attempted. It was recently hypothesised that crude protein (CP) will increase BMY in birds reared on shorter daylengths (Mlaba *et al.,* 2015). However increasing CP to levels higher than the perceived requirement did not increase BMY in broilers reared on short daylengths (Mlaba *et al.,* 2015). Commercial broiler systems in South Africa rear birds under lighting regimes of 16L: 8D. It has been observed that broilers reared on less than 12 hrs of light per day consume a substantial amount of their daily intake at night (Lewis *et al.,* 2008). If broilers are able to actively consume feed at night and protein inclusion levels are not a limiting factor than the reduction in BMY may be the result of increased energy expenditure. Increased energy expenditure will result in decreased protein deposition or a change in protein deposition in different areas other than breast (thigh and drumstick are due to walking or standing).

It is hypothesised in the current study that increasing dietary energy may increase BMY in broilers reared on shorter daylengths. Simultaneously, the added benefits will be improved bird welfare, reduced mortalities and reduced electrical costs whilst producing the most economically relevant carcass composition.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The increase in the consumption of poultry products can be attributed to advancements in processing methods, marketing practices and the improvement in commercial trade directly to the general population. The broiler industry has therefore transformed over the past 50 years and advancements have been seen in all areas relating to production. Genetic advancement boasts as the biggest contributor to creating the modern broiler into the highly efficient meat producing bird that it is today. However the incentives to increase broiler production to satisfy the growing demand of poultry products does not only apply to geneticists alone but also to nutritionists and broiler producers.

The broiler industry is bound by market demands and therefore must adjust to meet consumer requirements. At present, consumer demands point towards breast meat as the most valuable product of a portioned carcass. Increasing BMY in broilers therefore has an economic significance within the industry. This has prompted geneticists to breed broilers that are able to produce greater BMY compared to earlier genotypes. Nutritional and environmental factors also affect BMY therefore need to be adapted to assist in satisfying the consumer needs of increased BMY.

Researchers are constantly faced with the challenge of investigating ways in which to increase BMY and to rectify or stream line any areas within broiler production which could be corrected. One such are is the decrease in BMY as affected by shorter lighting regimes which are implemented as a method to improve broiler welfare.

It is therefore imperative that an evaluation of the effects of research relating to lighting and its effects in broiler production is well understood. It is also important to access a possible solution which may contribute to increasing BMY which in this case is altering nutrient density. This review therefore focuses on the main effects of lighting in broiler production and the effects of nutrient density on BMY.

2.2 LIGHTING IN BROILER PRODUCTION

Lighting in broiler production is an important environmental factor as it affects physiological and behavioural processes in birds. Lighting does not only allow visual acuity but also enables birds to establish regularity of essential functions that effect feeding and digestion. Lighting has an important bearing on the secretion of hormones which are involved in growth and sexual maturation (Benoit 1964). The behaviour of birds and activity is also affected by lighting factors (Kristensen *et al.,* 2007).

The increase in scale and advancement in complexity of broiler production means that each environmental factor is managed to maximize production. Commercial broiler production systems are able to manipulate environmental factors such as temperature, housing conditions and stocking rates to promote highest production circumstances. However broiler producers need to reassess the management of lighting practices due to reduced BMY in lighting regimes that ensure broiler welfare is enhanced.

2.2.1 Perception of Light and Circadian Rhythm in Broilers

Understanding the mechanisms to which birds perceive light and the subsequent effects will provide insight and understanding into the effects of light on the modern broiler. Birds are not only able to perceive light through their eyes but also through functional photo sensitive areas of the brain; light is able to permeate the skull to reach these photoreceptive areas. (Benoit 1964; Menaker & Keatts 1968).

Early studies performed by Benoit revealed that other photoreceptors besides that of the eye are responsible for reproductive development associated with change in photo periods in male domestic ducks, *Anas platyrhynchos* (Benoit & Assenmacher 1954). Such early studies involved the blinding of birds through various methods such as encircling the eye with rubber or metallic plates and removal of the eye altogether which is known as enucleation (Benoit 1964). Due to an increase in sensitivity with regards to animal welfare and ethics, experiments involving methods such as enucleation are no longer practiced.

Other famous work involving the enucleation of birds is the work performed by Menaker and his colleagues in the 1960's through to the 1970's. In a series of studies involving house sparrows (*Passer domesticus*), Menaker was able to show that blinded sparrows had no difference in activity and reproductive development affected by different lighting regimes when compared to sparrows that kept their ocular vision (Menaker 1968; Menaker *et al.,* 1968; Menaker *et al.,* 1970). Menaker and his colleagues showed how ocular vision is not necessarily the only way light is sensed by birds but that photoreceptors within the head are responsible. This was revealed by plucking feathers from the heads and injecting ink beneath the scalp of enucleated birds. Enucleated birds with feathers plucked from their heads were able to establish regular development and functionality in low light intensity while enucleated birds with Indian ink blocking photoreceptors in the brain were unable to become entrained to the applied photoperiods (Menaker *et al.,* 1970).

Since the early studies of Benoit and Menaker, successive research has suggested more specific areas of the brain which are photosensitive. Literature suggests evidence of the pineal gland and hypothalamus region as photoreceptive areas within the brain of birds (Yokoyama 1976; Collin & Oksche 1981). With photoreception from the retina (Bailey & Cassone 2005) and extraocular region of the brain, broilers have an acute perception to light.

Birds are able to synchronise their daily and seasonal functions in order to meet their survival and reproduction requirements (Immelmann, 1971). This is the same as with other species. The daily functions to meet requirements can be described as a circadian rhythm. Light has been observed to be a factor responsible for rhythmic changes in broilers (Bernard *et al.,* 1997).

Circadian entrainment is influenced by melatonin in vertebrates (Cassone *et al.,* 1986) It has been observed in birds that both the pineal gland and the retina are responsible for melatonin secretion (Pelham 1975; Foà & Menaker 1988). Melatonin secretion in chickens has been observed to be highest during the dark phase of a circadian cycle (Pelham 1975). A melatonin rhythm brought about by diurnal lighting regimes has been suggested to affect growth of organs in broilers (Li & Howland 2003; Lewis & Gous 2009b). Disease incidence has also been observed to be higher in chickens where melatonin deficiencies are induced (Machida *et al.,* 1995). Interactions with light and melatonin secretion may affect growth and disease incidence which make the use of correct circadian entrainment through lighting regimes a tool in broiler production.

2.2.2 Light Intensity

In poultry production it has been observed that difference in light intensity can affect broiler behaviour. Most notably the activity level has been seen to vary due to light intensity (Kristensen *et al.,* 2006; Alvino *et al.,* 2009). The artificial light offered to birds in commercial production systems can be altered in intensity. These artificial light sources are designed primarily for human vision and it has even been suggested that they may not be suitable for the vision of all birds (Evans *et al.,* 2012).

Literature suggests that varied light intensity can affect behaviour during the growing period of broilers and during handling procedures (Jones *et al.,* 1998b; Alvino *et al.,* 2009). Such literature promotes the use of various light intensities as an inexpensive tool in benefitting production and bird welfare (Kristensen *et al.,* 2007; Alvino *et al.,* 2009).

In recent studies where the activity level of broilers has been measured under various light intensities, a common result of increased activity with higher light intensities has been observed. This was noted by Kristensen *et al*. (2006) when observing the activity level of broilers in a step-wise alternating light intensity regime. Light intensity in this study was alternated daily or every two or four hours between 5 and 100 lux on a 16L: 8D regime. During periods of 100 lux light intensity, birds had a higher activity index (0.449) compared to periods of 5 lux intensity (0.289). In a subsequent paper, Kristensen *et al*. (2007) time budget for activity in broilers was observed under different light sources and intensities. It was reported that under 100 lux intensity birds spent a significantly greater time standing than birds under 5 lux light intensity. The results of Kristensen *et al*. (2006) and Kristensen *et al*. (2007) are further reiterated by the responses seen in Alvino *et al.* (2009). When observing time budgets in broilers reared under different light intensities, Alvino *et al.* (2009) reported that broilers reared on 5 lux light intensity spent more time sleeping than birds reared under 50 or 200 lux light intensity. A light level of 1 lux was offered to the broilers during the 8 h dark period on a 16L: 8D regime. It was observed that birds reared under 5 lux light periods were more active during the 1 lux dark period compared to those reared under 200 lux during the 16 h light period. The authors concluded that this may have been due to a lack in contrast between the light and dark period which brought about a wider spread in distribution of activity. Contrast between light and dark period can affect activity responses as was the case in Kristensen *et al*. (2006) where broilers responded faster to step up periods of 100 lux than to 5 lux. This was observed through a steeper incline in activity when modelling the dynamic responses of the birds. Deep *et al*. (2012) observed the activity of birds with 0.1 lux intensity during the dark period and intensities of 1, 10, 20 and 40 lux during light periods. It was found that birds reared under 1 lux light periods, rested more than birds reared under 10, 20 or 40 lux light periods. However in contrast to finding of Alvino *et al.* (2009), birds reared under all treatments showed diurnal rhythms and little or no activity was found during the dark period of 0.1 lux. The low light intensity of 0.1 lux must have been an appropriate contrast from 1 lux intensity to decrease activity during the dark period.

It is clear from these studies, that the higher light intensities which promote the activity and standing of birds will prevent lameness and the occurrence of skeletal disorders thereby improving the welfare of the flocks. However lower light intensities may also be utilised in protecting the welfare of birds as suggested by Kristensen *et al*. (2006) where it is recommended to use low light intensities on days when birds need to be captured. Calmer, less frightened birds may not struggle as much and there is a lowered risk of injury. This intern could enhance carcass quality by preventing bruising and bone breakages.

The use of different light intensities is an effective and inexpensive tool in protecting the welfare of the birds and controlling their activity and behaviour (Kristensen *et al.,* 2006). By controlling the activity level of the birds it is possible to decrease energy expenditure and promote higher growth rates and feed conversion efficiencies with lower light intensities. Higher light intensities present welfare benefits in decreasing incidences of leg disorders through promoting activity while the birds are under light however it has been observed that birds exposed to less than 12 hours of light per day consume a large proportion of their daily intake at night (Lewis *et al.,* 2009a). If birds are reared under high light intensities and less than 12 hours of light this may affect production as night feeding may be reduced due to increased activity during the light phase causing birds to rest more during the dark phase. This is an area where investigation will allow the incorporation of varied light intensity into lighting regimes to reap not only welfare benefits but production benefits as well.

2.2.3 Photoperiod Management

Photoperiod management and lighting regimes are an area within broiler production where continuous research is required. This is due to changed responses observed in the modern broiler to photoperiods which differ and often provide confounding results when compared to the broilers of years before. In the early 1960's, constant illumination was believed to be the most effective lighting practice in order to reach maximum growth potential and highest BW (Shutze *et al.,* 1961; Weaver & Siegel, 1968). The basis on which this practice was formed was that birds were encouraged to eat constantly due to uniform access to feed under artificial light exposure. Even though the modern broiler's performance is less affected by differing light regimes, one indispensable fact still remains; the welfare of broilers is adversely affected by constant or near constant (23L: 1D) lighting regimes.

It has been seen that the use of constant illumination results in higher incidences of skeletal and leg disorders (Buckland *et al.,* 1973; Riddell & Classen 1992; Sanotra *et al.,* 2002). Eye development is also detrimentally affected by constant illumination (Li *et al.,* 1995; Li *et al.,* 2003; Lewis *et al.,* 2009b). Incidences of mortality have also been noted to increase linearly with an increase of illumination greater than 12 hours (Brickett *et al.,* 2007; Lewis *et al.,* 2009a; Schwean-Lardner *et al.,* 2012a).

Continuous or near continuous exposure to light may not only have developmental effects but also negative behavioural effects. Schwean-Lardner *et al.* (2012b) reported that broilers reared under 23L: 1D lost certain behavioural activities such as dust bathing and running compared to broilers reared under 14L: 10D, 17L: 7D and 20L: 4D. In this study broilers reared on 23L: 1D were more lethargic to birds exposed to shorter days and spent less time at feeders. This contradicts previous notions that promoted the use of continuous lighting to encourage birds to spend maximum amounts of time feeding. Such evidence agrees with other work performed by Shwean-Lardner *et al.* (2012a) where feed consumption was not highest for birds reared under 23L: 1D but rather for birds reared under 20L: 4D at 39 days of age. The decrease in activity shown by birds reared under continuous light also raises welfare concerns as the decrease in movement promotes skeletal disorders and poor development (Sanotra *et al.,* 2002). Rozenboim *et al.* (1999) noted mortality to be higher for broilers reared on 23L: 1D compared to those exposed to 16L: 8D daylength cycles. Supporting evidence on the ill effect of long daylengths on bird mortality was noted by Lewis & Gous (2009b) where mortality increased proportionately with daylengths longer than 12 h.

However, in terms of broiler performance, increasing daylength has been shown to have a positive effect on BW (Classen 2004; Brickett *et al.,* 2007; Schwean-Lardner *et al.,* 2012a). Classen (2004) observed a linear increase in BW with increasing daylength. At 35d BW was highest for broilers reared on 20L: 4D compared to 16L: 8D and 12L: 12D which were 42 g and 85 g lighter, respectively. These findings coincide with those of Brickett *et al.* (2007) where broilers reared on 20L:4D were 120 g heavier than broilers reared on 12L: 12D at 35 d. Schwean-Lardner *et al.* (2012) found that at 39d, broilers reared on 20L: 4D were 28 g and 94 g heavier than broilers reared on 17L:7D and 14L:10D, respectively. Schwean-Lardner *et al.* (2012) did include a near continuous lighting treatment of 23L: 1D. This treatment however did not yield the highest BWs and were 46 g lighter than broilers exposed to 20L: 4D. Feed intake was also less for broilers reared on 23L: 1D compared to 20L: 4D. This result is in contradiction to previous studies which suggested that continuous or near continuous lighting regimes promote highest BW. The results also indicate that a certain period of darkness may be beneficial to the broilers not only from a welfare point of view but also for improved performance.

Welfare regulations in the European Union stipulate a minimum of 6 hours darkness for meat chickens within a 24 h period (European Commission, 2000). This means a maximum of 18 h on a 24 h cycle. Therefore the use of lighting regimes greater than 18L: 6D will no longer be applicable in the future as sensitivity to broiler welfare grows world-wide. Concern as to whether growth rate will be detrimentally affected by new welfare regulations has resulted in recent studies investigating lighting regimes which fall within the stipulated photoperiod limits.

Lewis & Gous (2007) observed the performance of broilers on short or step-up photoperiods. Decreasing daylength especially within the first 21 d of rearing slows the initial growth rate of the broilers. This allows for improved skeletal development preventing leg disorders but also relies on compensatory growth after 21 d to reach market weight. Lewis & Gous (2007) reared broiler females under 8L: 16D and 16L: 8D daylength cycles along with a step-up group transferred from 8L:16D to 16L:8D at 21d. The birds were reared to 42d. The results of this study showed that longer daylengths may not be necessary for greater BW as the broilers reared on constant 8L: 16D daylengths were heavier than birds under 16L: 8D daylengths ($P < 0.05$). Birds in the step-up groups also exhibited higher BWs than those reared on 16L: 8D daylengths ($P < 0.05$). Heavier BWs for 8L: 16D and step up groups at 22 d also meant the compensatory growth was irrelevant in comparison to the 16L:8D group for the 22-42 d period.

In a subsequent paper by Lewis *et al.* (2008), male broilers were also reared under 8L: 16D and 16L: 8D daylengths, along with step-up treatment groups from 8L: 16D to 16L: 8D. When data were pooled with the previous equivalent work performed on females (Lewis & Gous 2007), it was observed that birds kept on 8L: 16D and step-up groups from 8L: 16D to 16L: 8D had higher BWG and improved FCE at 35 and 42 d. Lewis *et al.* (2008) also found that birds reared on 8L:16D daylengths consumed almost half their feed during the 16 h dark phase whereas birds reared on 16L: 8D daylengths only consumed a small percentage of feed (10%) during the 8 h of darkness. Transfer groups reduced their nocturnal feeding once moved to 16L: 8D daylengths but continued to feed more than those in the constant 16L: 8D groups. These findings indicate the ability of the modern broiler (both male and female) to learn to consume a portion of its feed within the dark phase of a lighting regime. The theory behind providing light constantly may not be applicable to the modern broiler as the increased appetite in the today's broilers may prompt the birds to feed at night to achieve dietary satisfaction.

In order to gain a broader sense of responses to different daylengths, Lewis *et al*. (2009a) observed the photoperiodic responses over a range of daylengths from 2L: 22D to 21L: 3D in Cobb and Ross broiler males. It was observed that FI and BWG were positively correlated to daylengths ≥12L: 12D prior to 21 d but negatively correlated post 21 d. In agreement with Lewis *et al.* (2008), nocturnal feeding decreased with photoperiod exposure, however, it was observed that birds with daylengths ≤15L: 9D had learnt to feed in the dark by 5 d. Since Lewis *et al.* (2008) showed very little nocturnal feed consumption when exposing birds to 16L: 8D daylength cycles it may seem that a 15L: 9D or less daylength is the limit which prompts nocturnal consumption.

The FCE of broilers in Lewis *et al*. (2009a) peaked at 12L: 12D and birds reared on daylengths greater than 12 h of light also had increased mortality rates. These findings are in agreement with those of Classen (2004) where broilers reared under 12L: 12D had improved FCE compared to 20L: 4D with reduced mortality rate under 12L: 12D. However the results of Classen (2004) are conflicting as BW at 35 d was heavier for broilers reared under a 20L: 4D daylength as compared to 12L: 12D supporting previous findings of Ingram & Hatten (2000). Lewis *et al*. (2009a) found no difference in BW for broilers reared under a 12L: 12D compared to other lighting treatments with longer periods of light exposure (15L: 9D, 18L: 6D, 21L: 3D and 24L: 0D). Shwean-Lardner *et al*. (2012) also found conflicting results when rearing broilers under four different daylengths. In this trial all birds were reared under 23L: 1D for 7d before being transferred to treatment groups of 14L: 10D, 17L: 7D, 20L :4D and 23L: 1D. Shwean-Lardner *et al*. (2012) found the BW to be heaviest under 20L: 4D daylength at 32 d. However one can look at these results sceptically as the birds were reared under near constant illumination for the first week. This may have prevented the birds acquiring the ability to consume feed at night. It may well have caused a carry-over effect which prompted the broilers to be more receptive to longer daylengths which they were accustomed to by 7 d. The ability of birds to consume feed at night may contribute to the heavier weights under 12 and 15 light photoperiods in the Lewis *et al*. (2009) study.

Despite some evidence suggesting the ability of broilers to reach similar BW under shorter photoperiods a concern as far as carcass composition is the altering in yield of certain carcass parts. Lewis *et al.* (2009) did express concern with regards to a greater breast meat yield for birds reared under 21 h or continuous illumination. Similar effects due to lighting treatment were observed by Downs *et al.* (2006). When comparing a decreasing-increasing lighting regime (reducing the daylength followed by increasing daylength) against a continuous lighting regime, whole leg weight and yield was increased by 2.9%. Breast meat being the most economically relevant cut means that legislature forcing greater periods of darkness may reduce BMY if nutrient resources are being utilised more so for other carcass portions by the birds. Feed manipulation may be a possible solution in preventing BMY reduction.

Other studies have observed the effects of not only the use of altering daylengths through singular periods of light exposure within a 24 h period but also through the use of intermittent light exposure. Intermittent lighting regimes have been seen to improve broiler welfare by reducing incidences of metabolic disorders, improving immune functions and decreasing leg disorders (Buys *et al.,* 1998; Hassanzadeh *et al.,* 2000; Onbaşılar *et al.,* 2007; Abbas *et al.,* 2008). In terms of production, intermittent lighting regimes improve carcass characteristics by decreasing abdominal fat deposition and improve FCE (Rahimi *et al.* 2005; Abbas *et al.* 2008; Li *et al.* 2010). Abbas *et al.* (2008) observed heavier BW for broilers reared under an intermittent lighting regime of 2L: 2D when compared to a near continuous lighting regime of 23L: 1D and a restricted lighting regime of 12L: 12D. At 42 d, intermittent lighting produced broilers with BWs over 100 g heavier than birds reared under 23L: 1D and 12L: 12D. The number of broilers used for this trial was low at only 100 birds per treatment and replicates were determined by dividing each treatment group by pens and not splitting up birds within a treatment group into different rooms which may have *truly* replicated the treatments. The effect of intermittent lighting in this trial was also only determined by using one intermittent lighting treatment (2L: 2D). Another more recent study where a larger range of intermittent lighting regimes was observed was the work of Wen-bin Li *et al.* (2010). In this study an array of various intermittent lighting regimes were tested against a near continuous lighting regime of 23L: 1D. Intermittent lighting regimes of 20L: 4D (12L: 2D 8L: 2D), 16L: 8D (12L: 3D 2L: 3D 2L: 2D) and 12L: 12D (9L: 3D 1L: 3D 1L: 3D 1L: 3D) did not have a significant effect on BW at 35 d and 42 d. These results coincide with Rahimi *et al.* (2005) where an intermittent lighting regime of 1L: 3D had no effect on BW at 42 d when compared to 23L: 1D. Earlier studies by Buyse *et al.* (1996) and Buys *et al.* (1998) are also in agreement with no differences in BW being observed by 42 d. Comparing intermittent lighting regimes contains a higher complexity as various combinations of intermittency can be studied. However the welfare benefits of intermittent lighting regimes and reduced production costs through reduced electricity usage make it an attractive consideration in broiler production, especially if BW is unaffected and carcass characteristics improved through decreases in fat deposition.

Defining the ideal lighting regime for the modern broiler requires the ongoing investigation into the response of present genotypes to differing lighting programmes. With welfare concerns increasing in production enterprises, the use of lighting regimes to improve broiler welfare is an environmental aspect which can easily be manipulated with the advancements in modern rearing systems. Problems arising from the applications of welfare complying lighting regimes such as reduced BMY may be rectified by adjustments in nutrition.

2.2.4 Colour of Light

Artificial light provided for broiler production may vary in colour. The spectral wavelength of light produced by a source will determine its colour and has been seen to have different effects on broiler performance and behaviour (Prayitno *et al.,* 1997). It has been observed that green and blue light sources promote weight gain in broilers when compared to red or white sources (Wabeck & Skoglund 1974; Halevy *et al.,* 1998). Green light promotes muscle growth during the earlier part of rearing while blue light enhances growth in older birds (Halevy *et al.,* 1998). However it was also observed that red and white light promoted sexual maturation (Osol *et al.,* 1984). Modern studies have expanded the area of research by observing meat quality effects as well as identifying the mechanisms behind the differences seen in birds reared under different light colour (Xie *et al.,* 2008; Karakaya *et al.,* 2009; Liu *et al.,* 2010).

Karakaya *et al.* (2009) determined quality and performance effects of green and blue light mixture treatments against that of incandescent control treatments. It was observed for female broilers, that post-hatch treatments of green light transferred to blue light or blue and green light mixtures, promoted higher muscle weight, overall bodyweight and feed intake. Xie *et al.* (2008) observed effects of cell proliferation in the spleen of broilers exposed to different colour treatments. These results agreed with the positive and stimulatory effects of green and blue light observed by Karakaya *et al.* (2009). Spleen weight and cell proliferation were higher for green and blue light treatments compared to that of red and white (control) light treatments. Liu *et al*. (2010) found that green light promoted mitotic activity and growth of pectoral muscle compared to red light stimulation. Light of shorter wavelengths such as blue and green appears to stimulate growth and cell proliferation rather than light of longer wavelengths such as red and orange.

Over time studies have focused on minimising the light spectrum under which experiments are performed in order to verify more accurately the effect of colour on broiler performance. This has been achieved through the use of monochromatic light sources (Halevy *et al.,* 2006b; Xie *et al.,* 2008). Another development with regard to the effect of light colour on broiler performance is the use of colour treatment during egg incubation. Since the development in genetic selection and improved production methods, the time period needed to reach target weights of broilers has decreased. This means that the incubation period for broilers is becoming a larger proportion of the overall lifespan of the bird. For this reason, interest in manipulation of the incubation period has arisen in the hope of promoting subsequent benefits once the birds have hatched (Halevy *et al.*, 2006a; Rozenboim *et al.,* 2013).

Halevy *et al.* (2006a) investigated the effects of green light during the incubation period. It was observed that monochromatic green light photostimulation enhances skeletal muscle cell proliferation and promoted heavier body weights post-hatch. The authors suggested that the stimulatory effect of monochromatic green light during incubation allowed for greater myoblast and myofibre differentiation and synchronisation. Broiler eggs are commercially incubated in constant darkness and it has been suggested that the enhanced growth and proliferation of cells in chicks exposed to light stimulatory may be due to added heat from the lighting source (Halevy *et al.,* 2006b). However the use of intermittent lighting regimes during incubation has allowed the positive effects to be attributed to light stimulus (Rozenboim *et al.,* 2013).

The effects of light colour on the incubation and rearing in broiler production may easily be used to enhance overall production and achieve higher target weights.

2.3 NUTRIENT DENSITY AND BREAST MEAT YIELD

Nutritionists face the challenge of providing feeds that are economically viable while nutritionally sound to provide specific production outputs. On top of this challenge is the constant changing in genotypes of the modern broiler which need to be catered for. The modern day broiler requires increased amounts of nutrients in order to satisfy the potential rapid growth rate. Dietary protein and energy constituents need to match the requirements of both maintenance and muscle accretion in order to translate into saleable meat but, most importantly, breast meat.

2.3.1 Dietary Protein

As far as broiler production is concerned, feed accounts for the majority of production costs. Within each feed, the ingredients responsible for supplying the majority of the CP tend to be the most expensive. The direct relationship of dietary protein and protein accretion along with the high cost associated with protein feed sources means that this is a primary area of research relating to broiler production.

In order to reduce production costs and decrease nitrogen excretion, the lowering of crude protein has been researched. Studies where crude protein levels are lowered have shown adverse effects on growth performance (Ferguson *et al.,* 1998; Rezaei *et al.,* 2004; Kidd *et al.,* 2005). Ferguson *et al.* (1998) noted a 4.6% reduction in BWG over 22 to 43 d and 1 to 43 d when reducing dietary CP. In this study high, medium and low CP diets were allocated for starter and grower phases of commercial broilers. There were no differences in BWG between the high and medium grower treatments which contained 21% CP and 19% CP respectively. However a further reduction to 16.5% CP from the low grower treatment decreased weight gains by 86g for the 22 to 43d period and 98g from 1 to 43d. Such results suggest that a threshold for adverse effects on BWG by reducing CP exists. These results coincide with the findings of Rezaei *et al.* (2004) where BWG was reduced by 4.6% for a grower period of 21 to 42 d when reducing CP from 18.1% to 16.1%. Rezaei *et al.* (2004) was also able to identify a 6% reduction in BWG within the starter period of 1 to 21d when CP was reduced from

20.8% to 17.8%. In a similar study, Sterling *et al.* (2006) noted that BWG was higher for birds fed 23% CP compared to a reduced 17% within 7 to 21 d whilst increasing lysine levels. BWG is adversely affected by feeding low levels of dietary CP (Kamran *et al.,* 2008). Reducing the CP content in feed will reduce feed manufacture costs but may reduce profits on a cost-benefits basis as BWG is adversely affected. The modern broiler requires a high nutrient density and dietary CP requirements need to match the levels required for maintenance and muscle accretion which will translate into increased meat production.

It has been hypothesised that providing CP in levels which are deemed in excess may improve production and therefore reap greater profits on a cost-benefit basis (Bartov & Plavnik, 1998). This has prompted research into providing broilers with higher levels of CP in diets as opposed to what may be a commercial standard. Kidd *et al.* (2004) observed the effects of providing various levels of dietary protein ranging from what is considered high, average and low by commercial poultry producers in the US. Combinations of these dietary levels were fed across four phases, 1 to 14 d, 15 to 28 d, 29 to 35 d, and 36 to 49 d. It was noted that Ross 508 male and female broilers fed the high CP dense diets across all phases had greater BMY at 35 and 49 d ($P < 0.05$). Final BW was also improved as long as the starter and grower phases, 0 to 14 d and 15 to 28 d contained high CP inclusion levels of 23.35% and 21.77%, respectively. Corzo *et al.* (2005) also observed the effects of increasing dietary protein above that which is commercially considered adequate. In this study three strains of broilers were subjected to either a high or low CP diet. The three strains consisted of two multipurpose strains and a high yielding strain. Across all three strains of broilers, BW was improved by providing CP in excess of the commercially perceived requirement at 56 d. Within the high yielding strain, total BMY was improved by a high CP dense diet at 42 d. Across all three strains of broilers, BMY was decreased by 0.6 % at 42 d and 0.5% at 56 d by reducing CP. In a subsequent study, Kidd *et al*. (2005) observed the economic effect of feeding high CP dense diets to Ross 708 broilers. At 35 d, feed costs per kg BW decreased even though diet cost increased by feeding CP at higher levels. However at 55 d it was no longer cheaper to feed high CP dense diets as BMY yield differences did not occur between moderate and high CP dense diets from 35 to 55 d. This result highlights what was noted previously by Kidd *et al.* (2004) that high CP density applied in starter and grower phases may be beneficial all through the rearing process until market age by maximizing potential growth through a carry-over affect from early nutrition. However, Dozier *et al.* (2007) observed an increase in BMY through increasing dietary CP in a late finisher phase from 42 to 56 d. This would be taking advantage of the allometric growth relationship of breast tissue which becomes a larger proportion of the carcass weight at later stages (Gous *et al.,* 1999).

Conversely, increases in dietary CP may not always be a solution in terms of improving growth performance and BMY (Mlaba *et al.,* 2015). In the studies mentioned above, Kidd *et al.* (2004), Corzo *et al.* (2005), and Kidd *et al*. (2005) reared birds on long daylengths with the shortest daylength being 20 h of light with target weights being above that of 2.6 kg which took more than 35 d to achieve. It has been noted that under different production circumstances where short daylengths have resulted in reduced BMY (Lewis *et al.,* 2009), providing dietary protein in excess does not improve BMY as was noted by Mlaba *et al.* (2015). In this study birds were reared to only 35 d and various levels of dietary protein ranging from 0.8 to1.3 times of the Aviagen recommended amounts were administered (Aviagen, 2009). In birds reared under daylengths of 12 h or less, providing dietary CP in excess did not increase BMY. Wen-bin Li *et al.* (2010) found that under near constant (23L: 1D) and intermittent lighting regimes, leg and wing portions were increased by providing lower nutrient dense diets containing less ME and CP. If the change in carcass proportion was not a result of inadequate CP as described by Mlaba *et al.* (2015) then the reduction in ME levels may have been responsible for reduced BMY percentage.

2.3.2 Dietary Energy

Dietary ME has a direct bearing on FI in broilers (Leeson *et al.,* 1996a; Hidalgo *et al.,* 2004; Dozier *et al.,* 2007) making it an imperative consideration when evaluating nutrient density. This means that excessive or suboptimal supply of dietary ME will have an effect on overall nutrient intake affecting growth performance, body composition and FCE (Leeson *et al.,* 1996a; Downs *et al.,* 2006; Dozier *et al.,* 2011). Dietary ME is important for muscle deposition which equates to production of saleable meat (Noblet *et al.,* 1999). Nutrient densities in diets need to provide an optimal level of ME to promote maximum production output from the modern broiler.

Leeson *et al.* (1996a) illustrated the ability of broilers to adjust feed intake to meet ME requirements and the effect of ME on growth rate and carcass characteristics. Four dietary treatments were formulated only to differ in ME content. This resulted in four feeds consisting of 2700, 2900, 3100 and 3300 kcal ME/kg. Each feed was fed to treatment groups of male broilers from 4 to 50 d. Crude protein content for all treatment feeds was identical at 21 %. In the first experiment when broilers had *ad libitum* access to feed it was noted that FI increased linearly with reduced energy level ($P < 0.01$). Even though increased FI of the lower energy containing feeds caused an overall increase in CP consumed, weight of carcasses and BMY were unaffected ($P < 0.05$). Abdominal fat pad decreased linearly with decreased ME level ($P < 0.01$). In a second experiment, treatment groups were fed the same amounts of restricted feed throughout the trial period. In this experiment BW was less for birds fed the diet containing the lowest ME value (2700 kcal ME/Kg).The fact that all other treatment groups were not significantly lighter suggests a threshold where lowering the amount of dietary energy has a detrimental effect on growth rate. In a third experiment where birds were able to select between treatment feeds it was noted that broilers would consume smaller proportions of feeds containing lower ME levels. This underlined the ability of broilers to control FI to meet ME requirements. The lack of phase feeding in this study made it inapplicable to modern commercial practices along without allowing any insight into delineating the feeding of ME throughout the rearing period. However in terms of evaluating the effects of dietary energy, Leeson *et al.* (1996) is noteworthy as confounding effects of other nutrients such as differing levels of CP were kept constant confirming that differences in FI were dependant on dietary energy. This was confirmed in a similar study (Leeson *et al.* 1996b) where reducing ME content in feed through dilution increased FI even though protein requirements were met across all treatments.

Nutrient density for broilers needs to be formulated with the consideration of the effects of dietary ME on FI. Dozier *et al*. (2006) observed the effects of dietary energy levels in the later stages of production of heavy broilers from 30 to 59d. Results in this study confirm that of Leeson *et al.* (1996) where increased ME in diets reduced feed intake therefore improving FCE as BW was unaffected by AME inclusion levels. However when AME was increased from 3220 to 3265 or 3310 kcal/Kg, BMY was adversely affected. It was noted that birds were consuming feed to satisfy energy requirements and when consuming diets higher in AME an intake of CP was less than that of birds on lower AME treatments. Within this study a second experiment was performed and reduced BMY was corrected by simply increasing CP density in the 3310 kcal/Kg AME diet to equate to the decreased CP intake from reduced FI, this is in agreement with previously mentioned studies where increasing dietary CP increases BMY in heavy broilers (Corzo *et al.,* 2005; Dozier *et al.,* 2007).

Dozier *et al.* (2006) highlighted how dietary energy must be considered with dietary protein especially when altering inclusion levels that may cause FI differences. In order to provide broilers with diets containing optimum nutrient levels for maximum production, dietary ME requirements must first be well understood.

In younger birds FI is not only affected by ME concentrations but also restricted by gut capacity (Hidalgo *et al.,* 2004; Kamran *et al.,* 2008). Brickett *et al.* (2007) noted that within the first two weeks of rearing the ability of broilers to regulate FI as affected by nutrient density is limited. This means that in comparison to production systems where broilers are reared to heavier weights >2.5kgs and for longer periods of time where compensatory growth and FI can occur (Leeson *et al.,* 1996b; Downs *et al.,* 2006), the effect of suboptimal amounts of ME will be more pronounced. Hidalgo *et al*. (2004) illustrated that decreasing ME concentrations in broilers reared to 35 d adversely affected BWG, however the treatment diets were formulated to contain constant ME to CP ratios meaning that the reduced performance may be due to inadequate ME or CP intake. With regards to dietary ME and its affect in broilers reared to younger ages and lighter weights, little recent research has been performed.

In terms of solving the problems of reduced BMY in broilers reared on short daylengths, a study on dietary ME is warranted as it may provide a solution. Lei & Van Beek (1997) reported that when the activity levels of broilers are increased, ME intake is also increased. Under differing circumstances such as rearing birds under non continuous lighting regimes where the activity of broilers may be increased (Schwean-Lardner *et al.*, 2012), the requirement of dietary ME will increase simultaneously. If younger birds are limited by gut capacity than increasing ME concentrations may result in improved performance and carcass yields. Ohtani & Leeson (2000), noted that when applying an intermittent lighting regime to broilers of 1L:2 D, ME intake was increased and this resulted in higher BWG in comparison to broilers reared under a continuous lighting schedule. If broiler BW can be increased through increasing dietary ME intake then it is also possible that BMY can be improved under short daylength cycles.

2.4 CONCLUSION

Lighting as an environmental factor has a major effect on broiler production. The sensitivity of broilers to light means that all separate facets relating to light including intensity, colour and photoperiod length can affect production. It is valuable to consider all facets pertaining to light in order to provide a complete evaluation of its importance in production. In terms of commercial production, daylength plays a major role in affecting broiler performance response and is easily manipulated by producers.

Essentially the design of a lighting program that is best suited for the modern broiler which incorporates the limits imposed to protect bird welfare is yet to be produced. The conflicting results seen between studies concerning daylength and production responses also emphasises the need for further studies to be conducted to determine the actual true response of the modern broiler to differing daylengths.

Several questions regarding the response of the modern broiler to lighting programs are still unanswered. These include defining the extent at which carcass portions are affected by lighting regimes and the threshold to which short daylengths affect carcass portions or broiler performance adversely. Subsidiary is the determination of not only age but length of dark period which prompts broilers to consume feed at night.

The effect of daylength on activity and feeding habits of broilers also means that research regarding lighting programs must be considered simultaneously with nutrient and diet evaluation. Considering both factors simultaneously is therefore imperative in order to map the response of the modern broiler and provide insight into defining both lighting programs and dietary requirements in order to maximise production output.

CHAPTER 3

THE EFFECT OF INCREASED DIETARY ENERGY ON BROILERS REARED ON SHORT DAYLENGTHS FROM 0 TO 10 DAYS OF AGE

3.1 INTRODUCTION

The modern broiler has the ability to express an exceptional growth rate. Consequences of such a tremendous growth rate mean that target weights are met at an earlier age compared to years before (Havenstein *et al.,* 2003). In markets such as South Africa where broilers are reared to what is considered a smaller target weight, the time taken to achieve such weights is comparatively shorter than commercial markets where heavier broilers are sought after. In South Africa broilers are commercially reared to 1.6-2.2 kg which is achievable between 32 and 35d. In most overseas markets the precedent is to produce heavier broilers where target weights may exceed 3.6 kg, this is achievable between 49 and 56d. The practice of rearing broilers to smaller target weights and subsequently younger ages means that the starter phase forms a bigger proportion of the entire rearing period. Subsidiary is the fact that as genetic selection continuously improves broiler growth rate, target weights may be achieved at even younger ages. The starter phase of broilers may become an even bigger proportion of the entire rearing period. The modern broiler needs to be catered for correctly to achieve maximum production. This means determining the optimal nutrient requirement within the starter phase is an imperative consideration. Nutrient requirements also need to enable the production of a carcass which suits consumer demands.

Market demands suggest that the production of leaner white meat in the form of breast meat is paramount. Breast meat yield however, has been seen to be decreased when broilers are reared under welfare compliant lighting regimes (Lewis & Gous 2009b). It is likely that commercial broiler practices world-wide will adopt welfare compliant lighting regimes which incorporate periods of darkness as sensitivity to bird welfare increases with a more informed and concerned consumer. Under continuous or near continuous (23L:1D) daylengths, breast meat yield is enhanced through increasing dietary protein (Bartov & Plavnik 1998; Kidd *et al.,* 2004; Corzo *et al.,* 2005). However under conditions such as shorter daylengths and rearing birds to 35d, breast meat yield is not enhanced through increasing dietary protein (Mlaba *et al.,* 2015).

Nutrient requirements of broilers under short daylengths may be altered due to changes in activity in broilers due to daylength (Schwean-Lardner *et al.,* 2012), this may also result in the deposition of protein in other areas, namely thighs and drumsticks due to increased walking or standing. If dietary protein is not a limiting factor under short daylengths (Mlaba *et al.,* 2015), then it can be hypothesised that dietary energy may be a limiting factor in preventing the deposition of breast meat in broilers reared under short daylengths.

The threshold to which shortening daylengths has a negative impact on broiler production is also undefined. Conflicting results have been obtained in defining the ideal welfare compliant lighting regime for the modern broiler (Classen 2004; Lewis & Gous 2007; Lewis *et al.,* 2008, 2009a). Ideally reducing light exposure may benefit broiler welfare and reduce production costs, especially in developing countries such as South Africa, where electricity is a volatile resource. If broiler production can be equated or enhanced through the use of shorter daylengths this may be a tool of improving profitability in the broiler industry of South Africa.

3.2 METHODS AND MATERIALS

3.2.1 Housing and management

One thousand as-hatched Ross 308 broilers were reared in a light proof facility which had four independent rooms. Each room was split into two pens by a wire mesh barrier resulting in a total of eight separate pens. One hundred and twenty five chicks were randomly allocated to each pen at a stocking density of 19.23 birds/m^2. Male and female broilers were neither determined nor separated as the trial was conducted in a manner to mimic commercial practices as closely as possible. The floor of each pen was covered with 10 cm deep wood shavings. All broilers received 24hrs of light prior to the implementation of two lighting treatments. The lighting treatments consisted of a long daylength treatment of 16L: 8D which served as a control and short daylength treatment of 8L: 16D. Light was provided through the use of 14W warm-white fluorescent bulbs. All broilers had *ad libitum* access to feed and water. Heating was provided with gas spot-brooders, one mounted above each pen. A thermostat control for each room was set at an initial 31.5ºC and after 2 days it was decreased linearly by 1.5 ºC and was set at 27.5 ºC by 10 d. Ventilation was provided through a negative pressure system. Both temperature and ventilation protocols were conducted in a manner aimed at mimicking standard commercial rearing techniques used in South Africa. The animal ethics committee approved the use of broiler chicks for this experiment, reference number, 043/15/Animal.

3.2.2 Experimental treatments

All broilers initially received 24 h of continuous light prior to the implementation of two lighting treatments. Lighting treatments were maintained until the end of the trial which was 10 d. The lighting treatments consisted of a long daylength treatment of 16L: 8D which served as a control and short daylength treatment of 8L: 16D. Of the four light proof rooms, each room was randomly allocated a lighting treatment such that each lighting treatment was replicated twice.

Table 3.1 Ingredient composition (g/kg) of standard starter (SS) diet and high energy starter (SH) diet fed to broilers subjected to 8 or 16 h daylengths from 0 – 10 days of age

	SS	SH
Feed Ingredients (g/Kg)		
Yellow maize fine	601	570
Maize gluten 60	50	48
Soybean Oilcake meal 50	200	190
Sunflower Oilcake meal 34	30	30
Fish meal 65	50	47
L-lysine HCl	5.89	5.57
DL methionine	1.67	1.57
L-threonine	0.95	0.89
Choline Chloride 60%	1.18	1.11
Vit+min premix	2	1.89
Limestone	14.21	13.4
Monocalcium Phosphate	10	10
Sodium Bicarbonate	4.05	4
Soya Oil	29.15	76.4
Total	1000	1000
Composition (Calculated)		
AMEn chick (MJ/kg)	12.6	14.8
Crude protein (%)	23.0	23.0
Lysine (%)	1.57	1.57
Methionine (%)	0.60	0.60
Methionine+cystine (%)	0.98	0.98
Threonine (%)	0.95	0.95
Tryptophan (%)	0.23	0.23
Arginine (%)	1.34	1.34
Isoleucine (%)	1.00	1.00
Valine (%)	1.14	1.14
Calcium (%)	0.95	0.95
Avail. Phosphorous (%)	0.41	0.41

Two dietary treatments were used. The one diet was a standard starter ration (SS), formulated to meet the nutrient specifications described by the Ross Broiler Nutrient Specification Manual (Aviagen, 2014), The standard diet served as a control ration opposed to a high energy starter ration (SH) which was identical to the control ration however contained 15% higher ME content (Table 3.1). Both feed treatments were applied in each of the four light proof rooms. Dietary treatments were randomly allocated between each of the two pens within the light proof rooms. All feed was mixed at the University of Kwa-Zulu Natal research farm, Ukulinga. The feed was administered in a mash form and made available to chicks in feeding trays.

3.2.3 Measurements

All chicks were weighed on arrival in order to obtain a mean initial body weight. After which a random sample of 60 birds per pen were weighed at 7 d and 10 d. Sixty birds was an adequate statistical sample and fitted into a weighing tray allowing the birds to be weighed with minimal stress. These values allowed mean BW and BWG to be determined. Feed intake per pen was also calculated at 7 d and 10 d as the difference between the amount of feed administered to the chicks and the remainder of feed in trays on measuring days. Mortality was recorded daily and FI calculations were corrected for mortality by subtraction of mortalities from each test population. These measurements allowed FCR to be calculated as a FI to BWG ratio.

At 10 d, six birds from each combination of ration and lighting treatment were randomly selected for body part sampling analysis. This resulted in 24 birds being wing-banded and their identities recorded prior to BW and body part analysis. Body weight of each bird was recorded three times: once before cervical dislocation, the second after the feathers had been removed via hand plucking, and finally after the birds had been exsanguinated.

To determine effects of treatments on body part portioning, breast meat (without skin and bone), thigh and drum sticks (without skin) were dissected from each carcass and weighed. These were then able to be compared against BW as a relative percentage.

3.2.4 Experimental design and statistical analysis

A 2×2 factorial design resulted from the two lighting treatment levels (16L:8D and 8L:16D) and two dietary treatment levels (SS and SH) used, the main effects measured were therefore dietary nutrient concentration and daylength. The data were analysed using an analysis of variance to determine treatment means and least significant differences, this was performed using Genstat 14th edition analytical software.

3.3 RESULTS

3.3.1 Live weight, body weight gain, feed intake, feed conversion ratio and mortality

The main effects of both lighting and dietary energy had no effect on live weight, BWG, FI and FCR at 7 d or 10 d (Tables 3.2 and 3.3) ($P<0.05$). There were no significant differences or interactions between any performance variables measured at both 7 d and 10 d ($P<0.05$). Mortality was unaffected by any of the treatment combinations. Across treatments the mortality mean was measured to be 1.45%.

Table 3.2 The effects of lighting regime and dietary energy on live weight, body weight gain (BWG), feed intake (FI) and feed conversion ratio (FCR) in broilers at 7d

Main Effects	Live Weight (g)	BWG (g)	FI (g/bird)	FCR (g feed/ g BWG)
ME				
SH	150	103	118	1.2
SS	146	99	116	1.2
LSD	16.9	18.1	19.8	0.06
P	0.536	0.552	0.806	0.225
Lighting				
16L:8D	151	104	123	1.18
8L:16D	144	97	111	1.15
LSD	16.9	18.1	19.8	0.06
P	0.333	0.316	0.179	0.274
ME × Lighting				
SH × 16L:8D	154	108	125	1.16
SH × 8L:16D	145	97.7	111	1.14
SS × 16L:8D	148	101	121	1.2
SS × 8L:16D	144	96.1	111	1.16
LSD	23.95	25.61	28.05	0.0318
P	0.68	0.71	0.81	0.63

SS, standard starter diet. SH, high ME starter diet

3.3.2.1 Breast meat yield

The results for BMY are displayed in Table 3.4. Lighting and dietary energy had no effect on BMY weight or as a percentage of BW when solitary effects were considered ($P<0.05$). However a significant interaction was observed between the two factors where BMY was decreased for both weight and as a percentage BW at 10d for broilers reared under SH × 8L:16D conditions compared to SH × 16L:8D and SS × 8L:16D treatments (P<0.05).

Table 3.3 The effect of lighting regime and dietary energy on live weight, BWG, FI and FCR in broilers at 10d

Main Effects	**Live Weight** (g)	**BWG** (g)	**FI** (g/bird)	**FCR** (g feed/ g BWG)
ME				
SH	246	199	237	1.19
SS	238	191	237	1.23
LSD	16.7	17.6	16.4	0.08
P	0.304	0.322	0.971	0.178
Lighting				
16L:8D	243	197	238	1.21
8D:16L	241	193	236	1.22
LSD	16.7	17.6	16.4	0.08
P	0.671	0.608	0.85	0.65
ME × Lighting				
SH × 16L:8D	250	203	237	1.17
SH × 8L:16D	241	194	236	1.22
SS × 16L:8D	237	190	238	1.25
SS × 8L:16D	240	193	236	1.23
LSD	23.6	24.9	23.2	0.11
P	0.363	0.393	0.998	0.263

SS, standard starter diet. SH, high ME starter diet

3.3.2.2 Thigh yield

The results for thigh yield after 10 d are displayed in Table 3.4. Lighting and dietary energy as main effects did not alter thigh yield in terms of weight in grams (P<0.05). However a significant interaction between the two factors occurred for the SH × 16L: 8D treatment combination which expressed a greater thigh yield of 20.0g when compared to SH × 8L: 16D and SS × 16L: 8D treatment groups which yielded 18.4 g and 18.6 g, respectively (P<0.05). SS × 8L: 16D treatment combination was similar to all other treatment groups at 19.6 g. When expressed as a percentage of BW, lighting and dietary energy did not play a role in influencing this measure nor was there a significant interaction between the two factors.

3.3.2.3 Drumstick yield

The results for drumstick yield are displayed in Table 3.4. Drumstick yield was unaffected by lighting and dietary factors. Across all treatment combinations, drumstick yield was unaffected by experimental factors when expressed as a weight in grams or as a percentage of BW.

Table 3.4 The effect of lighting regime and dietary energy on breast, thigh and drumstick yield in broiler at 10d

	Breast Meat Yield		**Thigh Yield**		**Drumstick Yield**	
Main Effects	Weight (g)	% of BW	Weight (g)	% of BW	Weight (g)	% of BW
ME						
SH	25.8	10.7	19.3	8.0	18.0	8.7
SS	26.4	11.1	19.0	8.0	18.0	8.6
LSD	2.3	0.8	0.9	0.3	0.8	0.4
P	0.586	0.242	0.524	0.836	0.960	0.851
Lighting						
16L:8D	26.4	11.1	19.2	8.1	18.0	8.7
8L:16D	25.8	11.7	19.1	7.9	18.0	8.6
LSD	2.3	0.8	0.9	0.3	0.8	0.4
P	0.611	0.341	0.792	0.291	0.950	0.557
ME × Lighting						
SH × 16L:8D	27.7[a]	11.2[a]	20.0[a]	8.2	18.3	8.7
SH × 8L:16D	24.1[b]	10.1[b]	18.4[b]	7.8	17.7	8.6
SS × 16L:8D	25.3[ab]	10.9[ab]	18.6[b]	7.9	17.7	8.7
SS × 8L:16D	27.5[a]	11.3[a]	19.6[ab]	8.1	18.3	8.6
LSD	3.3	1.1	1.3	0.4	1.2	0.5
P	0.02	0.048	0.008	0.054	0.177	0.867

[a,b,c] Means within a column with no common superscript differ ($P < 0.05$). SS, standard starter diet. SH, high ME starter diet

3.4 DISCUSSION

The purpose of this study was to establish the main effects and interactions between lighting regimes and dietary energy on BMY within the starter phase of 0 to 10 d. This was in response to results obtained in literature which indicate the adverse effects of shortening daylength cycles on BMY (Downs *et al.,* 2006; Lewis *et al.,* 2007; Lewis *et al.,* 2009a). Secondary was the failure of increased protein levels to enhance breast meat in broilers reared on short daylengths (Mlaba *et al.,* 2015) thus dietary energy was considered as an alternative solution.

Narrowing down the effects of lighting regime within the starter period of 1 – 10 d does impose difficulty in providing direct comparisons to previously performed studies. However consistencies with that of other authors can be seen. Lewis *et al.* (2008) observed similar responses for BW, FI and FCE between broilers reared on 8L: 16D and 16L: 8D at 21 d. Such was the same response in the current study with no differences occurring due to lighting regime at 10 d for the same performance variables. However in contrast to these findings are that of Claasen (2004) where at 15 d, live weight was lower for broilers reared on 12L: 12D daylength, compared to a 16L: 8D daylength which produced heavier birds (P<0.05). Claasen (2004) also noted that FI was reduced with on shorter daylengths. This is in agreement with studies and theories suggesting that FI is enhanced through increasing daylength (Brickett *et al.,* 2007). However, within the present study FI was unaffected by lighting regime and this finding is supported by that of Lewis *et al.* (2009a) where it was seen that up until 21d, FI did not differ in broilers exposed to a range of photoperiods as long as the birds received a minimum daylength of 6 h. A reason for this could be explained by Lewis *et al.* (2008) where it was seen that birds reared under 8L: 16D consumed about half of their feed at night whereas chicks reared under 16L:8D consumed no more than 10% at night. The response of the modern broiler to lighting treatments and its effect on FI may have changed as the bearing that light duration had on FI has been outweighed by the appetite of the modern bird. The fact that lighting regime had no effect on live weight or BWG in the present study may be attributed to similar FI for each lighting treatment.

It has been seen in several studies that broilers regulate their FI in order to meet their energy requirements (Leeson *et al.,* 1996). One therefore would have expected a difference in feed intake between dietary treatments. Dozier *et al.* (2011) noted that in broilers from 36 to 47 d, FI decreased as dietary ME increased within a range of 13.0 to 13.6 MJ/kg (P<0.001). This result is in agreement with the findings of Leeson *et al.* (1996) where at 25 d, FI was higher for broilers fed diets containing 11.3 MJ/kg compared to 12.1 MJ/kg. Within the present study, broilers on the SS ration were receiving 12.6 MJ/Kg opposed to the SH ration which contained 14.8 MJ/kg. When comparing these dietary ME contents to the afore mentioned Dozier *et al.* (2011) and Leeson *et al.*(1996) studies, one would assume a difference in FI as the range between dietary energy is greater. A possible reason for the lack in FI difference in this study may be due to the age of the broilers and therefore a difference in developmental capacity. Brikett *et al.* (2007) reported that nutrient density did not affect FI within the first 13 d of rearing. However, in periods after this, nutrient density impacted FI. Younger broilers may not possess the ability to adjust their FI due to nutrient density as they are limited by gut capacity (Hidalgo *et al.* 2004; Kamran *et al.* 2008). This highlights the importance of ensuring the correct concentrations of dietary nutrients within starter phase feeds. Amino acids and CP content were constant between treatments which meant that if dietary treatments did affect any variable measured, it could be solely concluded that ME content was the attributer as FI intake did not differ. The lack in differences in FI means that chicks receiving the high energy treatment consumed a higher amount of energy overall. However, these birds were unable to utilise this extra energy to bring about differences in performance variable of live weight, BWG and FCR. Such results suggest a cautionary outlook for nutritionists to avoid over supplying of energy within starter phase feeds as this will be wasted and also be unbeneficial in terms of feed costs. The alternative outlook from these results suggest that since younger birds are unable to adjust feed intake due to nutrient density, the supply of nutrients below the requirements will have a more pronounced effect within the early phases of rearing.

When considering the effects of lighting on BMY, information provided from alternative studies focuses primarily on the later stages of rearing (Downs *et al.,* 2006). The obvious reason being that BMY differences in the final stage of broiler production has a direct relevance to the sale of breast meat as a consumable product. However focusing on the starter period does provide insight into the timing and may reveal information on the initial presence of changes in BMY brought about through different lighting regimes. Breast meat yield was unaffected by lighting when considered as a main effect. The results are in agreement with those seen in Lewis *et al.* (2009a) where there was no difference in BMY for Ross 308 broilers exposed to 8L: 16D and 15L: 9D. However, Lewis *et al.* (2009a) did observe an increase in BMY in broilers exposed to ≤21 h photoperiods. Brickett *et al.* (2007) found increased BMY for Ross 308 broilers under 20L:4D compared to 12L:12D. The threshold for increased BMY in broilers must lie around the 20 h daylength mark, providing an explanation as to why no difference was seen in BMY within the present study due to lighting effects.

Dietary ME had no effect on BMY in terms of weight or as percentage of BW at 10 d. These results are in agreement with that of Downs *et al.* (2006), Hidalgo *et al.* (2004) and Leeson *et al.* (1996) where differences in dietary ME did not influence BMY. The lack in differences between BMY due to dietary energy expels the notion that broilers reared under 8L: 16D lighting treatments require extra energy in order to assist protein deposition for BMY. However a significant interaction did occur between the experimental factors, ultimately describing which treatment combination was least beneficial to BMY. The treatment combination of SH × 8L: 16D yielded the lowest breast meat in terms of both weight in grams and as a percentage of BW (24.1 g and 10.1%).

Thigh yield was unaffected by both light and dietary treatments when considered as main effects at 10 d ($P<0.05$). However a similar trend of interaction between dietary and lighting treatment was expressed as seen with BMY. Thigh weights were lighter for birds reared on the SH × 8L: 16D treatment combination ($P<0.05$). In terms of thigh yield as a percentage of BW, there was a tendency for lower yields under this treatment combination ($P=0.054$). This suggests that increasing the replications of this study may have yielded a significant result. Drum stick yields however were unaffected by dietary and lighting treatments. This is contrary to results obtained by Downs *et al.* (2006) who reported an increase in drumstick weight (2.9%) by shortening overall daylength with a decreasing-increasing photoperiod treatment.

The significant interactions found between dietary and lighting treatments convey the notion that broilers under the SH × 8L: 16D performed differently compared to the other treatment combinations. Reasons behind the difference in BMY and thigh weight may be due to a change in the utilisation of feed resources under these conditions. Live weight, BWG, FCR and FI did not differ between treatment combinations meaning that the broilers under the SH × 8L: 16D used the nutrient resources equally as the other treatment combinations however deposition of these resources was different. It is possible that deposition of nutrient resources was directed more towards fat deposition. Fat pad weights were not measured in the present study nor was lipid content. Increase in fat deposition and lipid content would explain the similar live weight, BWG, FCR and FI between treatment combinations. Fat deposition may have been increased through decreased activity from a longer dark phase. Lei & Van Beek (1997) noted a 3% increase in fat pad weights when a high energy ration was fed to male broilers at 41 d ($P<0.05$). However when activity was increased through the use of fans forcing the birds to walk 3 times more, there was no difference between fat pad weights regardless of the ME content within the diets. It is possible that the birds in the present study reacted in the same manner. Broilers under the 8L: 16D may have reduced their activity levels and when they received the SH diet, deposited a greater amount of fat compared to those receiving the SS diet.

Information regarding the activity levels in broilers on welfare compliant lighting regimes is limited. Schean-Lardner *et al.* (2012) noted that increasing daylength reduced activity. However in that study the range of daylength was from 14L: 10D to 23L: 1D. A threshold may exist where increasing the dark period within a cycle also decreases broiler activity. Further study in the effects of longer dark periods on broiler behaviour may yield an explanation for the results in this study.

3.5 CONCLUSION

Within the starter phase of 0 to 10 d, BMY was not improved through the addition of dietary ME in the starter ration. Dietary ME decreased BMY in broilers reared on short daylengths of 8L: 16D at 10 d however performance parameters of live weight, BWG, FI and FCR were unaffected. A further avenue of study following these findings would be an investigation into the differences in fat deposition under short daylengths as affected by high dietary ME intake within the starter phase of broiler rearing. Expanding this study to continue into the grower and finisher phases would also provide insight into possible carry over or consequential effects of differing dietary ME content in the starter phase of broiler rearing. The present study does indicate that if standard starter rations are to be administered and short daylengths are to be practiced due to welfare concerns, the use of 8L: 16D daylengths should be used as production output will not differ from that of a 16L: 8D daylength and one will reap the benefits of reduced electricity costs.

CHAPTER 4

THE EFFECT OF INCREASED DIETARY ENERGY ON BROILERS REARED ON SHORT DAYLENGTHS WITHIN THE FINISHER PERIOD OF 25 TO 35 DAYS OF AGE

4.1 INTRODUCTION

The rapid changes in performance traits within the finisher phase of broiler production imposes difficulty in measuring these parameters. Such difficulty has resulted in lack of information within this production period where the use of short daylengths may be beneficial to producers. Within the finisher phase, common problems occurring such as increased mortality rates, leg disorders and depreciation of carcass portions may be rectified through the use of short daylengths. However the limitations of short daylengths must therefore also be considered.

One area of limitation would be the decrease in BMY and increase in other carcass portions such as thighs and drumsticks seen in broilers reared under short daylengths (Lewis *et al.,* 2009). Consumers demand lean breast meat over other carcass portions making it the most economically relevant portion. Whilst reducing daylength cycles improve broiler welfare (Buckland *et al.,* 1973; Riddell & Classen 1992; Li & Howland 2003) it has economic implications which require a counteractive solution.

Nutrient density has been seen to have a direct bearing on BMY. In particular the increase in dietary CP density has been seen to elevate BMY especially in broilers reared under continuous or near continuous light exposure (Kidd *et al.,* 2004; Corzo *et al.,* 2005; Brickett *et al.,* 2007). However under welfare compliant lighting regimes, the same solution does not hold true. Recently performed work by Mlaba *et al.* (2015) noted that BMY is not improved by increasing dietary crude protein under shorter daylengths.

Dietary energy is also required for the deposition of protein (Noblet *et al.,* 1999) and changes in lighting schedules have an effect on activity in broilers (Schwean-Lardner *et al.,* 2012) therefore also affecting energy requirements. It is therefore hypothesised that increasing dietary energy will improve BMY in broilers reared under short daylengths within the finisher phase of 25 to 35 days.

4.2 METHODS AND MATERIALS

4.2.1 Housing and management

One thousand as-hatched Ross 308 broilers were reared in a light proof facility which had four independent rooms. Each room was divided into two pens by a wire mesh barrier resulting in a total of eight separate pens. One hundred and twenty five birds were randomly allocated to each pen at a stocking density of 19.23 birds/m^2. Male and female broilers were neither determined nor separated as the trial was conducted in a manner to mimic commercial practices as closely as possible. The floor of each pen was covered with 10 cm deep wood shavings. Light was provided through the use of 14W warm-white fluorescent bulbs. All broilers had *ad libitum* access to feed and water. Heating was provided with gas spot-brooders, one mounted above each pen. A thermostat control for each room was set at an initial 31.5ºC and after 2d it was decreased linearly by 1.5 ºC and by 22d was maintained at 21.5 ºC. Ventilation was provided through a negative pressure system. Both temperature and ventilation protocols were conducted in a manner aimed at mimicking standard commercial rearing techniques used in South Africa. The animal ethics committee approved the use of broiler chicks for this experiment, reference number, 043/15/Animal.

4.2.2 Experimental treatments

All broilers initially received 24 h of continuous light prior to the implementation of two lighting treatments at 1 d. Lighting treatments were maintained until the end of the trial which was 35 d. The lighting treatments consisted of a long daylength treatment of 16L: 8D which served as a control and short daylength treatment of 8L: 16D. Of the four light proof rooms, each room was randomly allocated a lighting treatment such that each lighting treatment was replicated twice. Prior to 25 d all broilers were fed a commercial mash starter diet from 0-10 d followed by a commercial pelleted grower diet from 10-24 d. All birds were reared in the same chambers that the experiments took place in however were not the same birds from Chapter 3 as to prevent carry-over effects. Dietary treatments were applied at 25 d. Two dietary treatments were used. These consisted of a standard finisher ration (FS) which was formulated to meet the nutrient specifications described by the Ross Broiler Nutrient Specification Manual (Aviagen, 2014), this served as a control ration opposed to a high energy finisher ration (FH) which was similar to the control ration however contained 10% higher ME content (Table 4.1). Both feeds were applied in each of the four light proof rooms. Dietary treatments were randomly allocated between each of the two pens within the light proof rooms. Dietary treatments were mixed at the University of Kwa-Zulu Natal research farm, Ukulinga. The feeds were administered in a pelleted form and administered through the use of pan feeders.

4.2.3 Measurements

A sample of 60 birds was weighed at the start of the trial at 25 d and at the end of the trial at 35 d. Sixty birds was an adequate statistical sample and fitted into a weighing tray allowing the birds to be weighed with minimal stress. These values allowed mean BW and BWG to be determined. Feed intake per pen was calculated at 35 d as the difference between the amount of feed administered to the chicks at 25 d and the remainder of feed in trays at 35d. Mortality was recorded daily and FI calculations were corrected for mortality by subtraction of mortality from treatment population. These measurements allowed FCR to be calculated as a FI to BWG ratio.

Table 4.1 Ingredient composition (g/kg) of standard finisher (FS) diet and high energy finisher (FH) diet for broilers subjected to 8 or 16 h daylengths from 25 to 35 days of age

	FS	FH
Feed Ingredients (g/Kg)		
Yellow maize fine	589	565
Maize gluten 60	18	17
Soybean full fat oil cake	50	48
Soybean 50 oil cake	250	240
Sunflower 34 oil cake	6	6
L-lysine HCl	3	3
DL methionine	2	2
L-threonine	1	1
Choline chloride 60%	1	1
Vit+min premix	2	2
Limestone	14	13
Salt	2	2
Monocalcium phosphate	13	12
Sodium bicarbonate	3	2
Oil - soya	47	86
Total	1000	1000
Composition (Calculated)		
AMEn adult (MJ/kg)	13.1	14.6
Crude protein (%)	20.9	20.9
Lysine (%)	1.3	1.3
Methionine (%)	0.5	0.5
Methionine+cystine (%)	0.9	0.9
Threonine (%)	0.9	0.9
Tryptophan (%)	0.2	0.2
Arginine (%)	1.3	1.3
Isoleucine (%)	0.9	0.9
Valine (%)	1.1	1.1
Calcium (%)	0.8	0.8
Avail. Phosphorous (%)	0.4	0.4

FS, standard finisher diet. FH, high ME finisher diet

At 35 d, six birds from each combination of ration and lighting treatment were randomly selected for body part sampling analysis. This resulted in 24 birds being wing-banded and their identities recorded prior to BW and body part analysis. Birds were weighed three times: once before being electrically stunned, the second after the feathers had been removed via hand plucking, and finally after the birds had been exsanguinated. To determine effects on body part portioning, breast meat (without skin and bone), thigh and drum sticks (without skin) were dissected from each carcass and weighed.

4.2.4 Experimental design and statistical analysis

A 2×2 factorial design resulted from the two lighting treatment levels (16L: 8D and 8L: 16D) and two dietary treatment levels used (FS and FH), the main effects measured could therefore be dietary energy concentration and daylength. The data were analysed using an analysis of variance to determine treatment means and least significant differences, this was performed using Genstat 14th edition analytical software.

4.3 RESULTS

4.3.1 Live weight, body weight gain, feed intake, feed conversion ratio and mortality

The effects of lighting and dietary energy on performance measures are displayed in Table 4.2. There was no interaction between lighting and dietary energy, thus the main effects will be discussed alone. Dietary energy had a significant effect on both live weight and FI ($P<0.05$). Body weight was reduced in broilers fed the FH dietary treatment with a mean weight of 1.967 kg compared to a higher 2.15 kg in broilers which received the FS treatment. Feed intake was negatively influenced by the FH dietary treatment with a 1.27 kg amount consumed between 25 to 35 d, broilers receiving the FS dietary treatment consumed a greater amount of 1.49 kg. Dietary treatment did not affect BWG nor did it affect FCR. Lighting treatment did not have a bearing on any of the performance measures. Live weight, BWG, FI and FCR were not significantly different for both 16L: 8D and 8L: 16D treatments. Mortality was negligible with less than 1.7% across all treatments.

4.3.2.1 Breast meat yield

The effects of dietary ME and lighting regime on BMY are displayed in Table 4.3. Breast meat yield was unaffected by lighting treatments and there were no significant interactions between dietary and lighting treatments. However as a main effect, dietary ME significantly affected BMY as a percentage of BW ($P<0.05$). Broilers consuming the FH diet had a significantly higher yield percentage of 25.73% compared to broilers consuming the FS diet which achieved a lower percentage of 24.17%. Total BMY was unaffected by dietary treatments.

Table 4.2 The effect of lighting regime and dietary energy on live weight, body weight gain (BWG), feed intake (FI) and feed conversion ratio (FCR) in broilers at 35 d

Main Effects	Live Weight (kg)	BWG (kg)	FI (kg/bird)	FCR (kg feed/ Kg BWG)
ME				
FH	1.97[a]	0.75	1.27[a]	1.69
FS	2.15[b]	0.87	1.49[b]	1.71
LSD	0.15	0.16	0.09	0.24
P	0.031	0.112	0.002	0.821
Lighting				
16L:8D	2.10	0.84	1.42	1.70
8D:16L	2.02	0.79	1.34	1.70
LSD	0.15	0.16	0.09	0.24
P	0.198	0.432	0.066	0.982
ME × Lighting				
FH × 16L:8D	2.01	0.78	1.33	1.71
FH × 8L:16D	1.93	0.73	1.21	1.67
FS × 16L:8D	2.19	0.90	1.51	1.69
FS × 8L:16D	2.10	0.85	1.47	1.73
LSD	0.21	0.23	0.12	0.33
P	0.931	0.947	0.276	0.662

[a,b,c] Means within a column with no common superscript differ (P< 0.05). FS, standard finisher diet. FH, high ME finisher diet

4.3.2.2 Thigh yield

The results of mean thigh weight and yield are displayed in Table 4.3. Thigh yield in weight and percentage of BW were unaffected by lighting and dietary ME factors (P<0.05).

4.3.2.3 Drumstick yield

The results of drumstick yield are displayed in Table 4.3. Birds fed the FH treatment showed a lower mean weight of 174 g compared to a higher 191 g for the FS diet (P<0.05). However in terms of yield described as a percentage of BW no differences between the dietary treatments were found. There were also no significant differences due to lighting treatment or significant interactions found between lighting and dietary ME content.

Table 4.3 The effect of lighting regime and dietary energy on breast, thigh and drumstick yield in broiler at 35 d

	Breast Meat Yield		Thigh Yield		Drumstick Yield	
Main Effects	Weight (g)	% of BW	Weight (g)	% of BW	Weight (g)	% of BW
ME						
FH	402	25.7[a]	197	10.1	174[a]	8.9
FS	422	24.2[b]	210	9.8	191[b]	8.9
LSD	23.8	1.2	15.6	0.6	14	0.6
P	0.096	0.013	0.084	0.392	0.021	0.958
Lighting						
16L:8D	412	24.9	202	9.8	182	8.8
8L:16D	411	25	205	10	183	9
LSD	23.8	1.2	15.6	0.6	14	0.6
P	0.914	0.426	0.717	0.288	0.874	0.426
ME × Lighting						
FH × 16L:8D	405	25.5	193	9.8	174	8.8
FH × 8L:16D	399	25.8	200	10.4	173	9
FS × 16L:8D	420	24.2	211	9.7	189	8.7
FS × 8L:16D	423	24.1	210	9.9	192	9
LSD	33.6	1.8	22	0.9	19.9	0.8
P	0.653	0.842	0.561	0.479	0.816	0.842

[a,b,c] Means within a column with no common superscript differ ($P < 0.05$). FS, standard finisher diet. FH, high ME finisher diet

4.4 DISCUSSION

The objective of this study was to investigate whether BMY would be enhanced in broilers reared on short daylengths if increased dietary ME was fed within the finisher phase of production. Breast meat yield has been observed to be decreased in broilers reared on short daylengths (Lewis ***et al.*** 2009). Under continuous or near continuous (23L:1D) daylengths, increasing amino acid density in diets has shown enhancement of BMY (Corzo ***et al.,*** 2005; Kidd ***et al.,*** 2005). Mlaba ***et al.*** (2015) found that the same theory did not apply to broilers reared on short daylengths. Dietary ME was seen as a possible alternative solution. The narrowing down of effects within the finisher phase also provides insight into the final stage of production which may be critical as this is the last step before the birds move to processing and the commercial market.

Difficulty in providing direct comparisons to previously performed literature arises when comparing the effects of dietary ME on performance parameters. Much of the literature relevant to dietary ME includes the altering of amino acid densities simultaneously (Bartov & Plavnik 1998; Hidalgo ***et al.,*** 2004; Dozier ***et al.,*** 2007; Brickett ***et al.,*** 2007). Identifying the responsible variable for significant differences can therefore be difficult. Within the present study, protein and amino acids densities were kept constant with ME content being the only difference between dietary treatments. Leeson *et al.* (1996) did observe the effects of altering only dietary ME in diets from 0 to 49 d. However in terms of live weight the findings were on the contrary to those seen in this study. Leeson *et al.* (1996) observed no differences in live weight at 49 d when providing broilers with diets ranging in dietary ME from 11.3 MJ/Kg to 13.8 MJ/Kg. In a more recent study, Dozier *et al.* (2006) also noted no difference in live weight when observing a range of dietary ME from 13.3 MJ/Kg to 13.8 MJ/Kg in broilers from 30 to 59 d. However the treatment period of these two studies was much longer than the present study which was only to 10 days. It may be that broilers reared to younger ages and within a shorter treatment period are unable to achieve compensatory growth in the limited amount of time when FI is decreased through increasing dietary ME.

In the present study FI was significantly lower by 22 g per bird within the 25 to 35 d finisher period for broilers receiving the FH diets. FI was decreased through increasing dietary ME content. This result is in agreement with previously performed studies suggesting that FI is controlled by the broilers ability to consume feed to match its energy requirements therefore higher ME content reduces FI (Leeson *et al.,* 1996; Lei & Van Beek 1997; Downs *et al.,* 2006; Dozier *et al.,* 2011). The difference in live weight can be explained by the birds on the FH diet consuming less while appeasing their energy needs resulting in a decrease in amino acid intake which limited growth.

Feed conversion ratio was not affected by dietary ME and this can be explained as FI and live weight were both lower for broilers receiving the FH diets. This meant the proportionate ratio was similar to that of the FCR obtained from feeding the FS diet (1.71) compared to the FH diet (1.69). In studies where FCR was affected by dietary ME body weights were unaffected by ME while FI differed between dietary treatments (Downs *et al.,* 2006; Dozier *et al.,* 2007).

Lighting as a main effect did not alter any of the performance measurements of live weight, BWG, FI and FCR. This is in contrast with Lewis *et al.* (2008) where pooled data of male and female broilers reared under identical lighting treatments to the present study (8L: 16D and 16L: 8D) exhibited superior live weight, BWG and FCE when reared under 8L:16D daylengths. However, supporting results later obtained in Lewis *et al.* (2009) are similar with the present study in that BW, FI and FCE did not differ in broilers reared under 8L: 16D and 15L: 9D daylengths. Even though these results differ they still both expel theories that increasing daylength is required for increased body weight, and feed intake (Classen 2004; Brickett *et al.,* 2007). The modern broiler is able to perform equally as well under 8L: 16D as compared to 16L: 8D.

There were no significant interactions between lighting and dietary treatments on broiler performance for live weight, BWG, FI and FCR. This is in agreement with results obtained by Downs *et al.* (2006)

where performance parameters did not differ when daylength was reduced by an increasing-decreasing photoperiod regime and interactive effects with various dietary ME levels observed.

Differences in carcass portion yield were as expected and relate to previously performed studies in terms of lighting effect on carcass yields. Daylength has been seen to increase BMY when photoperiods are greater than 20 h and nutrient densities are not limited, comparisons between photoperiods less than 20 h have yielded similar BMY and other carcass portions (Brickett *et al.,* 2007; Lewis *et al.,* 2009; Mlaba *et al.,* 2015). Such was the case in this study.

However it was intended that BMY would be enhanced through increased dietary ME. Breast meat yield was greater as a percentage of BW when dietary energy was considered as a main effect with the FH diet providing an increase of 1.5% in proportion to BW. This can be explained as the BW of broilers on the FH diet was significantly lower so proportionately the FH breast meat yield was greater. The reduced BW in broilers receiving the FH diet is most likely due to insufficient amino acid intake. Since the BMY in weight was not affected by dietary ME it can be assumed that broilers primarily deposit protein sources as breast meat and when amino acid levels are reduced, another area of protein deposition will be neglected. This would explain the difference in drumstick weights between the FH and FS diets. The FH diet yielded a 17 g lower drumstick weight compared to the FS treatment.

4.5 CONCLUSION

The lack of significant interactions between lighting and dietary treatment in terms of carcass yield, could be explained that there was no extra energy requirement in broilers reared on 16L: 8D and 8L: 16D that would have resulted in increased BMY. As broilers are able to adjust their FI to meet ME requirements this would have also been seen within the treatment combinations and their effects on FI.

The results from this study suggest that in commercial systems where daylengths are used, it will be economically beneficial to use lighting regimes of 8L: 16D as production costs will be reduced through less electricity usage. In countries such as South Africa where the volatility of resources such as electricity is high, the usage of 8L: 16D photoperiods is beneficial in ensuring sustained enterprises where electricity is saved and the same volumes can be used over a longer period.

Dietary management as a tool in improving BMY in broilers reared on short daylengths can only be beneficial if changes are made which meet the nutritional requirements of the birds. Such was not the case in the present study; there was in fact no additional ME requirement in broilers reared on 8L: 16D or 16L: 8D daylengths. Thus increasing dietary ME did not improve BMY.

CHAPTER 5

GENERAL DISCUSSION AND CONCLUSION

The broiler industry is growing as the demand for poultry products increases. Appeasing the growing demand has challenged all involved sectors to increase efficiency and bolster broiler production. The production of poultry products must also be increased within the acceptable production parameters. With welfare concerns becoming increasingly important, one parameter within the industry which is therefore becoming ever more relevant is the use of short daylengths in order to protect broiler welfare. This study set out not only to provide further information on the use of short daylengths in broiler production (an area lacking in research relating to the modern broiler) but also to provide insight into a possible solution into enhancing the production of breast meat which has been seen to be negatively affected in broilers reared on short daylengths (Downs *et al.,* 2006; Lewis *et al.,* 2009a; Li *et al.,* 2010). Breast meat is the most valuable product in the processed market which means solutions or methods in enhancing BMY will carry economic relevance. The application of increased dietary energy was seen as a possible solution to improving BMY in broilers reared on shorter daylengths.

When broilers were administered starter diets containing a 15% increase in dietary ME from 1 to 10 d (Chapter 3) it was noted that BMY was not enhanced in birds reared on 8 or 16 h daylengths. The BMY in broilers reared on 8 h daylengths with added dietary ME had significantly lower BMY than those reared on the same daylength without the additional dietary ME. However the lack in live weight, BWG, FI and FCR suggests that broilers receiving the additional 10% dietary ME utilized the nutrient resources differently. Further research into the change in nutrient utilisation by broilers receiving diets containing nutrient densities above those considered adequate will provide insight into the effects and consequences of over supplying nutrients to broilers. Contrary to studies where older broilers are seen to regulate feed intake to meet energy requirements the present study indicated the lack in difference in FI within the starter phase of 1 to 10 d may also be a result of limited gut capacity. Further research into the age threshold at which developmental capacity does not limit the ability of broilers to adjust FI would allow nutritionists insight into the period where broiler diet specifications need to be closely met prior to the ability of adjusted feed intake to meet requirements.

Within the finisher phase of 25 to 35 d there were no significant interactions between lighting and dietary ME (Chapter 4). Breast meat was not increased through the additional dietary ME when reared under 8 or 16 h daylengths. Broilers responded to increased dietary ME as seen in previous studies where FI was reduced. If broilers are able to regulate their FI due to meet energy requirements, the results show that under short daylengths of 8 or 16 h an extra energy requirement does not exist. Had the extra energy requirement existed, the broilers receiving the high ME diet would have performed better as their nutrient requirements would have been more closely met. Body weight was reduced in broilers receiving the 10% higher ME finisher diet. This was most likely due to a reduced FI which resulted in a reduction in amino acid intake which did not allow the birds to fulfil their growth potential. Mlaba *et al.* (2015) reported that increasing CP levels in broilers reared on short daylengths was not enough to enhance BMY. Carrying on from the results in this study, it may be beneficial to investigate whether increasing both ME and CP nutrient density may improve BMY.

The results from both starter (Chapter 3) and finisher phases (Chapter 4) do provide insight into the effects of performance parameters of broilers under short daylengths. This relates to welfare compliant lighting regimes such as those stipulated by the European Union which require a minimum of 6 hours darkness for meat chickens within a 24 h period (European Commission, 2000). The results in this study suggest that no difference existed in the performance parameters of BW, BWG, FI and FCR from 8 or 16 h daylengths. Therefore it may be beneficial for producers under welfare compliant regimes to implement the short daylengths of 8 h as production is not inhibited however input energy costs will be reduced.

The ability of broilers to perform in the same way under 8 and 16 h daylengths highlights the resilience of the modern broiler which is less affected by lighting regimes. However it must also be noted that nutritional strategies must be put in place to maximize the potential of these birds. Management of nutritional and environmental conditions must be favourable to achieve maximum production. Research involving the modern broiler needs to be on going to continuously redefine the best conditions for broiler production.

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