THE IMPACT OF DAYLENGTH ON TURKEY PRODUCTIVITY, HEALTH AND BEHAVIOUR

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ABSTRACT

The impact of graded levels of daylength on the productivity, health and behaviour of hens and toms was studied in two experiments to 18 wk of age. Daylength treatments (trt) were 14 (14L), 17 (17L), 20 (20L) and 23 (23L) h and were started at 10 d of age. Turkeys (720 hens and 480 toms) were randomly allocated to 8 rooms (2 rooms per lighting trt) with six pens (3 hen and 3 tom) per room in each experiment. Body weight (BW) and feed consumption (FC) were assessed throughout the trial and feed efficiency (G:F; g of gain/g of feed) calculated from BW and FC values. Birds were checked daily for mortality and culls, and affected birds sent for necropsy. Bird well-being was evaluated by gait score (GS), the incidence of foot pad dermatitis (FPD), breast buttons and blisters, ocular size and pressure, and tom behavioural observations. Data were analyzed using SAS 9.3 based on a completely randomized design nested within four daylengths. Regression analysis established relationships between response criteria and daylength. Differences were considered significant at $P \leq 0.05$ and trends noted at $P \leq 0.10$. At 21 and 42 d, body weight increased linearly with daylength, but by 84 d tom weights decreased in a quadratic fashion and hen weights were unaffected by daylength. At 126 d, both male and female weights decreased linearly with increasing daylength, with the magnitude of the response gender dependent. Feed consumption corresponded to body weight changes, increasing for d 10-21 and 21-42, and decreasing for d 63-84, 84-105, and 105-126 with increasing daylength. Feed efficiency (G:F) was not affected by daylength for 10-84, 10-105 and 10-126 d periods. The incidence of mortality and culling was not affected by daylength for the 10-84 d period, but increased in a quadratic manner with increasing daylength for the 10-105 and 10-126 d periods. The incidence of skeletal disorders (valgus-varus and rotated tibia), injurious pecking and pendulous crops (females only) increased linearly with increasing daylength. Average GS increased linearly with daylength at 11 and 17 wk for both hens and toms, but the effect was larger in toms. Daylength did not affect FPD, but more lesions and more severe scores were found for hens than toms. The presence of breast buttons and blisters increased linearly with daylength (11 wk) with the effect on blisters predominately seen in toms. Eye weight increased and corneal diameter decreased linearly with increasing daylength at 12 and 18 wk. Dorso-ventral and media-lateral diameter, and anterior to posterior depth exhibited a quadratic relationship with the highest values seen for the 23L trt. Ocular pressure was not affected by daylength. Over 24 h of behavioural observation (both photo- and scotoperiod), resting increased, and walking, and environmental and feather pecking decreased with increasing daylength. During the photoperiod, inactive resting increased and feeding, drinking, standing, walking, preening, and environmental and feather pecking behaviours decreased as daylength increased. To conclude, daylength affects the growth and feed intake of turkeys in an age and gender specific manner, and mortality and culling increase with longer daylength. Health and welfare parameters are also affected by daylength with 23L demonstrating poorest overall bird well-being.

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LIST OF ABBREVIATIONS

trt	treatment
L	light
D	dark
BW	body weight
FC	feed consumption
G:F	feed efficiency
GS	gait score
FPS	footpad score
FPD	footpad dermatitis
IOP	intraocular pressure
ML	medio-lateral diameter
DV	dorso-ventral diameter
AP	anterior-posture depth
wk	week
d	day
h	hour
m	meter
cm	centimeter
mm	millimeters
kg	kilogram
g	gram
mmHg	millimeters of mercury

1.0 INRODUCTION

Canadian turkey production has increased from 96 million kg of meat in 1982 to 168 million kg in 2012 (Turkey Farmers of Canada, 2015). This increase in production has resulted from human population growth and increased export growth. But in comparison to the broiler industry, which produced 1.07 billion kg of meat in 2014 (Chicken Farmers of Canada, 2015), the turkey industry is relatively small. Due to this small nature, turkey research has been proportionally lower. One area that has seen little research is lighting and more specifically the impact of daylength. The majority of turkey lighting research was done in the 1980's and 1990's and therefore may no longer be relevant because of genetic changes in growth (Douglas, 2012; Krautwald-Junghanns et al., 2013). Turkeys are growing faster and achieving heavier market weights due to intense genetic selection (Douglas, 2012). A positive linear correlation exists between body weight and breast meat yield (Brake et al., 1995). These changes in the proportion of breast meat may result in heavy toms experiencing changes in posture and balance (Fournier et al., 2015). Consequently, with changes in bird genetics, research is needed to determine how current turkey strains respond to different lighting programs.

Extensive turkey research has been conducted regarding the influence of leg abnormalities in toms, illustrating the beneficial effects that shorter daylengths early in the production cycle have on skeletal development (Hester et al., 1983, 1985, 1986; Classen et al., 1994). Contrary to this, other productivity results are difficult to compare between daylength treatments with confounding factors like light intensity (Hester et al., 1986; Siopes et al., 1989; Lewis et al., 1998), daylength changes with age (Auckland, 1973), and strains and gender differences (Lilburn et al., 1992). Thus, results from previous studies are not consistent or comprehensive and do not permit a prediction of response.

Inadequacies in productivity measures of previous research have resulted in a lack of lighting program standards for turkey producers and daylength used can vary. In regards to 23 h of daylength or near continuous lighting programs, the rational for implementing one h of darkness is to accustom birds to the dark in the event of a power failure and to prevent panic (Sykes, 1988). Many producers also believe that more light allows unlimited access to feed thereby maximizing feed intake and in turn growth. In contrast, primary breeding companies recommend shorter daylengths (Aviagen, 2011a; Hybrid, 2013). Aviagen suggests at least four h of continuous darkness every 24 h, but recommend eight to ten h of darkness for turkeys after the brooding period. Hybrid recommends eight h of darkness and suggests introducing more h of light towards the end of production cycle to allow birds time for a “midnight” feeding. These lighting program recommendations do not appear to be based on scientific literature, but may be based on practical application experience. Consequently, research needs to be carried out to determine the effect of daylength on turkey productivity and welfare.

In contrast to the limited turkey lighting research, extensive research has been conducted on broiler chickens and daylength has been shown to have important effects on a wide range of characteristics affecting both economic and welfare aspects of broiler production (Schwean-Lardner et al., 2012b). Broiler growth responds to daylength in an age dependent manner with shorter daylength resulting in lighter weights at younger ages, but equal or heavier weights if birds are kept to older market ages (Schwean-Lardner et al., 2012b). Contrary to popular belief, 23 h of daylength did not maximize productivity measures like body weight and feed consumption regardless of age. Shorter daylength also resulted in improved feed efficiency and bird health (Schwean-Lardner et al., 2012ab, 2013). In regards to bird health and welfare, it has been noted that 23 h photoperiods increase the incidence of skeletal and metabolic disease

(Classen et al., 1994; Schwean-Lardner et al., 2013), increase ocular size (Schwean-Lardner et al., 2013), and increase inactivity and decrease mobility, comfort and nutritive behaviours (Schwean-Lardner et al., 2012a). Despite the detailed experiments with broilers, it is not possible to extrapolate these results to turkeys.

The majority of turkey research to date has compared two lighting programs, whether it is 24 or 23 h daylength with shorter daylengths, increasing (step-up), decreasing (step-down) or intermittent lighting programs. Inconsistent results in previous research and no lighting program standards further emphasize the need for research. A systematic research approach is required to provide comprehensive information on the effects of daylength on turkey productivity and welfare. An objective of the thesis is to summarize research on the effect of photoperiod length and distribution on the production and welfare of poultry with specific emphasis on turkeys. Further the thesis contains research using graded level of daylength to study its effect on the productivity and welfare of turkey toms and hens raised to 18 wk of age.

2.0 LITERATURE REVIEW

2.1 Lighting Programs

The term lighting program is multidimensional and can include wavelength, light source, light intensity and daylength. In this thesis, the focus will be on daylength. The daylength used in turkey lighting research can vary tremendously both in the duration and pattern of light (Table 2.1 and 2.2). Brooding period, defined as the first week of a bird's life, usually consists of 24 or 23 h of light to allow birds to locate feeders and waterers and after this period lighting programs are implemented. In diurnal lighting (one light and one dark period per 24 h), daylength can range from near continuous (23 h) or continuous (24 h), to relatively short (12 h). Intermittent lighting includes multiple periods of light and dark in a 24 h period and an example is 8L:4D:8L:4D. Lighting programs can also change throughout the production cycle. Programs where daylength increases or decreases gradually during the production cycle are also referred to as step-up or step-down lighting. Turkey lighting research has extensively examined step-up and step-down lighting programs (Tables 2.1 and 2.2; Auckland, 1973; Hester et al., 1983, 1985, 1986; Lilburn et al., 1992; Classen et al., 1994) because they slow down early growth and delay sexual maturity respectively. Other studies have looked at intermittent lighting programs (Siopes et al. 1986; Sherwin et al., 1999). Because of the difficulty in providing a statistically valid level of replication, most lighting programs have compared two lighting treatments, which does not permit the prediction of bird responses to intermediate or alternative treatments. To further complicate the interpretation of research results, other features such as wavelength, light intensity, and source of light have been incorporated into daylength comparisons, making it impossible to attribute treatments specifically to photoperiod (Manser, 1996). The majority of lighting studies have used near continuous lighting programs (i.e. 23L:1D) as a control, because it has been a common photoperiod used for meat-type fowl (Hester, 1994). It is worth mentioning that no studies using turkeys to date have compared graded levels of daylength as will be reported in this thesis.

Table 2.1. Productivity advantages and disadvantages of different photoperiod programs for turkeys 16 to 22 wk of age

Daylength	Comparison	Confounding Factors	Advantages[1]	Disadvantages[1]	Author
23 h	8, 12, 16 h	Light intensity	Better feed efficiency	Increased mortality and injurious pecking, decreased growth	Lewis et al., 1998
Step-up program (9 h d 4 to 15 h d 126)	Step-down (24 h d 4 to 15 h d 12)			Decreased growth, poor feed efficiency	Hester et al., 1985
Step-up (9 h d 4 to 15 h d 126)	Step-down (24 h d 4 to 15 h d 12)	Light intensity		Reduced growth, poor feed efficiency	Hester et al., 1986
Step-up (10 to 16 h)	Step-down (16 to 10 h)	Two stains	Increased growth		[2]Lilburn et al., 1992
23 h	14 h, step-down (22 to 14 h)		Heavier body weight, better feed efficiency		Auckland, 1973
24 h	Increasing - INC (6 h d 7 to 20 h d 63), decreasing - DID (same as INC to d 84, 10 h d 112)		Decreased injurious pecking	Increased mortality (skeletal and cardiac)	Classen et al., 1994
23 h	Intermittent programs - 6(1L:3D), 24(0.25:0.75D), 3L:11D:3L:7D			Decreased growth	Siopes et al., 1986
23 h	8 h	Light intensity	Better feed efficiency		Siopes et al., 1989

[1] Advantages and disadvantages compared daylength (column 1) versus comparison (column 2)
[2] Study conducted on hens

Table 2.2. Welfare advantages and disadvantages of different photoperiod programs for turkeys 17 to 24 wk of age

Daylength	Comparison	Confounding Factors	Advantages[1]	Disadvantages[1]	Author
Step-up (9 h d 4 to 15 h d 126)	Step-down (24 h d 4 to 15 h d 12)		Increased activity (eating, drinking, standing, and walking)		Hester et al., 1985
Step-up (9 h d 4 to 15 h d 126)	Step-down (24 h d 4 to 15 h d 12)	Light intensity	Improved skeletal health		Hester et al., 1983, 1986
24 h	Increasing INC (6 h d 7 to 20 h d 63), decreasing - DID (same as INC, 10 h d 112)			Decreased walking ability, eating, drinking, standing and sitting behaviours	Classen et al., 1994
24 h	12 h			Heavier eyes, increased size, corneal flattening, buphthalmos, choroid thickening, detached retina	Ashton et al., 1973; [2]Davis et al., 1986
8 h	8 h – Enriched 8(1L:2D) – Continuous intermittent, 4(1L:0.5D):4(0.5L:1D):12D – Intermittent plus night	Environmental enrichment	Increased musculo-skeletal function	Visual non-reactivity Wing and tail pecking	Sherwin et al., 1999
23 h	Increasing (8 to 23 h)			Increased incidence of breast blister and dirtier birds	Newberry, 1992

[1] Advantages and disadvantages compared daylength (column 1) versus comparison (column 2)
[2] Study conducted at 8 wk of age

2.2 Impact of Light on Productivity

2.2.1 Growth and Feed Consumption

The effect of daylength on turkey growth rate has been variable with studies demonstrating superior growth with long daylength, others demonstrating better growth with shorter days and some showing no effect. Auckland (1973) found that 23 h increased growth compared to 14 h daylength and a step-down pattern where daylength decreased from 22 h to 14 h in toms at 14 wk of age. Poor performance exhibited by the 14 h treatment was attributed to reduced feed intake associated with an abrupt lighting change from 23 to 14 h light at six wk of age. The implementation of lighting programs at six wk of age is late in comparison to other research and could have affected the results. It is not uncommon to observe a drop in feed intake when daylength is reduced as it takes some time for birds to adapt to shortened feeding time, and consequently results in a reduced growth rate. Similarly, Siopes et al. (1989) compared 23 to 8 h daylength in two trials and found 23 h toms at 22 wk of age in the first trial to have heavier body weights and in second trial similar results, although not significant. The increased body weight seen with long daylengths has often been attributed to higher feed intake associated with unlimited day access to feeders (Lewis and Morris, 2006).

Other turkey lighting studies have found no effect of daylength on body weight. Classen et al. (1994) compared 24 h daylength with two lighting programs with changing daylength. One treatment (INC) decreased from 24 to 6 h at 7 d and then increased gradually to 20 h by 63 d where it remained until trial end at 118 d. The other lighting treatment (DID) followed the INC program to 84 d, but then daylength gradually decreased to 10 h at 112 d. Lighting treatment did not affect final body weight, but a change in growth pattern was evident with turkeys in the INC and DID treatments growing slower than birds given 24 h daylength during the early stages of the experimental growth, but making compensatory gains later in the production cycle. Classen et al. (1991) had previously found compensatory gains in broiler chickens using a lighting program similar to the INC program noted above. Newberry (1992) reported a similar growth pattern for tom turkeys exposed to gradually increasing daylength (8 to 23 h) and in this experiment birds given the this treatment were heavier at 17 wk than those exposed to 23 h daylength. These trials demonstrate a reduction in growth rate at the implementation of the decreased daylength, likely due to reduced feed intake (as mentioned above), but compensatory gains thereafter to result in equal or superior final weights in comparison to birds continually given a long daylength.

Intermittent lighting programs use multiple light and dark periods in a 24 h period. Siopes et al. (1986) compared the effects of 23 h daylength to three intermittent lighting programs (1L:3D repeated six times daily, 0.25L:0.75D repeated 24 times daily, and 3L:11D:3L:7D) on the growth of toms from 2 to 22 wk of age. Turkeys from all intermittent lighting treatments, which provided six h of light per day, were heavier at 18 and 22 wk of age. Additionally, intermittent lighting programs resulted in increased feed consumption, which coincided with increased body weight gain. This research further illustrates the ability for turkeys to adapt to shorter periods of light exposure by altering feed consumption later on in the production period.

As mentioned previously, extensive research has been conducted on step-up and step-down lighting programs for turkeys. Hester et al. (1985) compared step-up (9 h d 4 to 15 h by d 126) and step-down (24 h d 4 to 15 h by d 12 until trial end, d 135) daylengths under low light intensity conditions (2.5 lux) and found that toms from the step-down program were larger and consumed more feed over a 19 wk experiment. This study attributed increased growth in step-down program to longer daylength early in bird’s life. Hence, the authors suggested longer periods of darkness were detrimental to birds early in life because they limit feed intake. Hester et al. (1986) later compared high intensity (20 lux) step-up and low intensity (2.5 lux) step-down lighting programs and again found toms from step-down programs to have heavier body weights at 20 wk of age. However, the results of this research are difficult to interpret because the effects of daylength are confounded by the simultaneous differences in light intensity. In contrast to toms, hens in a step-up lighting program (10 to 16 h) exhibited greater body weight and feed consumption at 16 wk of age than birds on a step-down (16 to 10 h) program (Lilburn et al., 1992). Of note, results from experiments that compare changing daylength (i.e. intermittent, step-up and step-down programmes) do not provide useful information to comparisons of daylength treatments, where daylength remains constant.

More extensive research has been completed on broiler chickens than turkeys and though it is not wise to extrapolate results from one species to another, the results may still benefit the understanding of daylength effects in turkeys and biological effects that are common to both species. Broiler chicken studies demonstrate compensatory gains for birds in an INC (6 h on d 4 to 23 h on d 35) and shorter (14 and 17 h) daylengths (Classen et al. 1991; Schwean-Lardner et al., 2012b) when compared to 23 h daylength. Birds in both studies had decreased growth and feed intake after the application of shorter daylength, but adapted and were equal or heavier than birds on long daylength later in their grow-out period. Lewis and Gous (2007) found birds on 8 h daylength and increasing treatments (8 h on d 21 to 16 h from d 22 to 42) to be heavier and consume more feed compared to birds exposed to 16 h daylength. These broiler chicken studies illustrate the long term beneficial effects of shorter daylengths on growth and feed intake.

2.2.2 Feed Efficiency

Similar to growth rate and feed consumption, the effect of daylength on turkey feed efficiency is inconsistent in the scientific literature. The use of longer photoperiods has been shown to improve feed efficiency (Auckland, 1973; Siopes et al., 1989; Lewis et al., 1998). When comparing 14 h, 23 h and decreasing daylength (23 to 14 h) treatments, the 23 h daylength resulted in an improved feed efficiency (Auckland, 1973). Likewise, Siopes et al. (1989) observed better feed efficiency for toms at 18 and 22 wk of age with 23 h in contrast to 8 h daylength. The authors speculated that better efficiency for the 23 h daylength was due to differences in feed intake and body composition with 23 h toms consuming less feed and having less abdominal fat. Similarly, Lewis et al. (1998) found toms on 23 h of daylength to have better feed efficiency relative to 8 h treatment. They speculated that the difference in feed efficiency was due to increased sexual maturation for 23 h birds and a reduction in fat deposition. Hester et al. (1985) found that a step-down (24 h d 4 to 15 h d 12) lighting program resulted in a better feed efficiency in comparison to a step-up program (9 h d 4 to 15 h d 126), which had fewer daily light h. In this trial, the better feed efficiency was attributed to activity level with birds in step-down program being less active in comparison to the step-up program. Of note, behavioural observations were taken over a two h period in the afternoon and may not be an accurate representation of behavioural repertoire. Therefore, improved feed efficiency observed for longer photoperiods has been attributed to differences in energy expenditure.

Intermittent lighting programs have also shown improved broiler feed efficiency compared to longer daylengths (Rahimi et al., 2005). A feature of intermittent lighting programs is the stimulation of feed intake multiple times throughout the day when the lights come on. In addition to increased stimulation of feed intake, intermittent programs have repeated dark periods, which alter metabolism (MacLeod et al., 1980; Apeldoorn et al., 1999), promote crop storage (Svihus et al., 2010), improved nutrient retention (Buyse et al., 1996) and reduce activity level (Rahimi et al., 2005). Similar to intermittent lighting programs, which provide more darkness than longer daylengths, feed efficiency improves with decreasing daylength in broilers (Schwean-Lardner et al., 2012b). Thus, the improved feed efficiency observed in intermittent lighting and shorter daylength could be due to decreased energy expenditure from reduced physical activity, altered metabolism, and improved nutrient retention during the dark period with birds resting.

2.2.3 Mortality and Morbidity

The majority of turkey research has not found a difference in the incidence of mortality due to lighting treatment (Auckland, 1973; Siopes et al., 1986; Siopes et al., 1989). However, Classen et al. (1994) found that INC and DID lighting programs reduced mortality compared to 23 h daylength. In particular lighting treatments with more darkness reduced the incidence of skeletal and cardiac diseases (Classen et al., 1994). Lewis et al. (1998) compared shorter daylengths (8, 12 and 16 h) to 23 h daylength and found lower mortality for shorter daylength treatments. The decrease in mortality on shorter daylengths has been attributed to decreased early growth, which allows for improved bone development and decreased metabolic load (Rath et al., 2000). Additionally, increased activity (exercise) and rejuvenation on shorter daylengths (Schwean-Lardner et al., 2013) have also been suggested to be beneficial.

A recent broiler chicken study utilizing graded levels of daylength (14, 17, 20 and 23 h) demonstrated that mortality increases linearly with longer daylength (Schwean-Lardner et al., 2012b). In addition to total mortality, metabolic (sudden death syndrome and ascites) and skeletal diseases increased with longer daylength (Schwean-Lardner et al., 2013). Increased mortality could not be linked exclusively to rapid growth rate because 23 h birds were not the heaviest. It was proposed that the time of rapid growth was more influential with earlier rapid growth being most detrimental. Other research has shown that management techniques that decrease early growth can be beneficial to bird health. Robinson et al. (1992) found that early feed restriction can be used to slow growth and impact bird health, in particular cardiac and skeletal diseases more than later cycle body weight reduction.

2.3 Defining Animal Welfare

The welfare implications of how domestic animals are raised for meat, milk and eggs has become increasingly important. Before considering the effect of daylength on poultry welfare, a definition of welfare is essential. Animal welfare is complex and traditionally had three approaches: biological or functioning, feelings based and natural living. Biological or functioning approach emphasises the health and normal functioning of an animal's biological systems (Broom, 1991). This approach is commonly used by scientists, veterinarians, producers and other animal care professionals as it can be scientifically measured. Such scientific measures in poultry include gait scoring to assess mobility, corticosterone (a stress hormone in blood or faeces), immune function and behavioural observation. The feelings based approach, as it implies, places emphasis on the psychological aspect of welfare by taking into account negative (suffering) and positive (pleasure) animal feelings (Duncan, 2002). This approach is difficult to assess because feelings are subjective and consequently challenging to measure indirectly (Duncan, 2005). Over the years there has been a shift in how animal welfare is viewed with increasing emphasis on the feelings based approach through preference and motivational testing and behavioural signs of pain, fear and frustration (Duncan, 2005). The last approach of natural living, states that animals should be allowed to live in their natural environment and express innate behaviours (Kiley-Worthington, 1989).

The five freedoms proposed by the Farm Animal Welfare Council (FAWC, 2011), which have been reworded from their original form to contain more descriptive categories, combine all three welfare approaches and are as follows:

1) Freedom from thirst, hunger and malnutrition – by ready access to fresh water and diet to maintain full health and vigour,
2) Freedom from discomfort – by providing a suitable environment including shelter and a comfortable resting area,
3) Freedom from pain, injury and disease – by prevention or rapid diagnosis and treatment,
4) Freedom to express normal behaviour – by providing sufficient space, proper facilities and company of the animal's own kind, and
5) Freedom from fear and distress – by ensuring conditions which avoid mental suffering.

This approach is widely used to assess animal welfare, but for some points there can still be questions of interpretation (e.g. What is normal behaviour?) and difficulty in accurately assessing them (pain, fear and distress).

It becomes clear that animal welfare is multidimensional encompassing physiological, health, production and behavioural measures. Welfare is expressed on a continuum ranging from good to poor. Poor welfare results when an animal is unable to cope with its environment, experiencing suffering and/or pain (Broom, 1991). Indicators that accompany reduced welfare include increased mortality and disease, reduced growth rate and changes in behavioural repertoire and behavioural expression such as increased inactivity or resting (Broom, 1991). Welfare encompasses many aspects of an animal's environment and condition, therefore, no single measure can be used to determine animal welfare; rather a more comprehensive evaluation of multiple criteria is needed. As a consequence, measuring animal welfare can be difficult.

2.4 Impact of Light on Health and Behaviour

2.4.1 Mobility

Mobility is defined as the ability to move or be moved freely and easily. As such it is influenced by a wide range of physical and mental factors. Physical aspects could include fractured bones, torn tendons, muscles or joints, while mental factors could include motivations or fears. For the purposes of this paper, mobility will be referring to physical factors, as they are easy to define, with particular attention on skeletal disorders. Skeletal disorders observed in turkeys have a diverse etiology, but commonly include valgus-varus, tibial dyschondroplasia and rotated tibia (Tatara et al., 2004). The causes of such disorders have been proposed to include rapid growth, level of activity (exercise), metabolic influences and infectious causes. Daylength can affect bird growth, metabolism, activity levels and immune function and therefore, should play an important role in skeletal health and associated welfare concerns.

Increasing lighting programs can lower the incidence of leg abnormalities. Research conducted by Hester et al. (1983) examined the effects of high intensity step-up (9 h d 4 to 15 h d 126) and low intensity step-down (24 h d 4 to 15 h d 12) lighting programs on the skeletal health of toms. They found that high intensity step-up programs reduced the incidence of leg abnormalities. The authors attributed decreased leg abnormalities to an increase in exercise and shortening of tarsometatarsus enhanced by earlier sexual maturity. It should be noted that body weight was not an influential factor as there was no significant difference between treatments. As mentioned earlier, this research is confounded with differences in light intensities in the step-up (20 lux) and step-down (2.5 lux) programs.

Gait scoring is an important method of assessing mobility in poultry (Garner et al., 2002). It has been well documented that long daylengths have a detrimental effect on gait score in both turkeys (Classen et al., 1994) and broiler chickens (Schwean-Lardner et al., 2013). Classen et al. (1994) illustrated that INC and DID lighting programs in comparison to 24 h daylength exhibit lower gait scores. The same treatments that improved gait scores also reduced the incidence of culling for leg abnormalities and increased bone breaking strength.

Increased activity of birds given shorter daylengths has been suggested to have a positive effect on skeletal health (Classen et al., 1994; Reiter and Bessei, 2009; Schwean-Lardner et al., 2013). The action of exercising facilitates the force of muscles pulling against bone, which stimulates the bone-building process (Lanyon, 1993). The degree of the effect relates to the nature of exercise with more strenuous exercise being more effective in increasing bone mass. In poultry, the cause and effect relationship between exercise and improved bone development is inconsistent. Rieter and Bessei (1995) found active birds to have thicker and denser cortical bone in the tibiotarsus compared to less active birds. On the contrary, Sherlock et al. (2010) argued against the hypothesis that increased activity promotes better skeletal health and speculated that differences between studies may be due to differences in exercise level and load. Reiter and Bessei (1995) trained birds to run on a treadmill, which is a more extensive exercise in comparison to Sherlock et al. (2010) where birds walked normally in their pen. The latter work compared step wise changes in light intensity altering from 10 to 200 lux and found no differences in gait score, and cortical bone density and thickness. It can be concluded that exercise is important in bone development, but knowledge is lacking on the amount and type of exercise required to reduce leg disorders in broiler chicken and turkey production.

Lame birds spend more time inactive (Weeks et al., 2000). Inactivity is likely due to pain, with evidence that analgesics administered to turkeys with leg abnormalities (degenerative hip disease) improved bird locomotion (Duncan et al., 1991). Buchwalder and Huber-Eicher (2005) found an increase in time spent walking and standing at seven and 12 wk of age when the analgesic, butorphanol, was administered to lame birds. Additionally, broiler chickens with abnormal gaits self-selected an analgesic feed more than sound birds and showed improved walking ability as a result (Danbury et al., 2000). Hence, the presence of leg pain in poultry is well documented and has significant welfare implications.

Broiler chicken studies have illustrated similar findings to turkeys with improved mobility on shorter daylengths (Classen et al., 1991; Brickett et al., 2007; Schwean-Lardner et al., 2013). Brickett et al. (2007) found that male and female broilers had poorer mobility reported with higher GS in 20 h daylength compared to 12 h daylength treatment. Schwean-Lardner et al. (2013) also saw an increase in average GS for broilers on longer daylengths when evaluating the effects of graded daylength (14, 17, 20 and 23 h) on bird mobility.

The mobility of modern meat strains of broiler chickens and turkeys decreases as they grow, presumably because of the increased body weight (Kestin et al., 2001; Nester et al., 2008) and proportionally breast meat yield (Corr et al., 2003). Decreased mobility is associated with birds sitting more, increased contact with the litter and the potential for an increased prevalence of skin lesions, such as breast blisters and footpad dermatitis (Krautwald-Junghanns et al., 2011).

Footpad dermatitis (FPD) is defined “as a necrotic lesion and inflammation of the footpad” (Watanabe et al., 2013). The cause of FPD is multifactorial, being influenced by external factors such as litter moisture, litter source, daylength, diet, stocking density and internal factors such as structure of the skin, sex, breed and body weight (Mayne, 2005). Perhaps the most influential factor is litter moisture. It has been well demonstrated that the prevalence of FPD increases with increased litter wetness (Martland, 1984, 1985; Mayne et al., 2007). Pain has been associated with FPD and one consequence may be a reduction in body weight due to a bird's reluctance to walk to a feeder (Martland, 1984, 1985). To the author's knowledge there are no turkey studies evaluating the effect of daylength on FPD. A broiler chicken study found that the incidence of FPD increases with increasing daylength and suggested it was due to decreased activity and consequently increased contact with the litter (Schwean-Lardner et al., 2013).

Breast blisters are another common lesion that are associated with poor mobility due to increased contact of breast skin with litter (Krautwald-Junghanns et al., 2011). Breast blisters can be defined as "encapsulated areas of swelling in the form of bursa praesternalis, which may be filled with serous fluids (hygroma) as well as pus (bursitis sternalis) and enflamed around the periphery" (Mitterer-Istyagin et al., 2011). Newberry (1992) observed fewer breast blisters and cleaner feather cover on turkeys exposed to an increasing photoperiod (8 to 23 h) versus 23 h daylength. Bacteria are not found in the affected tissue, and the causative agent of breast blisters has not been determined (Gonder and Barnes, 1986). Nevertheless, turkey toms have an increased incidence of breast blisters in comparison to hens, which has been speculated to be due to increased water consumption, decreased feather cover, increased weight and poorer mobility (Gonder and Barnes, 1986). Evidence that breast blisters cause pain or a welfare issue is lacking, but the degree of tissue damage suggests this might be the case.

2.4.2 Ocular Health

Vision is an important sense in poultry illustrated by relatively large eye size and a diurnal pattern of activity. Therefore, a loss of, or reduction in vision would compromise bird welfare. Birds kept under long or continuous daylength develop larger eyes, with shallow anterior chamber, reduced corneal diameter and increased thickness of the choroid layer (Whitley et al., 1984; Oishi and Murakami, 1985). These abnormalities could cause glaucoma or increased intraocular pressure (IOP) as a result of the size of the globe or eyeball reaching its elastic limit (Whitley et al., 1984). An ultimate outcome of increased IOP is blindness due to retinal detachment. Davis et al. (1986) illustrated that turkeys reared to 8 wk of age in 23 or 24 h photoperiods had increased eye weights, enlarged eye size and corneal flattening in comparison to a 12 h photoperiod. Ashton et al. (1973) observed 70 percent of turkeys in continuous light developed buphthalmos, corneal flattening and thinning of the retina and choroid compared to none of the birds given a 12 h photoperiod. Of note, eye abnormalities developed within one wk of continuous light exposure and could be reversed if birds were given a 12 h photoperiod (Ashton et al., 1973). Similar to turkeys, broiler chickens also exhibit increased eye weight with 23 h daylength (Schwean-Lardner et al., 2013), which may be linked to changes in eye growth with the reduction or elimination of circadian rhythms (Li and Howland, 2003; Rada and Wiehmann, 2006; Lewis and Gous, 2009).

In addition to photoperiod, light intensity can also have an effect on poultry eyes. Turkeys are commonly raised in low light intensities in order to minimize aggression. Thompson and Forbes (1999) found turkeys raised at 2 lux had significantly enlarged globes compared to a control group at 50 lux. An enlarged globe can result in buphthalmos and eventually blindness giving rise to ‘turkey blindness syndrome’ (Ashton et al., 1973). Siopes et al. (1984) found the development of eye abnormalities in turkey poults (two wk of age) reared at a light intensity of 1.1 lux in comparison to 11 lux or higher. The eye abnormalities that were observed included increased transverse diameter of the globe and corneal flattening. Studies with broiler chickens have illustrated similar findings with birds in low light intensities developing buphthalmos (Blatchford et al., 2009; Deep et al., 2010). Therefore, both photoperiod and light intensity can affect poultry eye development. Poultry reared in longer daylengths (i.e. 24 or 23 h) and low light intensity (i.e. less than 5 lux) have an increased chance of developing eye abnormalities. The most common eye abnormalities are enlargement of the globe and corneal flattening. These abnormalities can result in retinal detachment and consequently blindness after a prolonged period of time. The introduction of more darkness and increasing light intensity may help alleviate eye problems.

2.4.3 Behaviour

Observing bird behaviour can be an important tool in determining animal well-being. Behavioural changes, both increases and decreases in the incidence of particular behaviours, can potentially be a welfare concern. The use of behavioural observations to assess animal welfare has increased dramatically over the years due to advances in video equipment. Additionally, video behavioural monitoring is non-invasive and non-intrusive in comparison to many other scientific measures. Sherwin and Kelland (1998) assessed the ethogram of turkey toms over a 24 h period for a 12 h daylength program from 4 to 22 wk of age. Behaviours were mutually exclusive and included resting, standing walking, drinking, feeding, preening, environmental pecking, feather pecking, injurious pecking, and strutting. The amount of time spent expressing the majority of these behaviours decreased with increasing age (Hocking et al, 1999; Martrenchar et al., 1999; Busayi et al., 2006), with the exception of strutting, feather pecking and injurious peaking, which increased as birds reached sexual maturation (Sherwin and Kelland, 1998; Busayi et al., 2006).

The turkey behavioural repertoire in relation to daylength has not been recently investigated. Hester et al. (1985) determined that toms are more active in a step-up (9 h d 4 to 15 h d 126), which had fewer daily light h versus a step-down (24 h d 4 to 15 h d 12) lighting program. Step-up program had a significantly greater percentage of birds eating, drinking, standing, and walking. Classen et al. (1994) observed toms to be more active, showing superior walking ability and sitting less often in INC and DID treatments in comparison to 24 h treatment. Behavioural observations in both these studies were taken over a short period of time, two h (Hester et al., 1985) or 5, 10 and 15 min (Classen et al., 1994) and thus it is difficult to extrapolate results to a 24 h period. However, both studies illustrate that long daylength decreases bird activity in comparison to other lighting programs with more darkness. The cause of this decreased activity has been speculated to be the result of decreased mobility (Weeks et al., 2000), and/or sleep deprivation (Schwean-Lardner et al., 2012a).

Weeks et al. (2000) illustrated the behavioural modifications that occur in broiler chickens due to lameness between 39 and 49 d of age. Sound birds spend on average 76% of their time lying down in comparison to lame birds, which spend 86% of their time lying down. Broilers whether lame or not, spend three quarters of their time inactive, which author speculated may be due to birds feeling unbalanced with a forward center of gravity as a consequence of selection for high breast meat yield (Corr et al., 2003). Fournier et al. (2015) observed a change in the posture of turkey toms most likely due to the proportional increase in breast muscle as birds mature. Feeding behaviour was also altered with lame birds laying down more to eat, while sound birds were standing while eating. Additionally, the number of visits to feeder were reduced for lame birds averaging 30 in a 24 h period, while sound birds had over 50 visits. The increased time spent lying, lying and eating and eating few meals exhibited by lame broilers are an indicator of pain and clearly a welfare issue.

Schwean-Lardner et al. (2012a) concluded that shorter daylength (increased darkness) is beneficial to broiler welfare based on behavioural observations. This study looked at the effect of graded lighting programs (14, 17, 20, 23 h) on broiler behavioural expression over a 24 h period at 27 and 42 d of age. This research found a negative linear or quadratic response with increasing daylength for the percentage of time spent performing mobility (standing, walking), nutritive (eating) and comfort behaviours (preening, dustbathing, litter pecking, leg or wing stretching) and consequently an increase in inactivity. Differences in behavioural time budgets associated with 23 h daylength compared to birds given more darkness may be related to a lack of behavioural circiadian rhythms or a lack of rhythm synchronization (Schwean-Lardner et al., 2014). Both flock melatonin and behavioural circadian rhythms are missing from broilers given 23 h of daylength and the lack of synchrony may result in sleep disruption (shorter and less deep sleep) because of disturbance by pen mates (Bonnet, 2005). A consequence of sleep deprivation is effect on the brain with birds being fatigued and lethargic. A lethargic state has obvious welfare concerns with birds less able to perceive their environment.

Turkey toms in comparison to broiler chickens tend to be more aggressive, pecking and causing injury to pen mates. The aggression exhibited by turkeys is due at least in part to birds reaching sexual maturity, as a consequence of having a longer production cycle, 18 to 22 wk of age in comparison to broilers, which are marketed well in advance of sexual maturity. Sexual maturation is affected by daylength during the production cycle, with 23 h of daylength increasing plasma testosterone (Classen et al., 1994) and testicular weights (Siopes et al., 1989;

Lewis et al., 1998) in toms 17 to 22 wk of age. Although, Sherwin et al. (1999) found intermittent lighting treatments (continuous, 8(1L:2D) and plus night (4(1L:0.5D):4(0.5L:1D):12D)) compared to 8 h daylength to be successful in reducing wing and tail pecking, this was outweighed by other welfare concerns (shorter latency to sit and higher incidence of visual non-reactivity). However, the addition of environmental enrichment to the 8 h daylength treatment proved to be effective, decreasing wing, tail, and head pecking and improving musculo-skeletal function and vision.

2.5 Conclusion and Research Objective

In conclusion, turkey lighting research is limited and may be out of date in relationship to current turkey genotypes. In addition, results from these studies are variable in terms of impact of daylength on productivity and welfare measures and do not form a solid framework for commercial recommendations. The types of lighting program comparisons further complicate interpretation with little evidence of the impact of various daylengths. Therefore, the objective of this study is to determine the effect of graded levels of daylength on the productivity, health and behaviour of male and female meat turkeys.

3.0 THE IMPACT OF GRADED LEVELS OF DAYLENGTH ON TURKEY PRODUCTIVITY TO 18 WEEKS OF AGE

3.1 Abstract

The impact of graded levels of daylength on the productivity of hens and toms was studied in two experiments. Daylength treatments (trt) were 14 (14L), 17 (17L), 20 (20L) and 23 (23L) h and were started at 10 d of age. Turkeys (720 hens and 480 toms) were randomly allocated to 8 rooms (2 rooms per lighting trt) with six pens (3 hen and 3 tom) per room in each experiment. Body weight (BW) was assessed on d 10, 21, 42, 63, 84, and 126 of age; feed consumption (FC) was measured for comparable time periods and feed efficiency (G:F; g of gain/g of feed) calculated from BW and FC values. Birds were checked daily for mortality and culls, and affected birds sent for necropsy. Data were analyzed for light trt, gender and interaction effects using SAS 9.3 and a completely randomized design nested within four lighting trts (no significant block effect). Regression analysis was used to study the relationship between dependent variables and daylength. Significance was declared at $P \leq 0.05$ and trends at $P \leq 0.10$. At 21 and 42 d, body weight increased linearly with increasing daylength. At 84 d toms weights decreased in a quadratic fashion and hen weights were unaffected. At 126 d, both tom and hen weights decreased linearly with increased daylength, with magnitude of response gender dependent. Feed consumption corresponded with body weight changes, increasing for d 10-21, and 21-42 and decreasing for d 63-84, 84-105, and 105-126 with increasing daylength. Feed efficiency (G:F) was not affected by daylength for 10-84, 10-105 and 10-126 d periods. The incidence of mortality and culling was not affected by daylength for the 10-84 d period, but increased in a quadratic manner with increasing daylength for the 10-105 and 10-126 d periods.

To conclude, daylength affects the growth and feed intake of turkeys in an age and gender specific manner, and mortality and culling increase with longer daylength.

Keywords: light, toms, hens, growth, pendulous crop

3.2 Introduction

Daylength is an important aspect of managing poultry, with the nature of its use varying with age and production purpose. For example, broiler breeders, turkey breeders and laying hens use daylength to either delay or induce sexually maturity. Shorter daylength can also be utilized to reduce early growth rate in broiler chickens (Classen et al., 1991; Schwean-Lardner et al., 2012b) and turkeys (Classen et al., 1994; Lewis et al., 1998; Newberry, 1992), and thereby improve bird health. Despite the early reduction in growth rate, birds exposed to shorter daylength early in life often demonstrate compensatory gains later in comparison to birds in constant lighting regimes, resulting in equal or superior body weight at marketing (Classen et al., 1991; Classen et al., 1994; Lilburn et al., 1992; Schwean-Lardner et al., 2012b). The improvement in bird health associated with shorter daylength includes beneficial effects on skeletal development and the incidence of leg disorders (Classen et al., 1994; Hester et al., 1983; Kestin et al., 2001; Williams et al., 2004; Schwean-Lardner et al., 2013).

Shorter daylengths can also reduce metabolic diseases and infectious etiologies (Classen et al., 1994; Schwean-Lardner et al., 2013). Reduction in metabolic and infectious causes of mortality on shorter daylengths are the result of increased hours of darkness and potential beneficial effects on immune function (Abbas et al., 2008) and sleep (Rattenborg et al., 2005; Schwean-Lardner et al., 2013). The hormone melatonin is produced during the scotoperiod and plays an important role in the cyclic nature of circadian rhythms, including sleep (Bermudez et al., 1983). The act of sleeping alters metabolic rate, reducing it, and facilitates tissue rejuvenation (Everson, 2005). Therefore, shorter daylengths can offer beneficial effects to growth, mortality and overall bird health.

Although turkey studies have examined a variety of lighting programs that manipulate daylength, a clear indication of the response of turkeys to varying daylength is lacking. Near continuous lighting programs (23L:1D) has been suggested to maximize feed intake and growth to unlimited access to feed (Lewis and Morris, 2006). Auckland (1973) found that 23 h of daylength compared to 14 h and a step-down pattern, where daylength was reduced from 22 h to 14 h resulted in significantly heavier toms at 18 wk of age. The authors suggested that the poor performance for shorter daylength treatments may have been due to abrupt implementation of lighting programs at six wk of age. Similarly, Siopes et al. (1989) demonstrated that 23 h toms were heavier at 22 wk of age in comparison to bird exposed to an eight h daylength. These results are likely expected because of the short eight h daylength. The above experiments failed to compare sufficiently variable daylength or an early age of induction, which suggests that the superiority of the 23L:1D daylength was not conclusively determined.

Other turkey lighting studies results are more difficult to interpret with the comparison of step-up or increasing programs versus step-down or decreasing programs (Hester et al., 1985, 1986; Lilburn et al., 1992) and intermittent lighting programs (Siopes et al., 1986). Hester et al. (1986) found toms from low intensity step-down (24 h d 4 to 15 h d 12) program to have heavier body weights after 20 wk of age in comparison to high intensity step-up (9 h d 4 to 15 h d 126) program. However, the confounding effects of daylength and light intensity (2.5 versus 20 lux) make interpretation of these results difficult. Siopes et al. (1986) compared intermittent lighting programs (1L:3D repeated six times daily, 0.25L:0.75D repeated 24 times daily and

3L:11D:3L:7D), which all provided six h of light per day to 23 h treatment had significantly increased body weight and corresponding feed consumption at 18 and 22 wk of age. These studies suggested that shorter daylength later in a turkey's production cycle may be beneficial to growth producing heavier birds.

Previous research examining daylength and turkey feed conversion ratio (FCR) has indicated that longer daylengths improve FCR (Auckland, 1973; Hester et al., 1985; Siopes et al., 1989; Lewis et al., 1998). Toms on 23 h daylength compared to a shorter daylength (14 h) and a step-down (22 to 14 h) program demonstrated improved feed efficiency (Auckland, 1973). Likewise, Siopes et al. (1989) observed a better feed conversion for toms on 23 h daylength from 18 to 22 wk of age compared to an eight h treatment. This study speculated that better feed conversion on long daylength was due to reduced feed intake and altered body composition, with 23 h toms consuming less feed and having lower amounts of abdominal fat. Similarly, a step-down lighting program (24 to 15 h), which has more daylength, resulted in a better feed efficiency compared to a step-up program (9 to 15 h) (Hester et al., 1985). The latter authors suggested that improved efficiency in the step-down lighting regime was the result of lower levels of activity as indicated by behavioural observation. Therefore, differences in feed intake, body composition and energy expenditure could account for improved feed efficiencies under longer daylengths for turkeys.

In contrast to turkeys, broiler chicken studies have shown significant improvements in feed efficiency with more hours of darkness (Buyse et al., 1996; Rahimi et al., 2005; Schwean-Lardner et al., 2012b). The mechanism whereby darkness benefits feed efficiency is not clearly defined, but may relate to metabolic changes during the dark period. The hormone melatonin, which is produced in the retina and pineal gland and involved in circadian rhythms (Hau and

Gwinner, 1994), can also improve feed efficiency (Clark and Classen, 1995; Apeldoorn et al., 1999). Melatonin peaks at night and drops during the day with the amplitude of rhythm being more pronounced on longer periods of darkness (Schwean-Lardner et al., 2014). Additionally, the magnitude of rhythm and the duration of melatonin production was also greater on shorter daylengths. The feed efficiency effect may be related to the reduction in metabolic rate and energy expenditure associated with darkness (MacLeod et al., 1980). Despite the lower metabolism and activity during the scotoperiod, broilers given shorter daylengths are more active when behaviour is summarized over a 24 h period than birds given longer daylengths (e.g. 23 h; Schwean-Lardner et al., 2012a). Therefore, efficiency does not benefit from less overall activity. Improved nutrient retention has also been shown for birds exposed to periods of darkness, which could also contribute to improved feed efficiency (Buyse et al., 1996).

As shown above, previous turkey lighting research has mostly focused on comparing two lighting program extremes, such as constant (24 h) or near continuous (23 h) lighting programs and shorter daylengths, or increasing, decreasing, or intermittent lighting programs. Research to date has not examined the responses of meat turkeys to graded levels of daylength. Furthermore, the majority of the turkey lighting research was conducted prior to the 1990's and thus may be out of date for birds that continue to undergo continuous genetic improvements in a wide array of production and health parameters (Krautwald-Junghanns et al., 2013). Limited turkey lighting research, changes in bird genetics, and the lack of insight into graded daylength effects are the foundation for this study. The objective of this research was to determine the impact of graded levels of daylength on the productivity of male and female meat turkeys raised to 18 wk of age.

3.3 Materials and Methods

All experimental procedures were approved by the University of Saskatchewan Animal Care Committee and followed recommendations in the Guide to the Care and Use of Experimental Animals (Canadian Council of Animal Care, 1993).

3.3.1 Experimental Design

Two 18 wk trials were conducted in November of sequential years to study the effect of daylength, gender and their interaction on production parameters of hens and toms. Four lighting programs were implemented, including 14L:10D (14L), 17L:7D (17L), 20L:4D (20L) and 23L:1D (23L) at 10 d of age and maintained to 18 wk of age. Nicholas heavy strain (85 x 700) poults were obtained from a commercial hatchery (beak and toe treated) and randomly allocated to experimental rooms. Four hundred and eighty males and 720 females were randomly placed in eight identical rooms (12.19 x 7.01 m) in each trial. Two room replicates per lighting program were used in each trial, thereby providing four replications in the experiment. Each room contained six pens (2.3 x 4.0 m), with sexes housed separately and thus three male and three female pens per room.

During the brooding period poults received 23L:1D for first 5 d, after which daylength gradually decreased in a step-wise fashion (equal hours each day) to designated lighting treatments by d 10. Heat lamps were hung above brooding rings for the first wk to provide supplementary heat. Light was provided by one 100W incandescent light bulbs above the centre of each pen. Light intensity from room light (not including heat lamps) was 40 lux until d 5 and then gradually decreased to 5 lux by d 10. A light meter (Lutron LX 1010 Lux Meter, Acklands-Grainger, Inc., ON) was used to measure light intensity in the centre of the middle pen in each room at bird height at the time of poult placement, at lighting program initiation and every three wk thereafter. In both trials, light intensity was decreased to reduce injurious pecking and the specific detail for each trial is shown in Table 3.1. All lighting programs had 15 min simulated dawn and dusk periods daily included within the designated photoperiod.

Initially, pens contained 20 males and 30 females respectively, with three birds per pen being removed at 12 wk of age for meat yield determination (unpublished data). An estimated final stocking density of 35 kg/m^2 was targeted based on Nicholas performance objectives (Aviagen, 2011b).

Table 3.1. Light intensity changes for trial 1 and 2

Trial	Age	Lux
1	0-4 d	40
1	10 d	5
1	13 wk	4
1	15 wk	2
2	0-4 d	40
2	10 d	5
2	9 wk	4
2	11 wk	2

3.3.2 Housing and Management

All rooms utilized a negative pressure ventilation system. Room temperature was thermostatically controlled and heat was supplied by hot water pipes (84 cm from floor) along three of the four walls. Temperature was 35°C on d 0 and gradually reduced until it was 13°C at 13 wk of age, where it remained for the duration of the trial. Feed and water were provided *ad libitum*. A six phase feeding program based on Nicholas nutritional guidelines (Aviagen, 2011c) was provided by a commercial feed company (Table 3.2). Feed was provided in two aluminum tube feeders per pen with a diameter of 36 cm from day 0 to 42 and 44 cm thereafter. Form and amounts of feed provided for hens and toms are shown in Table 3.3. Water was provided via a Lubing EasyLine™ pendulum nipple drinker (Lubing, Cleveland, TN) with three drip cups per pen. Starter balls provided by the manufacture were utilized in drinker cups for first wk to raise the water level. Poults were raised on wood shavings with a wheat straw bedding base (approximately 7.5-10 cm thick) in brooding rings for the first 10 d of the trial. Pens were re-bedded with straw as necessary throughout the trial.

Table 3.2. Composition of diets for trial 1 and 2

Ingredients: (%)	Starter #1	Starter #2	Grower #1	Grower #2	Grower #3	Finisher #1
Soybean meal (48%)	29.99	26.00	21.69	15.38	11.40	9.41
Wheat	26.12	25.00	25.00	25.00	25.00	29.51
Corn gluten meal	15.00	15.00	13.54	20.00	20.00	17.35
Corn	7.62	16.80	23.96	22.83	27.65	30.00
Meat meal	5.00	3.00	2.00	4.36	4.35	2.00
Fish meal	4.93	5.00	5.00	4.58	4.00	4.00
Canola meal	4.00	2.00	2.00	2.00	2.00	2.00
Canola oil	3.80	3.80	3.80	3.80	3.80	3.80
Limestone	1.34	1.32	1.15	0.96	0.76	0.82
Mono Ca phosphate	0.66	0.59	0.42	0	0	0
Salt	0.11	0.13	0.16	0.17	0.18	0.20
Vit./min. premix[1]	0.25	0.21	0.19	0.18	0.18	0.16
Selenium	0.14	0.15	0.14	0.14	0.14	0.14
DL-Methionine	0.10	0.07	0.06	0	0	0
L-Lysine HCl	0.47	0.46	0.45	0.28	0.25	0.32
Pro-Bond (pea starch)	0.15	0.10	0.13	0.14	0.13	0.09
Sodium bicarbonate	0.16	0.16	0.13	0.06	0.04	0.06
BMD 110 G[2]	0.05	0.05	0.05	0.05	0.05	0.05
Rumensin[3]	0.50	0.05	0.05	0	0	0
Ronozyme [4]	0.03	0.03	0.03	0.03	0.03	0.03
Endofeed W[5]	0.02	0.02	0.02	0.02	0.02	0.02
Vitamin E 50	0.01	0.01	0.002	0.003	0.003	0
Biotin concentrate (2%)	0.001	0.001	0	0	0	0
Calculated composition (%)						
ME (kcal/kg)	3020	3100	3150	3250	3300	3350
Crude protein	34.60	29.70	26.00	29.50	27.60	24.80
Sodium	0.17	0.16	0.16	0.15	0.15	0.15
Calcium	1.49	1.38	1.24	1.14	1.00	0.93
Non-phytate phosphorus	0.76	0.69	0.62	0.57	0.50	0.51
Lysine	1.73	1.53	1.37	1.21	1.08	0.99
Methionine	0.66	0.61	0.59	0.50	0.47	0.47
Methionine + Cysteine	1.12	1.01	0.92	0.90	0.86	0.81

[1] Supplied per kilogram of diet: retinol, 2.83 mg; cholecalciferol, 0.076 mg; d-alpha tocopherol, 33.6 mg; menadione, 1.43 mg; thiamine, 1.95 mg; riboflavin, 6.5 mg; niacin, 65 mg; pyridoxine, 3.25 mg; cobalamine, 0.013 mg; pantothenic acid, 13.0 mg; folic acid, 1.1 mg; biotin, 0.163mg and antioxidant, 0.081 mg; iron, 55 mg; zinc, 60.5 mg; manganese, 74 mg; copper, 5.5 mg; iodine, 0.72 mg; and selenium, 0.3 mg

[2] Bacitracin Methylene Disalicylate (Zoetis Canada Inc.)

[3] Active ingredient Monensin (as monensin sodium) (Elanco)

[4] Phytase – enzyme that releases plant phosphorus (DSM Nutritional Products)

[5] Principle enzymes β-glucanase and xylanase (GNC Bioferm Inc., Canada)

Table 3.3. Feed form and amount for hens and toms

Feed Name	Feed Form	kg/bird	
		Hen	Tom
Starter # 1	Crumble	1.50	1.65
Starter # 2	Crumble	2.00	2.54
Grower # 1	Small pellet	3.04	6.24
Grower # 2	Pellet	4.09	9.48
Grower # 3	Pellet	5.05	7.71
Finisher # 1	Pellet	7.82	4.50
Finisher # 2[1]	Pellet	Fed for approx. last week	

[1] Finisher # 2 composition was the same as Finisher # 1 minus BMD.

3.3.3 Data Collection

Data were collected to assess the impact of daylength, gender and their interaction on turkey productivity. Poults on a pen basis were weighed on d 0, 10, 21, 42, 63, 84, 105 and 126; feed consumption was measured for the same time periods.

Birds were monitored twice daily for dead and sick birds. Birds were culled if they showed loss of body condition, inability or impairment to move, the presence of a pendulous crop or signs of injurious pecking. Cull birds were euthanized by cervical dislocation by trained barn staff. All mortalities and culls were necropsied to determine cause of death or morbidity (Prairie Diagnostic Services, Western College of Veterinary Medicine, University of Saskatchewan, Saskatoon, SK). The causes of mortality were divided into one of seven classifications (Table 3.4) for analyses. Data were expressed as a percentage in each category by time period.

Table 3.4. Mortality categories[1]

Category	
Skeletal disorders	Valgus-varus, broken wing, rotated tibia, muscular hemorrhage, leg fracture, tibial dyschonroplasis
Infectious disorders	Arthritis, pericarditis, bursitis, airsacculitis, peritonitis, hepatic necrosis, tendonitis, polyserositis, cellulitis, runt
Heart disorders	Right ventricle disease, perirenal hemorrhage, aortic rupture, cardiomyopathy, ascites, round heart
Pendulous crop (PC)	
Injurious pecking	
Other	Impacted gastrointestinal tract, accidental death
Unknown	No visible lesions (NVL)

[1] Order of causes indicates the incidence ranking.

3.3.4 Statistical Analysis

The main effects of light and gender and their interaction were analysed using Proc Mixed of SAS (SAS 9.3., Cary, NC) as a completely randomized design (CRD) nested within four lighting programmes. Block (trial) was not significant and therefore not included in the model. The experimental model was $Y = \mu + L + G + L(R) + L*G + e$, where

Y is the observation from dependent variable,

μ is the population mean of variable,

L is the light effect (fixed),

G is the gender effect (fixed),

R is the room,

L*G is the interaction effect between light and gender,

and e is the random error associated with observations.

The DDFM Satterthwaite option was used for approximating the degrees of freedom for means and paired difference test was used for multi-treatment comparison. Percentage data were log transformed (log+1) prior to analysis as it was not normally distributed using Proc Univariate. Proc Reg (Regression) and Proc RS Reg (Response Surface Regression) were used to study relationships between dependent variables and daylength. Significance was declared at $P \leq 0.05$ and trends were noted when $P \leq 0.10$.

3.4 Results

3.4.1 Body Weight

Early in the experiment (21 and 42 d), body weight increased in a linear fashion with increasing daylength (Table 3.5). Daylength treatments did not affect body weight on d 63. The interaction between daylength and gender on d 84 (Table 3.6) was significant, males showed a quadratic response with the lowest body weight for birds in the 23L treatment, while females were unaffected by daylength treatment. No effect of light was found at 105 d of age, but body weight tended to decline with increasing daylength (ANOVA, $P=0.0801$). An interaction was found for body weight at 126 d (Table 3.6), but the interaction was a difference in magnitude rather than trend as both toms and hens declined in weight linearly with increasing daylength. Males grew faster than females at all ages.

Table 3.5. Effect of daylength (h) and gender on body weight (kg) of meat turkeys from 10 to 126 d of age

	Daylength[1] (L)				Gender[2] (G)				
Age (d)	14	17	20	23	Male	Female	L x G	SEM[3]	Regression Equation[4]
10	0.24	0.25	0.25	0.25	0.26[a]	0.24[b]	NS	0.002	-
21	0.76	0.80	0.81	0.83	0.84[a]	0.76[b]	NS	0.009	Y=0.44+0.03X
42	2.99	3.12	3.15	3.21	3.32[a]	2.92[b]	NS	0.027	Y=1.99+0.10X
63	6.67	6.80	6.81	6.89	7.41[a]	6.17[b]	NS	0.067	-
84	10.71	10.77	10.78	10.54	11.88[a]	9.52[b]	0.0006	0.124	-
105	14.54	14.22	14.01	14.00	16.09[a]	12.30[b]	NS	0.201	-
126	17.72[a]	17.30[ab]	17.08[bc]	16.72[c]	19.98[a]	14.43[b]	0.0089	0.293	-

[a,b,c] Means with common letters within a main effect do not differ significantly (P≤0.05).
[1] Means represent the average response of four replicate rooms each containing three pens of males (20 birds) or three pens of females (30 birds)/daylength treatment.
[2] Means represent the average response of 48 pens of males (20 birds/pen) or 48 pens of females (30 birds/pen).
[3] Pooled standard error of the mean.
[4] Regression considered significant if P≤0.05.

Table 3.6. Significant interactions between daylength and gender for performance parameters

	Age or Period	Gender[1] (G)	Daylength[2] (h)				Regression Equation[3]
			14	17	20	23	
Body weight, kg	84 d	M	11.94[a]	12.03[a]	11.99[a]	11.56[b]	$Y = 7.80+0.50X-0.01X^2$
	84 d	F	9.48[c]	9.51[c]	9.56[c]	9.52[c]	-
	126 d	M	20.73[a]	20.16[ab]	19.79[bc]	19.23[c]	Y = 23.15-0.18X
	126 d	F	14.70[d]	14.44[d]	14.36[d]	14.21[d]	Y = 16.37-0.16X
Feed intake, kg/bird	84-105 d	M	14.82[a]	13.68[b]	13.05[c]	12.72[c]	Y = 25.30-1.06X
	84-105 d	F	10.61[d]	10.55[d]	9.80[e]	9.40[e]	Y = 9.67=0.20X
	105-126 d	M	15.11[a]	13.98[b]	13.45[b]	12.27[c]	Y = 18.79-0.25X
	105-126 d	F	10.04[d]	9.89[de]	9.18[ef]	8.79[f]	Y = 9.94+0.11X
$(G:F^m)^4$, g/g	63-84 d	M	0.441[ab]	0.447[a]	0.441[ab]	0.426[b]	-
	63-84 d	F	0.376[d]	0.384[cd]	0.401[c]	0.391[cd]	-
	10-105 d	M	0.545[a]	0.553[a]	0.522[b]	0.539[ab]	-
	10-105 d	F	0.487[c]	0.486[c]	0.500[c]	0.496[c]	-
	10-126 d	M	0.423[a]	0.426[a]	0.424[a]	0.435[a]	-
	10-126 d	F	0.376[cd]	0.375[d]	0.390[bc]	0.396[b]	Y = 0.40-0.004X

[a,b,c] Means with common letters within an age specific response variable do not differ significantly (P≤0.05).
[1] Means represent the average response of 48 pens of males (20 birds/pen) or 48 pens of females (30 birds/pen).
[2] Means represent the average response of four replicate rooms each containing three pens of males (20 birds) or three pens of females (30 birds)/daylength treatment.
[3] Regression considered significant if P≤0.05.
[4] $G:F^m$ = (final period weight + kg of mortality weight - initial period weight)/period feed consumption.

3.4.2 Feed Consumption

Table 3.7 illustrates the effect of daylength and gender on feed consumption. Feed consumption increases linearly with daylength for the first 42 d. Daylength treatment did not affect feed consumption from 42-63 d, but for 63-84 d, feed consumption decreases in a linear fashion with increasing daylength. Interactions between light treatment and gender were found for d 84-105 and d 105-126 (Table 3.6); males and females illustrate a linear decline in feed intake with increasing daylength with differences in magnitude. For overall feed consumption, both males and females ate less with increased daylength (linear). Table 3.7 also illustrated cumulative feed consumption from the initiation of lighting treatments to various potential market ages. For 10-105 d and 10-126 d (ANOVA P=0.0609), feed intake decreased with increasing daylength. Males consumed more feed than females throughout the trial.

Table 3.7. Effect of daylength (h) and gender on feed consumption (kg/bird) of meat turkeys from 10 to 126 d of age

Age (d)	Daylength[1] (L) 14	17	20	23	Gender[2] (G) Male	Female	L x G	SEM[3]	Regression Equation[4]
10-21	0.62	0.66	0.67	0.67	0.69[a]	0.62[b]	NS	0.007	Y=0.24+0.04X
21-42	3.17[b]	3.28[ab]	3.34[a]	3.38[a]	3.51[a]	3.08[b]	NS	0.027	Y=2.15+0.10X
42-63	6.43	6.50	6.44	6.53	6.92[a]	6.03[b]	NS	0.052	-
63-84	10.01[a]	9.63[ab]	9.56[ab]	9.26[b]	10.47[a]	8.76[b]	NS	0.108	Y=11.79-0.16X
84-105	12.71[a]	12.11[b]	11.42[c]	11.06[c]	13.56[a]	10.09[b]	0.0520	0.204	-
105-126	12.57[a]	11.94[ab]	11.32[b]	10.53[c]	13.71[a]	9.47[b]	0.0041	0.244	-
10-84	21.00	20.67	20.76	20.83	22.62[a]	19.01[b]	NS	0.221	-
10-105	38.60[a]	37.23[ab]	36.00[b]	36.87[ab]	42.53[a]	31.81[b]	NS	0.613	-
10-126	52.11	49.92	49.26	48.95	58.42[a]	41.71[b]	NS	0.922	-

[a,b,c] Means with common letters within a main effect do not differ significantly ($P \leq 0.05$).
[1] Means represent the average response of four replicate rooms each containing three pens of males (20 birds) or three pens of females (30 birds)/daylength treatment.
[2] Means represent the average response of 48 pens of males (20 birds/pen) or 48 pens of females (30 birds/pen).
[3] Pooled standard error of the mean.
[4] Regression considered significant if $P \leq 0.05$.

3.4.3 Feed Efficiency

Mortality corrected gain to feed ratios ($G:F^m$) as affected by daylength and gender are shown in Table 3.8. Corrected gain to feed ratio increased linearly with daylength during d 10-21. An interaction was found between daylength and gender for d 63-84 (Table 3.6). Males from 23L exhibited the lowest $G:F^m$ ratio, respectively, while values for birds from 14L, 17L and 20L were not different from other treatments. The highest and lowest $G:F^m$ ratios were found for females from the 20L and 14L treatments, with birds from 17L and 23L treatments were intermediate. A quadratic response was found between daylength and feed efficiency for d 84-105 with the lowest values for the 17L and 20L treatments. Daylength did not affect $G:F^m$ for all other time periods (d 21-42, d 42-63, and d 105-126). Cumulative corrected $G:F^m$ from d 10-84 decreased (linear) with increasing daylength. Interactions between daylength and gender were found for d 10-105 $G:F^m$, with values tending to decline with increasing daylength and females not showing difference among treatments (Table 3.6). An interaction was also found for d 10-126, with values for males approaching positive linear significance (P=0.06) and female $G:F^m$ increasing linearly with daylength. With the exception of 21-42 d, where no effect was found, males were more feed efficient than females.

Non-corrected gain to feed ratio (G:F) for d 10-21 increased in a linear fashion with increasing daylength (Table 3.9). From d 42-63, the highest ratio was found for 14L, and 17L, 20L and 23L treatments resulted in the lowest values. A quadratic relationship was shown for d 63-84 with highest value for the 17L treatment. Daylength did not affect G:F for d 21-42, d 84-105 and 105-121, as well as cumulative time periods (d 10-84, d 10-105 and d 10-126). With the exception of d 21-42, d 105-126, d 10-105, and d 10-126 periods, males had higher G:F than females.

Table 3.8. Effect of daylength (h) and gender on gain to feed ratio (g/g) with mortality correction ($G:F^{m}$)[1] of meat turkeys from 10 to 126 d of age

Age (d)	Daylength[2] (L)				Gender[3] (G)		L x G	SEM[4]	Regression Equation[5]
	14	17	20	23	Male	Female			
10-21	0.824	0.825	0.828	0.851	0.844[a]	0.821[b]	NS	0.0038	Y=0.978-0.019X
21-42	0.704	0.708	0.700	0.708	0.707	0.700	NS	0.0023	-
42-63	0.572	0.570	0.568	0.567	0.597[a]	0.542[b]	NS	0.0031	-
63-84	0.408	0.415	0.421	0.409	0.439[a]	0.388[b]	0.0306	0.0035	-
84-105	0.304	0.291	0.284	0.316	0.316[a]	0.281[b]	NS	0.0037	$Y=0.691-0.045X+0.001X^2$
105-126	0.249	0.254	0.268	0.249	0.286[a]	0.224[b]	NS	0.0044	-
10-84	0.678[a]	0.681[a]	0.669[ab]	0.643[b]	0.678[a]	0.657[b]	NS	0.0050	Y = 0.474+0.026X
10-105	0.516	0.520	0.511	0.517	0.540[a]	0.492[b]	0.0104	0.0035	-
10-126	0.399	0.401	0.407	0.416	0.427[a]	0.384[b]	0.0403	0.0026	-

[a,b,c] Means with common letters within a main effect do not differ significantly (P≤0.05).
[1] $G:F^{m}$ = (final period weight + kg of mortality weight - initial period weight)/period feed consumption.
[2] Means represent the average response of four replicate rooms each containing three pens of males (20 birds) or three pens of females (30 birds)/daylength treatment.
[3] Means represent the average response of 48 pens of males (20 birds/pen) or 48 pens of females (30 birds/pen).
[4] Pooled standard error of the mean.
[5] Regression considered significant if P≤0.05.

Table 3.9. Effect of daylength (h) and gender on gain to feed ratio (g/g) without mortality correction (G:F)[1] of meat turkeys from 10 to 126 d of age

	Daylength[2] (L)				Gender[3] (G)				
Age (d)	14	17	20	23	Male	Female	L x G	SEM[4]	Regression Equation[5]
10-21	0.818	0.820	0.819	0.844	0.833[a]	0.817[b]	NS	0.0037	Y=0.991-0.021X
21-42	0.702	0.706	0.700	0.703	0.705	0.700	NS	0.0024	-
42-63	0.567[a]	0.554[b]	0.562[ab]	0.553[b]	0.580[a]	0.538[b]	NS	0.0031	-
63-84	0.371	0.393	0.383	0.353	0.387[a]	0.363[b]	NS	0.0055	$Y=-0.058+0.051X-0.001X^2$
84-105	0.114	0.098	0.114	0.090	0.067[b]	0.142[a]	NS	0.0072	-
105-126	0.220	0.232	0.208	0.201	0.223	0.207	NS	0.0066	-
10-84	0.497	0.507	0.506	0.494	0.514[a]	0.488[b]	NS	0.0028	-
10-105	0.371	0.374	0.381	0.372	0.371	0.378	NS	0.0023	-
10-126	0.335	0.340	0.342	0.336	0.336	0.339	NS	0.0020	-

[a,b,c] Means with common letters within a main effect do not differ significantly (P≤0.05).
[1] G:F = (final period weight – initial period weight)/period feed consumption.
[2] Means represent the average response of four replicate rooms each containing three pens of males (20 birds) or three pens of females (30 birds)/daylength treatment.
[3] Means represent the average response of 48 pens of males (20 birds/pen) or 48 pens of females (30 birds/pen).
[4] Pooled standard error of the mean.
[5] Regression considered significant if P≤0.05.

3.4.4 Mortality and Morbidity

Daylength did not affect the incidence of mortality and morbidity except for the periods of 84-105 d, 10-105 d and 10-126 d (Table 3.10). For the latter periods, values responded in a quadratic fashion with increasing daylength. For the 84-105 d period, the lowest mortality was found for the 20L treatment, while for both the 10-105 d and 10-126 d periods, mortality increased with increasing daylength with the highest value for the 23L treatment. Although not significant it is worth noting that for the 10-84 d period mortality was approximately three percent higher for 23L treatment compared to other treatments. Males exhibited higher mortality and morbidity than females for all time periods. No interactions were found between daylength and gender.

Heart, infectious, unknown and other categories of mortality or culling were not affected by daylength (Table 3.11). Skeletal losses increased linearly with increasing daylength, while injurious pecking decreased with increasing daylength. An interaction between daylength and gender occurred for pendulous crop (Table 3.12) with the male incidence unaffected by daylength, but the incidence in 23L females was higher than other lighting treatments. When total mortality is divided into percentage of cull and dead birds a quadratic response is observed for culled birds with the highest incidence for 23L. The majority of these culls were due to skeletal issues and pendulous crops. Daylength did not affect the number of birds that died during this experiment. For the majority of the causes of mortality and morbidity, with the exception of pendulous crop, unknown and other categories, males had higher values.

Table 3.10. Effect of daylength (h) and gender on mortality (%) of meat turkeys from 10 to 126 d of age

	Daylength[1] (L)				Gender[2] (G)				
Age (d)	14	17	20	23	Male	Female	L x G	SEM[3]	Regression Equation[4]
10-21	1.18	1.32	1.74	1.83	1.99	1.04	NS	0.309	-
21-42	0.56	0.86	0.28	1.07	0.75	0.64	NS	0.181	-
42-63	0.87	2.00	0.82	1.57	2.20[a]	0.43[b]	NS	0.251	-
63-84	4.11	2.47	3.99	5.28	5.23[a]	2.70[b]	NS	0.451	-
84-105	4.18	3.29	1.43	4.30	4.72[a]	1.89[b]	NS	0.437	$Y = 38.90-3.93X+0.10X^2$
105-126	2.17	1.72	4.34	3.63	4.67[a]	1.26[b]	NS	0.476	-
10-84	6.75	6.92	6.75	9.95	10.15[a]	5.03[b]	NS	0.652	-
10-105	10.57	9.90	8.07	13.98	14.42[a]	6.84[b]	NS	0.761	$Y = 65.87-6.47X+0.18X^2$
10-126	12.30	10.76	11.26	16.12	17.63[a]	7.60[b]	NS	0.814	$Y = 64.09-6.18X+0.18X^2$

[a,b,c] Means with common letters within a main effect do not differ significantly ($P \leq 0.05$).

[1] Means represent the average response of four replicate rooms each containing three pens of males (20 birds) or three pens of females (30 birds)/daylength treatment.

[2] Means represent the average response of 48 pens of males (20 birds/pen) or 48 pens of females (30 birds/pen).

[3] Pooled standard error of the mean.

[4] Regression considered significant if $P \leq 0.05$.

Table 3.11. Effect of daylength (h) and gender on causes of mortality of meat turkeys from 10 to 126 d of age

	Daylength[1] (L)				Gender[2] (G)				
Cause (%)	14	17	20	23	Male	Female	L x G	SEM[3]	Regression Equation[4]
Heart[5]	0.76	1.53	0.83	1.67	1.98[a]	0.42[b]	NS	0.235	-
Skeletal[6]	4.44[ab]	2.92[b]	5.14[ab]	6.62[a]	7.82[a]	1.74[b]	NS	0.513	Y = 26.99-2.79X
Infectious[7]	2.08	1.04	0.90	1.82	2.30[a]	0.63[b]	NS	0.304	-
Pendulous crop	1.18[b]	1.11[b]	1.53[b]	3.49[a]	0.94[b]	2.72[a]	0.0309	0.268	-
Injurious pecking	2.37	1.60	0.90	0.14	1.88[a]	0.63[b]	NS	0.262	Y = 5.93-0.26X
Unknown[8]	0.76	1.60	1.18	0.83	1.56	0.63	NS	0.263	-
Other[9]	0.69	0.97	0.76	1.55	1.16	0.84	NS	0.227	-
Total	12.30	10.76	11.26	16.12	17.63[a]	7.60[b]	NS	0.814	$Y = 64.09-6.18X+0.18X^2$
Cull Total	9.45	7.43	8.97	13.21	13.46[a]	6.07[b]	NS	0.697	$Y = 59.46-6.01X+0.17X^2$
Dead Total	2.85	3.33	2.29	2.92	4.17[a]	1.53[b]	NS	0.405	-

[a,b,c] Means with common letters within a main effect do not differ significantly (P≤0.05).
[1] Means represent the average response of four replicate rooms each containing three pens of males (20 birds) or three pens of females (30 birds)/daylength treatment.
[2] Means represent the average response of 48 pens of males (20 birds/pen) or 48 pens of females (30 birds/pen).
[3] Pooled standard error of the mean.
[4] Regression considered significant if P≤0.05.
[5] Heart – right ventricle heart disease, perirenal hemorrhage, aortic rupture, cardiomyopathy, ascites, round heart.
[6] Skeletal – valgus-varus, broken wing, rotated tibia, muscular hemorrhage, leg fracture, tibial dyschondroplasia.
[7] Infectious – arthritis, pericarditis, bursitis, airsacculitis, peritonitis, hepatic necrosis, tendonitis, polyserositis, cellulitis, runt.
[8] Unknown – no visible lesions.
[9] Other – impacted gastrointestinal tract, accidental death.

Table 3.12. The interaction effects between daylength and gender on the incidence of pendulous crop

	Age or Period	Gender[1] (G)	Daylength[2] (h)				Regression Equation[3]
			14	17	20	23	
Pendulous crop, %	10-126 d	M	1.25^{bc}	0^{c}	0.83^{bc}	1.67^{bc}	-
	10-126 d	F	1.11^{bc}	2.22^{b}	2.23^{b}	5.32^{a}	Y = 13.08-1.61X

[a,b,c] Means with common letters within a main effect do not differ significantly ($P \leq 0.05$).
[1] Means represent the average response of 48 pens of males (20 birds/pen) or 48 pens of females (30 birds/pen).
[2] Means represent the average response of four replicate rooms each containing three pens of males (20 birds) or three pens of females (30 birds)/daylength treatment.
[3] Regression considered significant if $P \leq 0.05$.

3.5 Discussion and Conclusion

The effect of daylength on turkey growth rate has often been suggested to be related to access to feed; therefore longer daylengths with increased access should result in increased growth (Auckland et al., 1973; Siopes et al., 1989; Lewis et al., 1998). In the current study, this was found to be the case with the first 42 d of the trial with birds exposed to longer daylengths weighing and eating more than birds given shorter daylengths. However, as birds reached older ages, at 84 d and onward for toms and beyond 105 d for hens, higher body weight and corresponding feed consumption were found for birds given shorter daylengths. A portion of this change in daylength effect may relate to birds adapting eating behaviour to a shorter period of feed access. Turkeys are diurnal in nature and under usual circumstances eat during the day (Chapter 4). Therefore, the introduction of a longer dark period initially reduces feed intake. With time after switching to shorter days, birds anticipate the lights going on and off (May and Lott, 1994) and learn to eat more during a shorter time. A portion of the adaptation is increased feeding in anticipation of the dark period and increased crop storage to provide feed for the scotoperiod (Cutler et al., 2005). The adaptation to shorter daylength and compensatory gains seen in the present study are similar to previous reports (Siopes et al., 1986; Classen et al., 1994).

It seems counterintuitive that turkeys would eat more feed and gain more weight, which was evident for shorter daylength treatments in the current study. The higher feed consumption for shorter daylength is more likely a reflection of decreased feed intake for turkeys on long daylengths than a direct effect of shorter days. The decrease in feed consumption on longer daylengths could be due to decreased mobility and as a consequence feeding. The concept is supported by reduced gait scores and walking behaviour for 11 and 17 wk turkeys exposed to long in contrast to shorter days (Chapter 4). Similarly, Weeks et al. (2000) saw altered feeding behaviour in lame (GS 3) broiler chickens with fewer visits to the feeder in 24 h period (30 versus 50 by sound birds). These observations suggest that birds on longer daylengths are experiencing a degree of pain. In agreement, research using analgesics has demonstrated a strong correlation between lameness and pain in turkeys (Duncan et al., 1991; Buchwalder and Huber-Eicher, 2005) and broiler chickens (Danbury et al., 2000). Therefore, decreased productivity on longer daylengths noted in the current study is an indirect indicator of poor bird health and welfare.

The effect of daylength on growth was also found to be affected by gender. Although both toms and hens were negatively affected by long daylength at 126 d of age, this trend was observed for toms at 84 d of age. Gender differences between weight and daylength responses may be due to differences in growth curves. Hens grew at a slower rate in comparison to toms, which have a steeper curve slope and weighed more at 18 wk of age. Furthermore, differences may be due to mobility with toms exhibiting poorer mobility seen with higher incidences of skeletal abnormalities and gait scores (Chapter 4) at 11 and 17 wk of age on longer daylengths. This poor mobility associated with longer daylengths may affect the ability of males to walk to the feeder and consequently reduce growth rate.

Schwean-Lardner et al. (2012b) examined graded daylength (14, 17, 20 and 23 h) response on production parameters in broiler chickens and like the current turkey work, the effect of daylength on body weight and feed intake was age dependent. In the broiler work, the response was quadratic at all ages with maximal body weight being achieved with shorter daylength at older ages. Therefore, despite different response patterns (quadratic vs linear), the ability of birds to compensate for initially slower growth was seen in both species. Lower broiler body weights for the 23L treatment and a corresponding reduction in feed intake, were hypothesized to be at least partially due to pain and/or leg weakness seen in higher levels for this treatment (Schwean-Lardner et al., 2013). Schwean-Lardner et al. (2012a) also suggested sleep deprivation as a result of disruptions in melatonin and other circadian rhythms may also affect feed intake and feed efficiency.

The effect of daylength on $G:F^m$ was affected by bird age. From d 10 to 84 of age, shorter daylengths improved feed efficiency for both males and females. In contrast, from 10 to 126 d of age, longer daylengths resulted in better feed efficiency for females and a similar trend was seen for males (P=0.06). The change in response due to age may be related to decreased activity observed in 23 h birds (Chapter 4) and the resulting reduction in feed required for maintenance. Similarly, Hester et al. (1985) speculated that increased efficiency associated with longer photoperiods was due to decreased bird activity. Other studies have also illustrated better feed efficiency (no mortality correction) on 23 h daylength in turkey toms in comparison to shorter daylengths, (14 h - Auckland, 1973; 8 h - Siopes et al., 1989; 8, 12 and 16 h - Lewis et al., 1998). The latter two studies speculated that the improvement in feed efficiency was due to increasing sexually maturation in turkeys on the 23 h daylength. As toms approach sexual maturity, enhanced androgen production lowers fat production and in turn feed consumption, which could account for increased efficiency (Siopes et al., 1989). In the present study, proportional testicle weight was higher for 23L (0.17%) than 14L birds (0.09%) and abdominal fat pad was lower (1.84%) for 23L than 14L (2.17%) turkeys at 126 d of age, which is supportive of this mechanism (unpublished data). Similarly, other turkey studies have found increased testicular weight (Siopes et al., 1989; Lewis et al., 1998) and plasma testosterone (Classen et al., 1994) in toms given 23 h light treatments compared to birds exposed to shorter daylengths.

When feed efficiency was not corrected for mortality, differences between lighting programs were minimal. This is related to the incidence of mortality and culling among light treatments and in particular the higher levels for the 23L treatment. Death loss during the current research was generally quite low (range 2.85 to 3.33%), but the incidence of culling was high and affected by daylength. When mortality and culling are combined, the incidence was numerically (10-84 d) or significantly higher (10-105 d, 10-126 d) for the 23L treatment. Other studies have illustrated similar results (Classen et al., 1994; Lewis et al., 1998). Skeletal causes of mortality and culling in the current study were responsible for a large portion of the increased overall losses for the 23L treatment.

The majority of skeletal causes of mortality were culls, which were classified as valgus-varus and rotated tibia. In agreement with the higher loss percentages for the 23L treatments, these birds also exhibited poorer mobility as shown by higher average gait scores and decreased walking behaviour (Chapter 4). Increased skeletal abnormalities and poor mobility associated with longer daylengths are in agreement with previous turkey (Hester et al., 1983; Classen et al., 1994) and broiler chicken studies (Classen and Riddell, 1989; Schwean-Lardner et al., 2013). Rapid growth rates early in a bird's life can be detrimental to skeletal health (Williams et al., 2004) with the slowing of early growth being beneficial (Hester et al., 1983; Newberry, 1992; Classen et al., 1994; Schwean-Lardner et al., 2012b). This study demonstrated that shorter daylengths starting at an early age were effective at decreasing growth for the first 42 d and later resulted in compensatory gains. Birds were more active over 24 h period as observed behaviourally at 11 and 17 wk of age (Chapter 4) for shorter daylength and may help explain the decrease in skeletal abnormalities. It has been proposed that exercise has a beneficial effect on bone development (Reiter and Bessei, 1995). Nonetheless, the cause and effect relationship of exercise and improved bone development is inconsistent between studies (Reiter and Bessei, 1995; Sherlock et al., 2010). Hence, the cause of skeletal abnormalities is complex and has a multifactorial nature making it difficult to determine pathology.

The second major reason for increased mortality and morbidity in 23L birds was the incidence of pendulous crops (1 to 4%). In this case the daylength effect was on females only. It is possible that the increase in pendulous crop in 23L treatment birds is due to reduced crop use and as a result crop health (Classen et al., 2015). As noted previously, as birds adapt to periods of darkness, they increase feeding and crop utilization before the end of the day. This promotes fermentation in the crop and a healthier environment (Cutler et al., 2005). Why females are more susceptible to pendulous crop is not obvious, but gender differences to eating behavior may be responsible. Although not quantified, it was apparent when observing behavioural repertoire (Chapter 4) that females were social eaters, eating more frequently than males. If males ate less frequently, it may induce more crop storage, and in turn promotion of crop health. Fewer visits to the feeder by males could be due to constraints on mobility or lack of socially facilitated feeding behaviour (Vallortigara et al., 1990). Further research needs to be conducted in this area to confirm the lighting effect and determine the definitive cause of observed gender differences.

Injurious pecking decreased in a linear fashion with increasing daylength. Although beneficial in terms of mortality, the mechanism whereby this effect is mediated may rule it out as a control method for this vice. The causes of injurious pecking are considered to be multifactorial in nature, being influenced by genetics, the environment and nutrition (Dalton et al., 2013). However, the observed decrease in incidence associated with increasing daylength is most likely related to decreased mobility (Chapter 4) with birds having difficulties getting up and walking and consequently less able to perform this as well as other behaviors. Additionally, birds on longer daylengths could be experiencing sleep deprivation (Schwean-Lardner et al., 2014). Schwean-Lardner et al. (2014) found that broiler chickens on 23 h of light lacked synchronized melatonin and behavioural circadian rhythms and suggested a consequence was sleep fragmentation due to active birds disrupting other birds that were resting. These birds were lethargic and lacked responsiveness to human presence. Based on this research, turkeys given long daylength may be fatigued and lack the motivation and awareness of their surroundings to perform injurious pecking.

In conclusion, daylength affects turkey productivity in an age and gender dependent manner. At young ages, growth rate increased with increasing daylength, but this effect was reversed in older birds, with the reversal occurring sooner in males (84 d) than females, both males and females showing the effect by 126 d. With mortality correction, feed efficiency decreased in a linear fashion with daylength during early growth (10-84 d), but was reversed in pattern over the 10 to 126 d period. Without correction for mortality and culling, feed efficiency was not affected by daylength. Mortality and culling levels were higher for the 23L treatment over the 10-84, 10-105 and 10-126 d periods, although only significantly so for the latter two periods. Therefore, shorter daylength treatments had beneficial effects on older birds and had a more pronounced effect on males.

4.0 THE IMPACT OF GRADED LEVELS OF DAYLENGTH ON TURKEY HEALTH AND BEHAVIOUR TO 18 WK OF AGE

4.1 Abstract

The impact of graded levels of daylength on turkey health and behaviour were determined in hens and toms raised to 18 wk of age. Birds were allocated to one of four lighting treatments (trts) providing 14 (14L), 17 (17L), 20 (20L) and 23 (23L) h of daylength. Two experiments were completed with each providing 2 rooms per lighting trt and each room having 3 hen and 3 tom pens. Data collection included gait score (GS), the incidence of foot pad dermatitis (FPD), breast buttons and breast blisters, ocular size and pressure and behavioural observations. Data were analyzed using SAS 9.3 based on a completely randomized design nested within four lighting trts (no significant block effect). Regression analysis established relationships between response criteria and daylength. Differences were considered significant at $P \leq 0.05$ and trends noted at $P \leq 0.10$. Gait score, FPD and the incidence of breast buttons and blisters were assessed on 5 birds per pen at 11 and 17 wk of age. Average GS increased linearly with daylength at 11 and 17 wk for both hens and toms, but the effect was larger in toms. Daylength did not affect FPD, but more lesions and more severe scores were found for hens than toms. The presence of breast buttons and blisters increased linearly with daylength (11 wk) with the effect on blisters predominately seen in toms. Eye weight increased and corneal diameter decreased linearly with increasing daylength at 12 and 18 wk. Dorso-ventral and media-lateral diameter, and anterior to posterior depth exhibited a quadratic relationship with the highest values seen for the 23L trt. Ocular pressure was not affected by daylength. Infrared cameras recorded tom behaviour over a 24 h period and behaviours were classified over 10 min intervals using a scan sampling technique at 11 and 17 wk. Alterations in behavioural repertoire were

observed during the photoperiod with a linear increase in inactive resting and a linear decrease in feeding, drinking, standing, walking, preening, and environmental and feather pecking behaviours with increased daylength. To conclude, daylength effects mobility and incidence of breast blisters in an age and gender specific manner, and time spend inactive increased with longer daylength.

Keywords: photoperiod, gait score, breast blisters, footpad, eye size, behaviour

4.2 Introduction

Daylength is an important and easily implemented management tool in the poultry industry. Daylength has biological and physiological significance via the regulation of circadian rhythms (Zawilska et al., 2006, 2007; Schwean-Lardner et al., 2014), and providing periods of rest and regeneration (Malleau et al., 2007), among other effects. It also affects poultry production including growth, feed efficiency and bird health (Newberry, 1992; Classen et al., 1994; Lewis et al., 1998; Chapter 3). Daylength can also influence factors that affect bird welfare including the incidence of skeletal abnormalities (Hester et al., 1983, 1986; Classen et al., 1994; Schwean-Lardner et al., 2013), bird behaviour (Sherwin et al., 1999; Schwean-Lardner et al., 2012a) and eye health (Ashton et al., 1973; Whitley et al., 1984; Davis et al., 1986).

The benefits of short daylength (darkness) on skeletal well-being has been well documented for broiler chickens (Classen and Riddell, 1989; Sørensen et al., 1999; Schwean-Lardner et al., 2013) and turkeys (Hester et al., 1983; Classen et al., 1994). It is difficult to define the exact reason for the improvement in skeletal condition because of the difficulty of separating potential contributing mechanisms. However, decreased early growth (Classen et al., 1994), increased activity (exercise; Hester et al., 1983), and improved bone modelling due to changes in bird metabolism and rejuvenation that occur during the scotoperiod (Classen and Riddell, 1990; Schwean-Lardner et al., 2013) have all been projected as beneficial mechanisms.

Birds with poor mobility are reluctant to move because of lameness and associated pain (Danbury et al., 2000; Duncan et al., 1991; Buchwalder and Huber-Eicher, 2005). Strong evidence that these birds are experiencing pain come from the work showing an increase in mobility of poorly mobile birds via administration of analgesics (Duncan, 1991; Buchwalder and Huber-Eicher, 2005). Furthermore, if poorly mobile birds are given a choice, they will self-select feeds containing an analgesic (Danbury et al., 2000), suggesting their awareness of and need to relieve pain. Bird mobility is assessed through gait scores (Kestin et al., 1999; Garner et al., 2002) with studies finding high gait scores (poor mobility) on longer daylengths (Classen et al., 1994; Schwean-Lardner et al., 2013). Consequently, skeletal abnormalities have obvious welfare implications with associated pain and lameness and can be effectively decreased by the use of shorter daylengths.

Behavioural observations can be used to assess mobility and other aspects of bird well-being. Weeks et al. (2000) demonstrated broiler chickens experiencing lameness (GS 3 or higher), spent more time lying down (86%) compared to sound birds (76%). In regards to lighting, longer daylengths decrease turkey activity in comparison to other lighting programs (Hester et al., 1985; Classen et al., 1994). Hester et al. (1985) demonstrated that toms are more active in a step-up versus a step-down lighting program with a greater percentage of time spent eating, drinking, standing and walking. Classen et al. (1994) also observed toms to be more active in increasing and decreasing treatments in comparison to a 24 h daylength treatment. Similarly, Schwean-Lardner and colleagues (2012a) observed decreased mobility (standing, walking), nutritive (eating) and comfort behaviours (preening, dustbathing, litter pecking, leg and wing stretching) and consequently an increase in inactivity on longer daylengths in broiler chickens. Decreased activity seen in the latter research was speculated to be the result of decreased mobility (discussed above), and/or sleep deprivation. Birds can experience sleep deprivation as a result of unsynchronized flock circadian rhythms (Schwean-Lardner et al., 2014). In conclusion, behavioural observations can be a valuable tool to assess a number of aspects of bird welfare.

Additional welfare concerns arise with poorly mobile birds sitting more, increasing their litter contact time and hence prevalence of skin lesions, such as breast blisters and footpad dermatitis (FPD; Bessei, 2006). Although FPD has a multifactorial nature (Mayne, 2005), lighting programs are influential with an increased incidence occurring in broilers exposed to longer daylengths (Schwean-Lardner et al., 2013), possibly due to decreased mobility and hence increased resting. Unlike broiler chickens, no turkey studies have been conducted examining the relationship between FPD and daylength. It is suspected that longer periods of rest experienced on longer daylengths predispose birds to pathological changes in skin integrity (Krautwald-Junghanns et al., 2011). Histopathology of foot pad lesions reveals hyperkeratosis, inflammation, and necrosis of *stratum germinativum* (deepest layer of dermis), resulting in ulceration, scab formation and dermal inflammation (Martland, 1984). Consequently, pain is likely associated with FPD and in turn a depression in growth rate due to affected bird's reluctance to walk to the feeder (Martland, 1984). Therefore, the potential increased prevalence of FPD in longer daylengths warrants examination in turkeys.

Similar to FPD, breast buttons and blisters accompany poor mobility due to increased litter contact time. Their causation is speculated to be multifactorial in nature and consequently difficult to determine. The suggested influential factors include body weight (Gonder and

Barnes, 1986), and litter moisture and management practices (Mitterer-Istyagin et al., 2011). Daylength has been shown to affect breast blisters, with fewer breast blisters for turkeys given an increasing photoperiod versus 23 h daylength (Newberry, 1992). Research on pain assessment in relation to blisters in birds appears to be lacking.

Daylength can have profound effects on ocular health. Turkeys kept in constant or near continuous lighting programs exhibit increased eye weights, enlarged eye size, corneal flattening and thinning of the retina and choroid (Ashton et al., 1973; Davis et al., 1986). These abnormalities may cause glaucoma and/or increased intraocular pressure (IOP) as a result of the size of the globe or eyeball reaching its elastic limit (Whitley et al., 1984). The ultimate outcome of this increased IOP is blindness as a consequence of retinal detachment. Similar to turkeys, broiler chickens also exhibit increased eye weight in near continuous lighting programs (Schwean-Lardner et al., 2013), which may be linked to increased eye growth as a result of reduced or eliminated circadian rhythms (Lewis and Gous, 2009). Hence, eye abnormalities are a welfare concern with birds potentially incapable of perceiving their surroundings in later stages of pathology development.

Lighting studies clearly illustrate that near continuous lighting programs exhibit many health and welfare concerns, including the increased incidence of leg abnormalities, increased inactivity, increased prevalence of FPD and breast blisters, and decreased ocular health. These issues appear contrary to the fact that continuous lighting programs are still commonly used in the industry for meat producing birds. Thus, increased hours of darkness could have beneficial effects on turkey health and welfare. Unlike previous studies, this research will take a systematic approach to assess welfare measures in relation to graded levels of daylength. The objective of this study was to determine the impact of graded levels of daylength on the health and behaviour of male and female meat turkeys.

4.3 Materials and Methods

All experimental procedures followed the Guide to the Care and Use of Experimental Animals (Canadian Council of Animal Care, 1993) and were approved by the University of Saskatchewan Animal Care Committee.

4.3.1 Experimental Design

Two 18 wk trials were conducted in November of sequential years to study the effect of daylength, gender and their interaction on health and behaviour parameters of hens and toms. Four lighting programs were implemented 14L:10D (14L), 17L:7D (17L), 20L:4D (20L) and 23L:1D (23L) at 10 d of age and maintained to 18 wk of age. Nicholas heavy strain (85 x 700) poults were obtained from a commercial hatchery (beak and toe treated) and randomly allocated to experimental rooms. A total of 480 males and 720 females were randomly placed in eight identical rooms (12.19 x 7.01 m) for each trial. Two room replicates per lighting program were used for each trial, thereby providing four replications over the two trials. Each room contained six pens (2.3 x 4.0 m), with sexes housed separately (three male and three female pens per room).

For first 5 d of the experiment, poults received 23L:1D (room lighting) and then daylength was gradually reduced in a step-wise fashion (equal hours each day) to treatment specification by d 10. Heat lamps, which were hung above brooder rings, effectively provide 24 h of light per d during this time. Light was provided by a 100 W incandescent light bulb above the centre of each pen. A light meter (Lutron LX 101 Lux Meter, Acklands-Grainger, Inc., ON) was used to measure light intensity in the centre of the middle pen in each room at bird height at the time of poult placement, at lighting program initiation and every three wk thereafter. Refer to Chapter 3 for light intensity changes for both trials (Table 3.1). Light intensity was decreased to 2 lux during the trial to reduce injurious pecking. All lighting programs had 15 min simulated dawn and dusk periods included in their designated photoperiod. Initially, pens contained 20 males and 30 females respectively, with three birds per pen being removed at 12 wk of age for meat yield determination (unpublished data). An estimated final stocking density of 35 kg/m^2 was targeted based on Nicholas performance objectives (Aviagen, 2011b).

4.3.2 Housing & Management

A negative pressure ventilation system was utilized in all of the rooms. Room temperature was thermostatically controlled and heat was supplied by hot water pipes (84 cm from floor) along three of the four walls. Room temperature was 35°C on d 0 and gradually reduced until it was 13°C at 13 wk of age, where it remained for the duration of the trial. Feed and water were provided *ad libitum*. A six phase feeding program based on Nicholas nutritional guidelines (Aviagen, 2011c) was provided by a commercial feed company (Chapter 3, Table 3.2). Feed was provided in two aluminum tube feeders per pen with a diameter of 36 cm from day 0 to 42 and 44 cm thereafter. Form and amounts of feed provided for hens and toms are shown in Chapter 3, Table 3.3. Lubing EasyLine™ pendulum nipple drinkers (Lubing, Cleveland, TN) provided water with three drinking cups per pen. Brooding balls were utilized to raise water level for first wk. Poults were raised on wood shavings with a wheat straw bedding base (approximately 7.5-10 cm thick) in brooding rings for the first 10 d. As the trial progressed pens were re-bedded as necessary with straw.

4.3.3 Data Collection

Gait score (GS). Gait score was used to assess bird mobility at 11 and 17 wk of age utilizing a broiler technique (Garner et al., 2002) slightly modified for turkeys (Table 4.1). Gait scores were determined on five birds per pen by two scorers with the final score based on consensus. Birds were randomly selected, separated from pen mates and walked down a straw covered pathway in the pen. In brief, the technique scores birds on a six point scale of 0 to 5, where 0 represents no abnormality in gait and 5 represents a complete loss of mobility. Data were expressed as an average GS and as a percentage within each score and the sum of scores 3, 4 and 5.

Table 4.1. Gait score (GS) descriptions (modifications + Garner et al., 2002)

GS	Degree of Impairment		Description
0	None	Original	Smooth, fluid locomotion. The foot is furled while raised.
		Modified	Straight legs.
1	Detectable, but unidentifiable abnormality	Original	The bird is unsteady, or wobbles when it walks. However, the problem leg is unclear, or cannot be identified in the first 20s of observation. The bird readily runs from the observer in the pen. The foot may remain flat when raised, but the rest of the stride is fluid and appears unimpaired.
		Modified	Gait appears unstable (shaky or stomping).
2	Identifiable abnormality, that has little impact on overall function	Original	The leg producing the gait defect can be identified within 20 s of observation. If a problem leg is identified after 20 s of observed locomotor behaviour then the bird is classed as gait score 1. However, the defect seems to have only a minor impact on biological function. Thus the bird will run from the observer spontaneously or if touched or nudged with the padded stick. If the bird does not run at full speed, it runs, walks or remains standing for at least 15 s after the observer in the pen has ceased to move towards or nudge it. Birds in this, and previous, scores are often observed to scratch their face with their feet-again indicating little impact on function. (The most common abnormality in this score is for the bird to make short, quick, unsteady steps with one leg, where the foot remains flat during the step.)
3	Identifiable abnormality which impairs function	Original	Although the bird will move away from the observer when approached or touched, or nudged, it will not run, and squats within 15 s or less of the observer in the pen ceasing to approach or nudge it. If the bird squats after 15 s have elapsed it is classified as gait score 2.
4	Severe impairment of function, but still capable of walking	Original	The bird remains squatting when approached or nudged. This criterion is assessed by approaching the bird, and if it remains squatting, gently nudging or touching the animal for 5 s. Animals may appear to rise but still resting upon their hocks. Only rising to stand on both feet within 5 s of handling is counted—a bird which takes longer than 5 s to rise, or which does not rise at all is scored as 4, while a bird that rises in 5 s or less is counted as a 3 (or lower if its gait is good). Nevertheless, the bird can walk when picked up by the observer and placed in a standing position, but squats immediately following one or two steps. (Squatting often involves a characteristic ungainly backwards fall.)
		Modified	Bird requires wings for balance.
5	Complete lameness	Original	The bird cannot walk, and instead may shuffle along on its hocks. It may attempt to stand when approached but is unable to do so, and when placed on feet unable to complete a step with one or both legs.

Footpad dermatitis (FPD) and breast blisters. Footpad lesions were scored according to the procedure of Hocking et al. (2008) (Table 4.2) at 11 and 17 wk of age on the same five birds per pen used for GS. Data was collected from different birds at 11 and 17 wk of age. In brief, the left footpad was washed and scored on a five point scale of 0 to 4, with 0 representing no swelling or necrosis and 4 representing more than half of footpad covered by necrotic cells. Data were expressed as an average footpad score (FPS) and as a percentage within each score. Additionally, the presence of a breast buttons or blisters was recorded at 11 and 17 wk of age on the same five birds per pen.

Table 4.2. Footpad scoring technique (Hocking et al., 2008)

Score	Description of Footpad
0	No external signs of footpad dermatitis. The skin of the footpad feels soft to the touch and no swelling or necrosis is evident.
1	The pad feels harder and denser than a non-affected foot. The central part of the pad is raised, reticulate scales are separated and small black necrotic areas may be present.
2	Marked swelling of the footpad. Reticulate scales are black, forming scale shaped necrotic areas. The scales around the outside of the black areas may have turned white. The area of necrosis is less than one quarter of the total area of the footpad.
3	Swelling is evident and the total footpad size is enlarged. Reticulate scales are pronounced, increased in number and separated from each other. The amount of necrosis extends to one half of the footpad.
4	As score 3, but with more than half the footpad covered by necrotic cells.

Eye measures and ocular pressure. At 12 and 18 wk of age, three males and three females per pen (different birds for two age groups) were stunned using an electrical charge (VS 200 stunner knife, Midwest Processing System, Edina, MN) and then killed by exsanguination. Left eyes were removed and weight and dimensions (corneal diameter, medio-lateral (ML) diameter, dorso-ventral (DV) diameter (Figure 4,1) and anterior-posterior (AP) depth) were determined using digital calipers. Anterior-posterior depth (not illustrated in Figure 4.1) was measured from the back of the eye, where the optic nerve is located to the front of the cornea. Intraocular pressure (IOP) was measured for three males per pen at 9, 12, 15 and 18 wk of age. Pressure was measured three times on both eyes with a TonoVet® Tonometer (TV01, icare, Finland) and averaged for each eye.

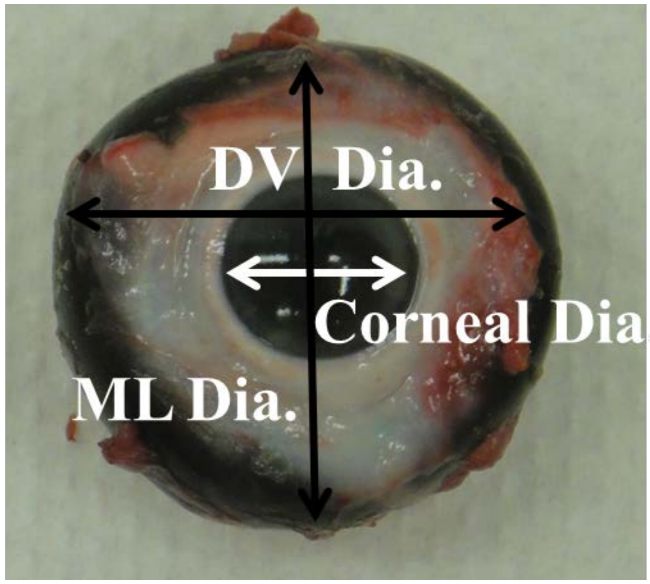

Figure 4.1. Locations of corneal diameter, and medio-lateral (ML) and dorso-ventral (DV) diameters.

Behavioural observations. Bird behaviour was recorded continuously for a 24 h period at 11 and 17 wk of age using an infrared camera (WZ45 Integrated IR Dome Camera, Bosch Security System, Inc., Fairport, NY) mounted to the ceiling above one male pen per room. The camera was able to capture the entire area of the pen. A scan sampling technique was used to analyze video data (Genetec Omnicast Live Viewer 3.5, Genetec Inc., Montreal, QC). The behavioural expression of each bird in the pen was determined every 10 min in a 24 h period (24 h x 6 measurements per h). The video frame was frozen and individual behaviours were counted. For active behaviours, the frame was moved two sec before and after the selected frame. Mutually exclusive behaviours assessed are described in Table 4.3. Data were expressed as a percentage of time performing behaviours over the entire 24 h period as well as the photo and scoto-periods.

Table 4.3. Behaviours defined.

Behaviour	Definition
Resting	Lying down not performing any other behaviours, may be sleeping
Walking	
Standing	
Feeding	Standing or sitting with head in feeder
Drinking	Standing or sitting with head in drinker
Preening	Manipulating feathers while standing or sitting
Stretching	Extension of wings and/or legs
Environmental pecking	Pecking walls, cage or litter while standing or sitting
Feather pecking	Pecking pen mates feathers while standing or sitting
Aggression	Forceful pecking at a pen mates head, body or snood while standing or sitting, victim usually moves
Strutting	Standing or walking slowly with feathers erect and breast thrust forward
Other	Other behaviours performed at a low frequency (i.e. dustbathing, scratching, feather ruffle, wing flapping)

4.3.4 Statistical Analysis

The main effects of light and gender and their interaction were analysed using Proc Mixed of SAS (SAS 9.3., Cary, NC) as a completely randomized design (CRD) nested within four lighting programmes. Block (trial) was not significant and therefore not included in model. The experimental model was $Y = \mu + L + G + L(R) + L*G + e$, where

Y is the observation from dependent variable,

μ is the population mean of variable,

L is the light effect (fixed)

G is the gender effect (fixed),

R is the room,

L*G is the interaction effect between light and gender,

and e is the random error associated with observations.

Behaviour and intraocular pressure data were analyzed using a completely randomized design with light as main factor. The DDFM Satterthwaite option was used for approximating the degrees of freedom for means and paired difference test was used for multi-treatment comparison. Percentage data were log transformed (log+1) prior to analysis as it was not normally distributed using Proc Univariate. Proc Reg (Regression) and Proc RS Reg (Response Surface Regression) were used to study relationships between dependent variables and daylength. Significance was declared at $P \leq 0.05$ and trends were noted when $P \leq 0.10$.

4.4 Results

4.4.1 Mobility

Gait score (GS). At 11 wk of age, the percent of birds in GS 0 decreased linearly with daylength, while the percent of birds in GS 2, GS 4 and GS 3+4+5, and the average GS increased with increasing daylength (Table 4.4). The proportion of birds in GS 3 tended to increase with increasing daylength (P=0.09). Interactions between daylength and gender were noted (Table 4.6) for GS 3, GS 4, GS 3+4+5, and average GS. Gait score 3+4+5 increased linearly in males with increasing daylength, but no trends were found in females because birds with these scores were almost absent. Both male and female average GS responded linearly, values increasing with increasing daylength, but incidence values were higher for males. A higher proportion of females than males were categorized as GS 0 and males had higher values for GS 3, 4, and 5, and for average GS.

The results for 17 wk of age followed a similar pattern (Table 4.5). Linear decreases in values with increasing daylength were found for GS 0 and increases with daylength were shown for GS 4, and average GS. Interactions were present for GS 3 and GS 3+ 4+5 and are shown in

Table 4.6. The incidence of these categories increased linearly for males with increasing daylength, while for females no birds were found in these categories for the 14L and 17L treatments, and statistically similar values were found for 20L and 23L treatments. The percent of males in GS 0 were lower than for females, while males had higher percentages for GS 3, and 4, GS 3+4+5 and average GS.

Table 4.4. Effect of daylength (h) and gender on gait score[1] at 11 wk of age

	Daylength[2] (L)				Gender[3] (G)				
% In category	14	17	20	23	Male	Female	L x G	SEM[4]	Regression Equation[5]
0	63.33^{a}	46.67^{b}	39.17^{b}	26.67^{c}	25.00^{b}	62.92^{a}	NS	3.000	Y = 154.74-8.20X
1	25.83	36.67	31.67	30.00	37.08^{a}	25.00^{b}	NS	2.071	-
2	7.50^{b}	7.50^{b}	15.83^{ab}	23.33^{a}	15.42	11.67	NS	1.609	Y = 48.07-5.85X
3	2.50	7.50	9.17	8.33	13.33^{a}	0.42^{b}	NS	1.285	-
4	0.83^{b}	1.67^{b}	4.17^{b}	11.67^{a}	9.17^{a}	0^{b}	0.0004	1.202	-
5	0	0	0	0	0	0	NS	0	-
3+4+5	3.33^{c}	9.17^{bc}	13.33^{ab}	20.00^{a}	22.50^{a}	0.42^{b}	0.0007	1.959	-
Average score	0.52^{b}	0.81^{b}	1.08^{ab}	1.48^{a}	1.45^{a}	0.50^{b}	0.0022	0.075	-

[a,b,c] Means with common letters within a main effect do not differ significantly (P≤0.05).
[1] Modified from Garner et al. (2002).
[2] Means represent the average response of four replicate rooms each containing three pens of males (sampling 5 birds) or three pens of females (sampling 5 birds)/daylength treatment.
[3] Means represent the average response of 48 pens of males (sampling 5 birds/pen) or 48 pens of females (sampling 5 birds/pen).
[4] Pooled standard error of the mean.
[5] Regression considered significant if P≤0.05.

Table 4.5. Effect of daylength (h) and gender on gait score[1] at 17 wk of age

% In category	Daylength[2] (L)				Gender[3] (G)		L x G	SEM[4]	Regression Equation[5]
	14	17	20	23	Male	Female			
0	35.83	30.00	15.00	10.83	14.17[b]	31.67[a]	NS	2.424	Y = 93.74-4.71X
1	38.33	31.67	32.50	30.83	30.83	35.83	NS	2.149	-
2	24.17	30.00	30.00	30.00	31.25	25.83	NS	2.130	-
3	0.83	5.00	14.17	17.50	14.17[a]	4.58[b]	0.0061	1.700	-
4	0.83	3.33	7.50	10.83	9.17[a]	2.08[b]	NS	1.411	Y = -7.78+0.28X
5	0	0	0.83	0	0.42	0	NS	0.208	-
3+4+5	1.67	8.33	22.50	28.33	23.75[a]	6.67[b]	0.0005	2.420	-
Average score	0.93[b]	1.20[ab]	1.69[a]	1.87[a]	1.75[a]	1.10[b]	NS	0.077	Y = -1.54+0.21X

[a,b,c] Means with common letters within a main effect do not differ significantly (P≤0.05).
[1] Modified from Garner et al. (2002).
[2] Means represent the average response of four replicate rooms each containing three pens of males (sampling 5 birds) or three pens of females (sampling 5 birds)/daylength treatment.
[3] Means represent the average response of 48 pens of males (sampling 5 birds/pen) or 48 pens of females (sampling 5 birds/pen).
[4] Pooled standard error of the mean.
[5] Regression considered significant if P≤0.05.

Table 4.6. Significant interactions between daylength and gender for gait score (GS), foot pad scores (FPS) and incidence of breast blisters

	Age or Period	Gender[1] (G)	Daylength[2] (h)				Regression Equation[3]
			14	17	20	23	
GS 4, %	11 wk	M	1.67^{bc}	3.33^{bc}	8.33^{b}	23.33^{a}	Y = 88.59-11.37X
	11 wk	F	0^{c}	0^{c}	0^{c}	0^{c}	-
Average GS	11 wk	M	0.77^{de}	1.23^{c}	1.62^{b}	2.17^{a}	Y = -0.61+0.07X
	11 wk	F	0.27^{f}	0.38^{ef}	0.53^{def}	0.80^{d}	Y = 0.80-0.10X
GS 3, %	17 wk	M	1.67^{b}	10.00^{b}	15.00^{ab}	30.00^{a}	Y = 19.96-3.85X
	17 wk	F	0^{b}	0^{b}	13.33^{b}	5.00^{b}	-
GS 3+4+5, %	11 wk	M	6.67^{c}	18.33^{b}	25.00^{b}	40.00^{a}	Y = -12.63+0.13X
	11 wk	F	0^{c}	0^{c}	1.67^{c}	0^{c}	
GS 3+4+5, %	17 wk	M	3.33^{bc}	16.67^{bd}	26.67^{ab}	48.33^{a}	Y = 10.95-3.73X
	17 wk	F	0^{c}	0^{c}	18.33^{bc}	8.33^{bc}	-
FPS 2, %	17 wk	M	3.33^{c}	15.00^{bc}	10.00^{c}	3.33^{c}	-
	17 wk	F	38.33^{a}	30.00^{a}	25.00^{ab}	40.00^{a}	-
Breast blister, %	11 wk	M	6.67^{b}	5.00^{bc}	1.67^{bc}	13.33^{a}	$Y = -1.87+11.59X+0.37X^2$
	11 wk	F	0^{c}	0^{c}	1.67^{bc}	0^{c}	

[a,b,c] Means with common letters within a main effect do not differ significantly (P≤0.05).
[1] Means represent the average response of 48 pens of males (sampling 5 birds/pen) or 48 pens of females (sampling 5 birds/pen).
[2] Means represent the average response of four replicate rooms each containing three pens of males (sampling 5 birds) or three pens of females (sampling 5 birds)/daylength treatment.
[3] Regression considered significant if P≤0.05.

Footpad dermatitis (FPD). Footpad lesions were not affected by daylength at 11 wk of age (Table 4.7). Females had a lower percentage of birds in category 0 than males, but higher values for categories 2, 3, and 4, and average score. No interactions were found between daylength and gender treatments. With the exception of category 1, daylength did not affect the incidence of FPD at 17 wk of age (Table 4.8). The proportion of birds in category 1 decreased linearly with increasing daylength. An interaction was noted for footpad score 2 at 17 wk (Table 4.6), females had a higher percentage in all treatments, but in both males and females no clear trend in relationship to daylength was found. The proportion of females in category 1 at 17 wk of age was lower for the males, but for all other categories and the average score for females was higher than for males.

Breast buttons and blisters. Table 4.9 shows the effects of daylength and gender on the incidence of breast buttons and blisters at 11 and 17 wk of age. At 11 wk of age breast buttons increased linearly with daylength. An interaction was present for the incidence of breast blisters (Table 4.6) at this age, with a quadratic response to daylength for males and the highest occurrence in the 23L treatment; the values for females were much lower than males and unaffected by daylength. Daylength did not affect the incidence of breast buttons and blisters at 17 wk of age. Males had a higher level of breast buttons and blisters at both ages.

Table 4.7. Effect of daylength (h) and gender on footpad score[1] at 11 wk of age

	Daylength[2] (L)				Gender[3] (G)				
% In category	14	17	20	23	Male	Female	L x G	SEM[4]	Regression Equation[5]
0	45.00	30.83	50.00	52.50	65.42[a]	23.75[b]	NS	3.485	-
1	19.17	21.67	21.67	14.17	18.33	20.00	NS	2.071	-
2	21.67	23.33	19.17	15.00	7.92[b]	31.67[a]	NS	2.304	-
3	10.00	15.00	7.50	6.67	5.00[b]	14.58[a]	NS	1.539	-
4	4.17	9.17	1.67	11.67	3.33[b]	10.00[a]	NS	1.693	-
Average score	1.09	1.50	0.89	1.11	0.63[b]	1.67[a]	NS	0.095	-

[a,b,c] Means with common letters within a main effect do not differ significantly (P≤0.05).

[1] Hocking et al. (2008).

[2] Means represent the average response of four replicate rooms each containing three pens of males (sampling 5 birds) or three pens of females (sampling 5 birds)/daylength treatment.

[3] Means represent the average response of 48 pens of males (sampling 5 birds/pen) or 48 pens of females (sampling 5 birds/pen).

[4] Pooled standard error of the mean.

[5] Regression considered significant if P≤0.05.

Table 4.8. Effect of daylength (h) and gender on footpad score[1] at 17 wk of age

% In category	Daylength[2] (L)				Gender[3] (G)		L x G	SEM[4]	Regression Equation[5]
	14	17	20	23	Male	Female			
0	45.00	35.00	45.83	44.17	75.00[a]	10.00[b]	NS	3.853	-
1	21.67	18.33	11.67	12.50	10.42[b]	21.67[a]	NS	1.978	Y = 75.42 -5.42X
2	20.83	22.50	17.50	21.67	7.92[b]	33.33[a]	0.0113	2.124	-
3	6.67	10.00	13.33	9.17	1.67[b]	17.92[a]	NS	1.451	-
4	5.83	14.17	11.67	12.50	5.00[b]	17.08[a]	NS	1.749	-
Average score	1.07	1.50	1.33	1.33	0.51[b]	2.10[a]	NS	0.104	-

[a,b,c] Means with common letters within a main effect do not differ significantly (P≤0.05).
[1] Hocking et al. (2008).
[2] Means represent the average response of four replicate rooms each containing three pens of males (sampling 5 birds) or three pens of females (sampling 5 birds)/daylength treatment.
[3] Means represent the average response of 48 pens of males (sampling 5 birds/pen) or 48 pens of females (sampling 5 birds/pen).
[4] Pooled standard error of the mean.
[5] Regression considered significant if P≤0.05.

Table 4.9. Effect of daylength (h) and gender on the incidence of breast blisters and buttons at 11 and 17 wk of age

% In category	Daylength[1] (L)				Gender[2] (G)		L x G	SEM[3]	Regression Equation[4]
	14	17	20	23	Male	Female			
11 wk									
Button	2.50^{b}	5.00^{b}	8.33^{ab}	15.83^{a}	11.67^{a}	4.17^{b}	NS	1.307	Y = 26.17-3.69X
Blister	3.33	2.50	1.67	6.67	6.67^{a}	0.42^{b}	0.0075	0.783	-
17 wk									
Button	8.33	7.50	8.33	7.50	13.75^{a}	2.08^{b}	NS	1.307	-
Blister	4.17	5.00	4.17	5.00	8.33^{a}	0.83^{b}	NS	1.09	-

[a,b,c] Means with common letters within a main effect do not differ significantly (P≤0.05).
[1] Means represent the average response of four replicate rooms each containing three pens of males (20 birds) or three pens of females (30 birds)/daylength treatment.
[2] Means represent the average response of 48 pens of males (20 birds/pen) or 48 pens of females (30 birds/pen).
[3] Pooled standard error of the mean.
[4] Regression considered significant if P≤0.05.

4.4.2 Ocular Health

Eye measures. Daylength affected eye weight and dimensions at 12 (Table 4.10) and 18 (Table 4.11) wk of age. At 12 wk of age, positive linear responses with increasing daylength were found for eye weight and eye weight to body weight ratio, while corneal diameter decreased linearly with longer daylength. Dorso-ventral (DV) and medio-lateral (ML) diameters and anterior-posterior (AP) depth responded in a quadratic fashion with daylength at 12 wk; highest values were found for the 23L treatment for all measurements. An interaction between daylength and gender was found for corneal diameter at 12 wk of age (Table 4.12), but the gender response of increasing daylength differed only in magnitude as values declined linearly for both males and females. An interaction for AP depth was also found at 12 wk. For both males and females, the highest value was for the 23L treatment, but the pattern of the response was quadratic for males and linear for females. Similar to 12 wk data, corneal diameter decreased with increasing daylength at 18 wk of age. Eye weight, eye weight ratio, DV and ML diameters and AP depth responded in a quadratic fashion with daylength, with the highest values found in 23L birds. No interactions between daylength and gender for eye measurements were found at 18 wk of age. With the exception of eye to body weight ratio, where males had a lower value than females, males had higher values for all eye measures at 12 and 18 wk of age.

Intraocular pressure (IOP). Intraocular pressure was not affected by daylength treatments (Table 4.13).

Table 4.10. Effect of daylength (h) and gender on eye weight and dimensions at 12 wk of age

	Daylength[1] (L)				Gender[2] (G)				
Measure	14	17	20	23	Male	Female	L x G	SEM[3]	Regression Equation[4]
Body wt. (kg)	10.59	10.84	10.83	10.70	11.83[a]	9.64[b]	NS	0.135	-
Eye wt. (g)	6.76	7.16	7.35	7.82	7.48[a]	7.06[b]	NS	0.116	$Y = 5.94+0.03X$
Eye wt./body wt. (%)	0.13	0.13	0.14	0.15	0.13[b]	0.15[a]	NS	0.003	$Y = 0.15-0.004X$
Corneal dia. (mm)	12.47[a]	12.11[bc]	12.22[ab]	11.83[c]	12.47[a]	11.84[b]	0.0430	0.055	-
DV dia.[4] (mm)	25.49[b]	25.47[b]	25.68[b]	27.10[a]	26.87[a]	25.00[b]	NS	0.137	$Y = 36.07-1.31X+0.04X^2$
ML dia.[5] (mm)	25.77[b]	26.06[b]	26.22[b]	28.01[a]	27.39[a]	25.63[b]	NS	0.143	$Y = 36.07-1.31X+0.04X^2$
AP depth[6] (mm)	19.81[b]	19.81[b]	20.09[b]	20.96[a]	20.85[a]	19.49[b]	0.0163	0.105	-

[a,b,c] Means with common letters within a main effect do not differ significantly ($P \leq 0.05$).
[1] Means represent the average response of four replicate rooms each containing three pens of males (sampling 3 birds) or three pens of females (sampling 3 birds)/daylength treatment.
[2] Means represent the average response of 48 pens of males (sampling 3 birds/pen) or 48 pens of females (sampling 3 birds/pen).
[3] Pooled standard error of the mean.
[4] Regression considered significant if $P \leq 0.05$.
[5] Dorso-ventral (DV) diameter.
[6] Medio-lateral (ML) diameter.
[7] Anterior-posterior (AP) depth.

Table 4.11. Effect of daylength (h) and gender on eye weight and dimensions at 18 wk of age

	Daylength[1] (L)				Gender[2] (G)				
Measure	14	17	20	23	Male	Female	L x G	SEM[3]	Regression Equation[4]
Body wt. (kg)	17.80	17.77	17.38	17.31	20.58^{a}	14.54^{b}	NS	0.324	-
Eye wt. (g)	7.64^{b}	7.46^{b}	7.94^{b}	9.63^{a}	9.23^{a}	7.14^{b}	NS	0.149	$Y = 21.41-1.71X+0.05X^2$
Eye wt./body wt. (%)	0.09^{bc}	0.08^{c}	0.09^{b}	0.11^{a}	0.09^{b}	0.10^{a}	NS	0.001	$Y = 0.27-0.02X+0.0007X^2$
Corneal dia. (mm)	12.68	12.57	12.45	12.18	12.89^{a}	12.07^{b}	NS	0.067	$Y = 12.08+0.10X$
DV dia.[4] (mm)	26.70^{b}	26.20^{c}	26.71^{bc}	28.47^{a}	28.22^{a}	25.85^{b}	NS	0.165	$Y = 44.15-2.12X+0.06X^2$
ML dia.[5] (mm)	26.11^{b}	25.81^{b}	26.45^{b}	27.94^{a}	27.77^{a}	25.42^{b}	NS	0.173	$Y = 39.21-1.63X+0.05X^2$
AP depth[6] (mm)	20.03^{b}	19.85^{b}	20.17^{b}	21.37^{a}	21.27^{a}	19.46^{b}	NS	0.123	$Y = 30.31-1.27X+0.04X^2$

[a,b,c] Means with common letters within a main effect do not differ significantly ($P \leq 0.05$).
[1] Means represent the average response of four replicate rooms each containing three pens of males (sampling 3 birds) or three pens of females (sampling 3 birds)/daylength treatment.
[2] Means represent the average response of 48 pens of males (sampling 3 birds/pen) or 48 pens of females (sampling 3 birds/pen).
[3] Pooled standard error of the mean.
[4] Regression considered significant if $P \leq 0.05$.
[5] Dorso-ventral (DV) diameter.
[6] Medio-lateral (ML) diameter.
[7] Anterior-posterior (AP) depth.

Table 4.12. The effects of the interaction between daylength and gender on ocular health

	Age or Period	Gender[1] (G)	Daylength[2] (h)				Regression Equation[3]
			14	17	20	23	
Corneal Dia., mm	12 wk	M	12.93^{a}	12.33^{bc}	12.57^{ab}	12.00^{cd}	$Y = 13.68-0.04X$
	12 wk	F	12.02^{cde}	11.78^{de}	11.86^{de}	11.66^{e}	$Y = 12.39-0.02X$
AP depth[4], mm	12 wk	M	20.72^{bc}	20.22^{c}	20.84^{b}	21.60^{a}	$Y = 30.45-1.19X+0.02X^2$
	12 wk	F	18.90^{d}	19.39^{d}	19.34^{d}	20.32^{bc}	$Y = 21.36-0.36X$

[a,b,c] Means with common letters within a main effect do not differ significantly ($P \leq 0.05$).

[1] Means represent the average response of 48 pens of males (3 birds/pen) or 48 pens of females (3 birds/pen).

[2] Means represent the average response of four replicate rooms each containing three pens of males (sampling 3 birds) or three pens of females (sampling 3 birds)/daylength treatment.

[3] Regression considered significant if $P \leq 0.05$.

[4] Anterior-posterior depth.

Table 4.13. Effect of daylength (h) on male turkey intraocular pressure (mmHg) at 9, 12, 15 and 18 wk of age

	Daylength[1]					
	14	17	20	23	SEM[2]	Regression Equation[3]
9 wk	14.89	15.17	14.86	15.47	0.267	-
12 wk	17.33	17.11	16.78	17.06	0.270	-
15 wk	17.36	17.14	17.89	17.39	0.430	-
18 wk	18.94	19.28	18.89	19.06	0.385	-

[a,b,c] Means with common letters within a main effect do not differ significantly ($P \leq 0.05$).

[1] Means represent the average response of four replicate rooms each containing three pens of males (sampling 3 birds)/daylength treatment. Both eyes were assessed three times in three males per pen and the values from both eyes were averaged for statistical analysis.

[2] Pooled standard error of the mean.

[3] Regression considered significant if $P \leq 0.05$.

4.4.3 Behavioural Observations

The effects of daylength on male turkey behaviour over a 24 h period at 11 and 17 wk of age are shown in Tables 4.14 and 4.15, respectively. At 11 wk of age, inactive resting increased linearly with increasing daylength. Drinking, walking and environmental pecking behaviours responded linearly, decreasing with increasing daylength. Feather pecking exhibited a quadratic relationship with increasing daylength with lowest frequency for 23L birds. At 17 wk of age, although not significant, (ANOVA P=0.06) the percentage of birds inactive resting was numerically higher for 23L birds. Similar to 11 wk of age, 17 wk walking, and environmental and feather pecking display linear declines with increasing daylength. Quadratic responses for strutting (P=0.07) and aggression (P=0.08) behaviours approached significance.

Table 4.16 (11 wk of age) and Table 4.17 (17 wk of age) illustrate behaviours during the photoperiod in relation to daylength. At 11 wk of age, feeding, drinking, standing, walking, preening, and environmental and feather pecking decreased linearly with increasing daylength, while resting increased in a similar fashion. At 17 wk of age, feeding, drinking, standing, preening, and environmental and feather pecking behaviours again increased linearly with increased daylength. Walking decreased in a quadratic fashion with increasing daylength, while inactive resting decreased in a linear fashion. Similar to 24 h results, strutting and aggression behaviours illustrated quadratic trends (P=0.09 and P=0.09, respectively) in response to daylength, with higher percentages for 17L and 20L treatments.

During the scotoperiod, birds were primarily inactive. The proportion of time resting for the 14, 17, 20 and 23L treatments were 97.2, 97.9, 98.9 and 100% at 11 wk of age and 95.4, 97.3, 99.1 and 99.2% at 17 wk of age. The response at both ages was statistically interpreted as linear in nature. Night-time standing, walking and preening behaviours decreased linearly with longer daylength at 11 and 17 wk of age (Appendix). No other behaviours were expressed during the dark period.

Table 4.14. Effect of daylength on male turkey behaviour at 11 wk of age over 24 h period

Behaviour	Daylength[1] (h) 14	17	20	23	SEM[2]	Regression Equation[3]
Resting	73.91[b]	73.77[b]	73.91[b]	78.35[a]	0.771	Y = 108.85-4.27X
Feeding	2.24	2.41	2.36	2.42	0.128	-
Drinking	1.73	1.78	1.37	1.37	0.083	Y = 1.91+0.01X
Standing	8.70	8.27	8.71	8.10	0.271	-
Walking	3.60[a]	3.01[a]	3.01[a]	2.08[b]	0.190	Y = 2.53+0.21X
Preening	6.52	7.03	7.67	6.38	0.256	-
Stretching	0.48	0.61	0.57	0.45	0.075	-
Env. pecking[4]	1.81[a]	1.68[a]	1.40[a]	0.53[b]	0.185	Y = -2.89+0.62X
Feather pecking	0.95[a]	1.19[a]	0.85[ab]	0.23[b]	0.132	$Y = -5.49+0.79X-0.02X^2$
Strutting	0.08	0.08	0	0	0.027	-
Aggression	0.07	0.09	0.12	0.06	0.016	-
Other[5]	0.07	0.07	0.03	0.03	0.013	-

[a,b,c] Means with common letters within a main effect do not differ significantly (P≤0.05).
[1] Means represent the average response of four replicate rooms each containing one pen of males (20 birds)/daylength treatment.
[2] Pooled standard error of the mean.
[3] Regression considered significant if P≤0.05.
[4] Env. pecking = environmental pecking (cage, walls, litter).
[5] Other = behaviours at low frequency (dustbathing, wing flapping, feather ruffle, and scratching).

Table 4.15. Effect of daylength on male turkey behaviour at 17 wk of age over 24 h period

Behaviour	Daylength[1] (h)				SEM[2]	Regression Equation[3]
	14	17	20	23		
Resting	66.85	71.73	68.29	73.04	1.286	-
Feeding	3.56	3.01	2.99	2.92	0.160	-
Drinking	1.77	1.68	1.60	1.62	0.071	-
Standing	13.64	12.43	13.40	13.07	0.579	-
Walking	5.14	2.87	3.19	2.96	0.395	Y = 26.15-2.31X
Preening	5.69	4.48	5.71	4.38	0.263	-
Stretching	0.09	0.11	0.11	0.10	0.018	-
Env. pecking[4]	0.79^{a}	0.83^{a}	0.63^{ab}	0.27^{b}	0.081	Y = -1.90+0.35X
Feather pecking	0.70^{a}	0.54^{ab}	0.37^{b}	0.09^{c}	0.069	Y = 0.64+0.05X
Strutting	1.68	2.18	3.67	1.46	0.368	-
Aggression	0.03	0.12	0.07	0.03	0.019	-
Other[5]	0.06	0.02	0.04	0.06	0.014	-

[a,b,c] Means with common letters within a main effect do not differ significantly ($P \leq 0.05$).
[1] Means represent the average response of four replicate rooms each containing one pen of males (20 birds)/daylength treatment.
[2] Pooled standard error of the mean.
[3] Regression considered significant if $P \leq 0.05$.
[4] Env. pecking = environmental pecking (cage, walls, litter).
[5] Other = behaviours at low frequency (dustbathing, wing flapping, feather ruffle, and scratching).

Table 4.16. Effect of daylength on male turkey behaviour at 11 wk of age during photoperiod

Behaviour	Daylength[1] (h) 14	17	20	23	SEM[2]	Regression Equation[3]
Resting	57.08[c]	63.80[b]	68.89[b]	77.62[a]	2.091	Y = 44.05+0.17X
Feeding	3.87	3.41	2.83	2.50	0.225	Y = 7.20-0.29X
Drinking	2.98[a]	2.52[a]	1.65[b]	1.41[b]	0.191	Y = 7.58-0.41X
Standing	13.39[a]	10.98[a]	10.25[ab]	8.38[b]	0.596	Y = 25.49-1.09X
Walking	6.11[a]	4.21[b]	3.61[b]	2.15[c]	0.416	Y = 15.71-0.86X
Preening	10.86[a]	9.81[a]	9.19[a]	6.59[b]	0.492	Y = 3.17+1.14X
Stretching	0.82	0.86	0.69	0.47	0.114	-
Env. pecking[4]	3.13[a]	2.37[ab]	1.68[bc]	0.55[c]	0.314	Y = 3.64+0.11X
Feather pecking	1.65[a]	1.68[a]	1.02[ab]	0.24[b]	0.205	Y = -3.32+0.67X
Strutting	0.14	0.12	0	0	0.041	-
Aggression	0.11	0.13	0.15	0.06	0.022	-
Other[5]	0.12	0.10	0.04	0.03	0.020	-

[a,b,c] Means with common letters within a main effect do not differ significantly (P≤0.05).
[1] Means represent the average response of four replicate rooms each containing one pen of males (20 birds)/daylength treatment.
[2] Pooled standard error of the mean.
[3] Regression considered significant if P≤0.05.
[4] Env. pecking = environmental pecking (cage, walls, litter).
[5] Other = behaviours at low frequency (dustbathing, wing flapping, feather ruffle, and scratching).

Table 4.17. Effect of daylength on male turkey behaviour at 17 wk of age during the photoperiod

Behaviour	Daylength[1] (h) 14	17	20	23	SEM[2]	Regression Equation[3]
Resting	50.14[c]	61.04[b]	63.86[ab]	71.89[a]	2.285	Y = -6.66-5.22X
Feeding	5.64[a]	4.26[a]	3.41[b]	3.05[b]	0.296	Y = 18.66-1.32X
Drinking	2.83[a]	2.38[a]	1.85[b]	1.69[b]	0.144	Y = 7.29-0.43X
Standing	19.70	16.85	15.16	13.61	0.908	Y = 40.70-2.01X
Walking	7.81[a]	4.03[b]	3.60[b]	3.09[b]	0.569	$Y = 43.71-3.85X+0.09X^2$
Preening	8.61[a]	6.04[b]	6.50[b]	4.58[c]	0.417	Y = 19.52-1.05X
Stretching	0.13	0.16	0.12	0.11	0.024	-
Env. pecking[4]	1.31[a]	1.17[ab]	0.74[bc]	0.28[c]	0.134	Y = 0.11+0.21X
Feather pecking	1.13[a]	0.76[ab]	0.42[bc]	0.09[c]	0.113	Y = 3.17-0.16X
Strutting	2.58	3.09	4.29	1.53	0.466	-
Aggression	0.05	0.18	0.08	0.03	0.026	-
Other[5]	0.06	0.03	0.04	0.06	0.016	-

[a,b,c] Means with common letters within a main effect do not differ significantly ($P \leq 0.05$).
[1] Means represent the average response of four replicate rooms each containing one pen of males (20 birds)/daylength treatment.
[2] Pooled standard error of the mean.
[3] Regression considered significant if $P \leq 0.05$.
[4] Env. pecking = environmental pecking (cage, walls, litter).
[5] Other = behaviours at low frequency (dustbathing, wing flapping, feather ruffle, and scratching).

4.5 Discussion and Conclusion

Mobility is a key indicator of turkey well-being and the results of this research indicated that daylength has a strong impact on this trait. Mobility was examined using gait scoring at 11 and 17 wk of age, and at both ages mobility declined in a linear fashion for males as daylength increased. In contrast, females were not affected at 11 wk, as hens generally had good mobility and a very low incidence of birds in upper gait scores (3+4+5). Even at 17 wk, hen mobility was generally good, but 20L and 23L treatments had birds categorized in the upper gait scores (3+4+5) categories. This supports the concept that longer daylength negatively affects skeletal mobility and this effect is in agreement with more culling due to skeletal abnormalities (Chapter 3).

The welfare implications of poorer mobility relates to pain as well as access to resources, such as feed and water. Gait scores higher than 3 have been well documented to be associated with pain in broiler chickens (McGeown et al., 1999; Danbury et al., 2000). Since the gait scoring technique used in this work is a modification of one used for broilers, it can be assumed that turkeys in these categories are also in pain. Further, the use of analgesics in both broiler chickens (Danbury et al., 2000) and turkeys (Duncan et al., 1991; Buchwalder and Huber-Eicher, 2005) has proven to be effective in alleviating leg pain and altering bird mobility with lame birds self-selecting feeds containing analgesics more than sound birds (McGeown et al., 1999; Danbury et al., 2000). Not only are lame birds experiencing pain, but they could have difficulty reaching food and water (Martland, 1984; McGeown et al., 1999; Garner et al, 2002) and may be less able to escape other birds or compete for resources (Yalcin et al., 1998). These characteristics were evident in the current research with turkeys given longer daylengths consuming less feed (Chapter 3) and spending less time at feeders and drinkers.

The poorer GS in males than females can be linked to their more rapid early growth and steeper growth curve compared to females. In turn, this effect is compounded by longer daylengths producing the fastest early growth (Hester et al., 1983, 1986; Classen et al., 1994; Chapter 3). Rapid early growth increases the potential for improper skeletal development and more leg disorders (Vestergaard and Sanotra 1999; Kestin et al., 2001). Males are also heavier than females, and heavier birds have been shown to have reduced mobility (Kestin et al., 2001). Of note, in this study, male mobility at 11 wk of age was strongly affected by daylength, but hens at 17 wk of age, were only marginally affected despite heavier weights than males at 11 wk. This implies that either growth rate or other inherent characteristics such as bird stance or posture are responsible. Fournier et al. (2015) found that the angle between the horizontal and the tom turkey breast decreased from 20.5 to 1.9 degrees between 82 and 139 d of age. It is not known if hen stance follows a similar pattern, but a more horizontal posture may reduce bird mobility. Therefore, inherent poorer mobility, rapid growth curves and altered stance of males may contribute to their increased susceptibility to gait abnormalities.

Exercise has been proposed to have an effect on skeletal health, reducing bird lameness through its influential role on bone development (Hester et al., 1983; Reiter and Bessei, 1995). The force of muscles pulling against bones stimulates the bone-building process (Lanyon, 1993) with level of activity being an influential factor. Behavioural observations indicated turkeys walked more over a 24 h period on shorter daylengths and thus exercise could be an influential factor on bone health. Although bone properties were not evaluated, other turkey studies have shown increased activity on shorter daylengths in addition to higher breaking strength (Classen et al., 1994). Culling rates for skeletal issues in the current trial were higher than expected possibly due to small pen size and birds not being able to move around as much, which may have been an influential factor.

Footpad dermatitis was not affected by daylength in this study. Research with broilers has shown that the incidence of FPD can either be affected negatively (Sørensen et al., 1999) or positively (Schwean-Lardner et al., 2013) by longer daylength. The failure to see a consistent effect may relate to its multifactorial nature and the finding that litter moisture is the most influential factor (Martland, 1984, 1985; Mayne et al., 2007). Schwean-Lardner et al. (2013) suggested that the reduced incidence with shorter daylength noted in that study was related to birds resting less over the 24 h observation period and therefore spending less time in contact with litter; this despite birds resting for virtually all the night period. Birds were also more active on shorter daylength leading to more disruption and drying of the litter. As noted below, turkeys on shorter daylength also spend less time resting in comparison to longer daylength, but in this case it did not influence FPD.

Hens were found to have a higher incidence of FPD than males and this agrees with previous work with turkeys (Krautwald-Junghanns et al., 2011). The authors speculated differing stocking densities between genders accounted for results with females being stocked heavier, thereby increasing litter moisture. In the current work, stocking density (kg/m^2) was planned to be the same, but increased tom mortality (Chapter 3) resulted in decreasing stocking density in comparison to hens. Differences in susceptibility of the footpad epidermis to lesions may also account for decreased incidence of FPD in males, which are considered to have a tougher epidermis (Mayne, 2005). Even though daylength did not affect the influence of FPD, the presence in the flock represents an animal welfare concern, because of the pain associated with these lesions (Martland, 1984, 1985; Buda et al., 2002).

Breast buttons and blisters are another form of contact dermatitis, which are often grouped with FPD as their causation factors are suggested to be similar. The incidence of breast buttons was only affected by daylength in toms at 11 wk of age, with the response being quadratic and the highest incidence found for the 23L treatment. Males had a higher incidence of both breast buttons and blisters at both 11 and 17 wk of age, which is in agreement with previous work (Gonder and Barns, 1987; Mitterer-Istyagin et al., 2011). It has been speculated that males are more susceptible to breast blisters due to their increased leg abnormalities (Chapter 3) and inherent poorer mobility leading to longer resting periods and consequently increased litter contact (Gonder and Barns, 1987). In the current study, gait correlated positively with breast buttons and blisters for males and females at 11 wk of age (Table 4.18). This finding supports poor mobility being an influential factor in the development of breast blisters and buttons.

Table 4.18. Pearson correlation coefficient and correlation significance of gait between breast buttons and blisters at 11 wk of age for males and females

	Button[1]		Blister[1]	
Gait	Male	Female	Male	Female
r	0.2761	0.3997	0.3324	0.3029
p-value	0.0575	0.0049	0.0210	0.0364

[1] Means represent the average response of 48 pens of males (sampling 5 birds/pen) or 48 pens of females (sampling 5 birds/pen).

Eye size increased at 12 and 18 wk of age with increasing daylength. Birds exposed to 23L treatment demonstrated largest effect. This is in agreement with previous literature where turkeys had larger eye size and weight under constant and near continuous lighting programs in comparison to 12 h of light (Ashton et al., 1973; Davis et al., 1986). Eye growth is related to melatonin production with growth occurring during the light period and ceasing during the dark

(Rada and Wiechmann, 2006). Similar to turkeys, broilers also exhibit increased eye weight under 23 h daylength (Schwean-Lardner et al., 2013), which may be linked to the absence of circadian changes in eye growth (reduced growth during the scotoperiod; Lewis and Gous, 2009). The lack of this rhythm is supported by the lack or de-synchronization of physiological and behavioural rhythms in broilers given 23 h of daylength (Schwean-Lardner et al., 2013). Of note, low light intensities can also induce changes in ocular size and turkeys raised at or below 2 lux have significantly enlarged eyes (Siopes et al., 1984; Thompson and Forbes, 1999). Turkeys in this study were exposed to 1 lux by trial end in order to reduce injurious pecking. Despite reaching such a low light intensity, the impact of daylength remained, suggesting that diurnal patterns in eye growth were still occurring. This is supported by work in broilers, where melatonin rhythms were maintained at a photoperiod light intensity of 1 lux (Deep et al., 2012).

In regards to intraocular pressure (IOP), no differences between daylength treatments were noted in the current study. This is in agreement with previous broiler chicken (Kinnear et al., 1974; Lauber and Kinnear, 1979) and turkey (Davis et al., 1986) studies. Other studies speculate that IOP increases as a consequence of ocular changes occurring with longer daylengths, but did not measure IOP directly.

The behavioural repertoire of toms in this study was similar to previous research (Hughes and Grigor, 1996; Sherwin and Kelland, 1998), but differences were seen among daylength treatments. When summarized over the 24 h of observation (photo- and scoto-period), resting increased and drinking, walking and environmental and feather pecking decreased with increasing daylength at 11 wk of age. At 18 wk of age the effect of daylength was less, but walking and environmental and feather pecking still decreased with increasing daylength. Examination of behaviour over 24 h permits a closer examination of overall activity and exercise, which has implications for a number of health and production parameters. Even though toms are virtually inactive during the dark period for all the daylength, birds with shorter daylength tended to rest less and be more active.

When behaviour was compared only during the photoperiod, the effects of daylength were more pronounced. Longer daylength resulted in more inactive resting and less feeding, drinking, standing, walking, preening and pecking behaviours. Changes attributed to daylength relate at least partially to the reduced time to perform behaviours in shorter days. Differences may also be explained by poor mobility and an increased incidence of skeletal abnormalities (above and Chapter 3). Similar behavioural differences due to daylength have been reported in turkeys previously (Classen et al., 1994) and decreased activity due to decreased mobility was suggested to be a potential reason. Broiler chicken studies illustrate similar findings with birds resting more on 24 h compared to 16 h daylength (Bayram and Özkan, 2010) and 23 h compared to 17 and 14 h (Schwean-Lardner et al., 2012a). Schwean-Lardner et al. (2012a) measured bird response to an observer and found a quadratic response in relation to daylength with 23L birds being least reactive regardless of age. It has been suggested that increased sitting or decreased standing and walking behaviours indicate muscular skeletal weakness (Weeks et al., 1994). Furthermore, Corr and colleagues (2003) found lame birds spend more time lying, lying and eating and eating fewer meals.

Preening behaviour can be classified as a maintenance behaviour, which is suggested to be performed when a birds primary needs are met (Delius, 1988). Thus, the observed decrease in preening behaviour on longer daylengths could be an indicator that birds are choosing to redirect their time and energy into basic needs (resting and nutritive). However, preening can also be performed as a coping mechanism by birds in stressful situations (Delius, 1988). Consequently, it is difficult to speculate if the change in preening is negative or positive. However, when taken in conjunction with the decrease in nutritive (feeding and drinking) and mobility (walking and standing) related behaviours in birds that have longer to perform the behaviours (longer daylengths), a negative welfare impact is more plausible.

Environmental pecking also decreased with longer daylengths, and this effect can be considered in the same context as reduced activity. However, it is also possible that expressions of pecking, preening and also active behaviours are affected by sleep deprivation (Schwean-Lardner et al., 2012a). The state of sleep deprivation has been proposed to occur as a consequence of birds lacking flock circadian rhythms, which has been demonstrated in longer daylengths in broiler chickens (Schwean-Lardner et al., 2014). In the absence of synchronized circadian rhythms, it is likely that some birds will be resting, while others will be feeding or walking, and disrupting the sleep of others. The result is lethargic birds that are fatigued, lacking motivation and/or stimulation and are ultimately unaware of their environment. A reduction in exploratory behaviours, like environmental pecking, which is considered to have a motivational purpose (Newberry, 1999) is a further indicator of reduced welfare.

Feather pecking decreased with longer daylengths. This may indicate once again that birds are not motivated, and/or have poor mobility and are less able to complete the behaviour (discussed above). Since feather pecking may lead to injurious pecking if skin breaks and blood is present (Hale and Schein, 1962), a positive outcome of longer daylength would be less culling and death loss, which is reported elsewhere for this group of turkeys (Chapter 3). However, it is debatable as to whether or not this is an acceptable reason to use longer daylengths, as the overall changes in turkey behaviour suggest negative impacts on bird well-being.

In conclusion, daylengths during the production cycle of tom and hen turkeys affects a number of criteria that have negative welfare implications. In general, longer daylength has negative welfare implications in regards to turkey health and behaviour for both toms and hens, but with the effect more pronounced in toms. Mobility decreased in a linear fashion with increasing daylength for both the toms and hens, but the proportion of birds in the upper GS categories thought to be associated with pain increased with daylength only in toms. Similarly, the incidence of breast blisters increased in a linear fashion with increasing daylength only in toms. Changes in eye size were noted in both toms and hens and are indicative of reduced welfare, with the impact particularly pronounced for the 23L treatment. Behaviour was only observed in males, so it is not possible to confirm the presence of a gender effect, but the finding of increased resting and decreases in active behaviours are suggestive of lethargy, and a lack of ability or motivation to perform some behaviours.

5.0 OVERALL CONCLUSIONS

Previous turkey lighting research is limited and out of date, with the majority conducted in the 1990's. The turkeys used in these studies may have responded in a different manner than today's birds due to the continuous genetic changes that have occurred since then. Additionally, the majority of the past lighting research only examined two lighting treatments, which included constant (24L) or near continuous lighting (23L) programs, shorter photoperiods, increasing, decreasing, or intermittent lighting programs. Thus, this study through its use of graded lighting programs was able to observe response curves for different output variables in relation to daylength, which has not been done to date for turkeys.

Currently, there are no lighting program standards for the turkey industry. The Turkey Farmers of Canada codes of practice state that a period of darkness is required in an uninterrupted 24 h period to prevent bird panic in the event of a power failure. No minimal hours of darkness are stated and thus producers are able to choose their own program with many believing that more light will result in highest growth rate. However, the right lighting program should be based on both economical and welfare criteria. These criteria may vary with gender and age at marketing and therefore this section of the thesis will evaluate tom and hen responses at young (84 d) and older (126 d) ages. In Canada, turkeys can be marketed at a variety of ages for various purposes, but young birds (11-13 wk – primarily hens) are often used for the whole carcass market and older birds (16-18 wk – primarily toms) usually are used for further processing. Tables 5.1 and 5.2 summarize economic and welfare criteria which can be used to assist with formulating daylength recommendations.

Table 5.1. Summary of the effects of daylength on key economic and welfare criteria of hen turkeys at 84 and 126 d of age

	84 d	126 d
Body Wt.	No effect	Linear decrease, 23L weigh least
G:F	No effect	No effect
Mortality	Linear trend, culling and PC, 23L highest	Quadratic, culling and PC, 23L highest
GS	Linear increase, average GS, 23L highest	Linear, GS 3+4+5 present in 20 and 23L
Blisters	No effect	No effect
Eye Size	Linear, 23L largest	Quadratic, 23L largest

Table 5.2. Summary of the effects of daylength on key economic and welfare criteria of tom turkeys at 84 and 126 d of age

	84 d	126 d
Body Wt.	Linear decrease, 23L least	Linear decrease, 23L least
G:F	No effect	No effect
Mortality	Linear trend, culling, 23L highest	Quadratic, culling, skeletal, 23L highest
GS	Linear, average, GS 3+4+5	Linear, GS 3+4+5
Blisters	Quadratic, 23L highest	No effect, culling?
Eye Size	Linear, 23L highest	Quadratic, 23L highest
Behaviour	Linear, inactivity, 23L highest	Linear, walking, 23L least

Growth rate is clearly important from an economic perspective, but unexplained decreases in growth also indicate less than optimum bird welfare. Feed efficiency affects the economics of turkey production, but in this work was not affected by daylength, so plays no role in determining a daylength recommendation. Mortality (including birds culled) have both economic and welfare implications; no effect of daylength was found on the incidence of bird dying, but the incidence of culling was affected regardless of gender or age. The reasons for culling reflect bird welfare, as major categories such as bird mobility and skeletal disorders indicate pain. Similarly, gait score assesses bird mobility, which can be due to pathology of related systems and/or motivation indicative of sleep deprivation/fragmentation. The changes in eye characteristics over long term exposure to 23 h daylength are a welfare concern. Simair et al. (2015; unpublished) compared turkeys exposed 14 and 23 h of daylength in the second experiment of the current research. They found significant changes in the ocular pathology of birds given 23 h of daylength including globe enlargement, flattened cornea, shallow anterior chamber, decreased cone function and photoreceptor nuclei, decreased choroidal thickness, vitreal degeneration, cataract and astigmatism. The degree of welfare concern in younger birds, where pathology has not fully developed, can be debated. However, it appears that even smaller amounts of darkness (e.g. 4 h) minimize the eye effect, so recommendations should take this potential welfare issue into consideration. This research represents the first time behaviour has been examined over a 24 h period of time in turkeys comparing multiple lighting programs. In contrast to shorter observation periods during the photoperiod, this permits an overall evaluation of important criteria such as inactivity or resting. Behaviour is another factor that should be considered in establishing daylength recommendations as it is based on the bird's response to its environment. Reduced activity and increased resting associated with long daylengths, particularly when considered along with other criteria, suggest a condition of reduced bird well-being. It is likely that birds on longer daylengths are experiencing sleep deprivation/fragmentation, further compromising their welfare.

For hens marketed at 84 d of age a maximum of 20 h of daylength is recommended. Although no effects of daylength are found for growth and feed efficiency, birds on 23 h daylength had the highest level of loss with culling and pendulous crops being most influential. Eye size was affected by daylength, but 23 h birds were mostly affected. Although, 24 h behavioural observations were not conducted on hens, it is likely that similar trends would be observed to that of toms (increased inactivity), but possibly with reduced magnitude due to increased mobility.

For many criteria, older hens (126 d) react to daylength in a similar fashion to males, but generally with a reduced degree of response. For example, body weight at 126 d decreases with increasing daylength, but the difference between 14 and 23 h of daylength was 0.5 kg for females and 1.5 kg for males. Similar to 84 d of age, mortality (culling and pendulous crop) is highest for 23 h daylength. At this age, GS in the higher (predicted painful) categories (GS 3+4+5) were found for the 20 and 23 h treatments. Again, not the same degree of effect, but the trend is the same as found in males. Eye size was highest again on 23 h daylength. Based on these findings, the daylength recommendation for 126 d hens is 14 to 17 h. The degree and nature of response of hens to daylength changes with age (84 vs 126 d), and therefore recommendations for intermediate ages should transition between recommendations.

For toms marketed at 84 d of age, shorter daylengths (14 to 17 h) are recommended. This recommendation is based on poorer mobility (average GS and higher percentages of GS 3+4+5), increased resting/inactivity, and a higher incidence of breast blisters on longer daylengths; these characteristics all have a pain association and therefore welfare implications. Similar to hens, eye characteristics are affected the most for 23 h daylength. In addition, body weight decreased with increasing daylength. The response of toms at older ages to daylength is similar to 84 d and therefore the recommendation remains 14 to 17 h of daylength. An exception is that lack of daylength effect on the incidence of breast blisters for an unknown reason(s). However, this difference is not sufficient to change the recommendation, because of the relative importance of other criteria such as growth rate, culling levels, gait score and behaviour.

In conclusion, for both hens and toms regardless of the age, 23 h of daylength is not acceptable because of reduced welfare, with birds experiencing poorer mobility (higher GS, decreased walking, and increased skeletal disorders), increased ocular size and increased mortality and culling. For toms and older hens, the rationale for not recommending 23 h daylength also includes reduced growth rate. Further, the nature of the response daylength in the latter birds results in a recommendation of shorter daylength than hens at younger ages. Therefore, lighting program recommendations for meat turkeys are dependent on gender and the age at which birds are marketed. For hens marketed at a younger age (84 d), a maximum of 20 h of daylength is recommended, while the recommendation for older hens (126 d) and toms is between 14 and 17 h.

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7.0 APPENDIX

Table not published. Effect of daylength (h) and gender on causes of mortality of meat turkeys from 10 to 84 d of age

Cause (%)	Daylength[1] (L)				Gender[2] (G)		L x G	SEM[3]	Regression Equation[4]
	14	17	20	23	Male	Female			
Heart[5]	0.63	1.32	0.21	0.76	1.25[a]	0.21[b]	NS	0.191	-
Skeletal[6]	2.22	1.81	2.30	3.56	3.96[a]	0.98[b]	NS	0.374	-
Infectious[7]	1.25	0.49	0.69	1.40	1.36	0.56	NS	0.228	-
Pendulous crop	0.69	0.56	1.12	1.75	0.52[b]	1.54[a]	0.0360	0.193	Y = 5.84-0.67X
Injurious pecking	0.49	0.35	0.69	0	0.42	0.35	NS	0.125	-
Unknown[8]	0.63	1.25	0.97	0.63	1.25	0.49	NS	0.241	-
Other[9]	0.69	0.69	0.63	1.35	1.05	0.63	NS	0.219	-
Total	6.60	6.46	6.61	9.44	9.81[a]	4.74[b]	NS	0.633	-
Cull Total	4.10	3.47	5.15	7.29	6.58[a]	3.42[b]	NS	0.532	Y = 23.55-2.47X
Dead Total	2.50	2.99	1.46	2.15	3.23[a]	1.32[b]	NS	0.351	-

[a,b,c] Means with common letters within a main effect do not differ significantly ($P<0.05$).
[1] Means represent the average response of four replicate rooms each containing three pens of males (20 birds) or three pens of females (30 birds)/daylength treatment.
[2] Means represent the average response of 48 pens of males (20 birds/pen) or 48 pens of females (30 birds/pen).
[3] Pooled standard error of the mean.
[4] Regression considered significant if $P <0.05$.
[5] Heart – heart disease, ascites, round heart, perirenal hemorrhage, cardiomyopathy.
[6] Skeletal – valgus-varus, rotated tibia, leg weakness, leg fracture, broken wing.
[7] Infectious – tendonitis, arthritis, pericarditis, air sacculitis, peritonitis, hepatic necrosis, runt, bursitis.
[8] Unknown – no visible lesions.
[9] Other – impacted gastrointestinal tract, accidental death.

Table not published. Effect of daylength (h) and gender on causes of mortality of meat turkeys from 10 to 105 d of age

Cause (%)	Daylength[1] (L)				Gender[2] (G)		L x G	SEM[3]	Regression Equation[4]
	14	17	20	23	Male	Female			
Heart[5]	0.76	1.32	0.42	1.32	1.56[a]	0.35[b]	NS	0.208	-
Skeletal[6]	3.89	2.50	2.99	5.57	6.15[a]	1.32[b]	0.0135	0.450	$Y = 36.82-3.89X+0.11X^2$
Infectious[7]	1.67	0.83	0.90	1.40	1.78	0.63	NS	0.264	-
Pendulous crop	1.18[b]	0.97[b]	1.53[ab]	2.65[a]	0.73[b]	2.44[a]	0.0175	0.235	$Y = 10.73-1.20X$
Injurious pecking	1.67[a]	1.18[ab]	0.69[ab]	0.14[b]	1.35	0.49	NS	0.215	$Y = 3.50-0.11X-0.002X^2$
Unknown[8]	0.76	1.46	0.97	0.83	1.46	0.56	NS	0.259	-
Other[9]	0.69	0.97	0.63	1.55	1.16	0.77	NS	0.226	-
Total	10.63	9.24	8.13	13.48	14.19[a]	6.55[b]	NS	0.751	$Y = 67.70-6.67X+0.19X^2$
Cull Total	7.78	6.25	6.47	10.77	10.54[a]	5.09[b]	NS	0.648	$Y = 55.78-5.69X+0.16X^2$
Dead Total	2.85	2.99	1.67	2.71	3.65[a]	1.46[b]	NS	0.373	-

[a,b,c] Means with common letters within a main effect do not differ significantly ($P<0.05$).

[1] Means represent the average response of four replicate rooms each containing three pens of males (20 birds) or three pens of females (30 birds)/daylength treatment.

[2] Means represent the average response of 48 pens of males (20 birds/pen) or 48 pens of females (30 birds/pen).

[3] Pooled standard error of the mean.

[4] Regression considered significant if $P <0.05$.

[5] Heart – heart disease, ascites, round heart, perirenal hemorrhage, cardiomyopathy.

[6] Skeletal – valgus-varus, rotated tibia, leg weakness, leg fracture, broken wing.

[7] Infectious – tendonitis, arthritis, pericarditis, air sacculitis, peritonitis, hepatic necrosis, runt, bursitis.

[8] Unknown – no visible lesions.

[9] Other – impacted gastrointestinal tract, accidental death.

Table not published. Effect of daylength (h) on male turkey behavior at 11 wks of age during the scotoperiod

	Daylength[1]						
Behaviour	14	17	20	23	P-value	SEM[2]	Regression Equation[3]
Resting	97.18[c]	97.86[bc]	98.87[ab]	100.00[a]	0.0036	0.327	Y = 96.85-0.16X
Feeding	0	0	0	0	NS	0	-
Drinking	0	0	0	0	NS	0	-
Standing	2.19[a]	1.73[ab]	1.01[b]	0[c]	0.0037	0.261	Y = 0.62+0.33X
Walking	0.11	0.09	0	0	NS	0.022	Y = 0.48-0.03X
Preening	0.51[a]	0.32[ab]	0.12[bc]	0[c]	0.0128	0.064	Y = 2.05-0.14X
Stretching	0	0	0	0	NS	0	-
Env. Pecking[4]	0	0	0	0	NS	0	-
Feather pecking	0	0	0	0	NS	0	-
Strutting	0	0	0	0	NS	0	-
Aggression	0	0	0	0	NS	0	-
Other[5]	0	0	0	0	NS	0	-

[a,b,c] Means with common letters within a main effect do not differ significantly (P≤0.05).
[1] Means represent the average response of four replicate rooms each containing three pens of males (20 birds)/daylength treatment.
[2] Pooled standard error of the mean.
[3] Regression considered significant if P≤0.05.
[4] Env. Pecking = environmental pecking (cage, walls, litter).
5 Other = behaviours at low frequency (dustbathing, wing flapping, feather ruffle and scratching).

Table not published. Effect of daylength (h) on male turkey behavior at 17 wks of age during the scotoperiod

	Daylength[1]						
Behaviour	14	17	20	23	P-value	SEM[2]	Regression Equation[3]
Resting	95.39[b]	97.32[a]	99.14[a]	99.24[a]	0.0030	0.490	Y = 72.71+2.33X
Feeding	0.06	0	0	0	NS	0.015	-
Drinking	0	0	0	0	NS	0	-
Standing	3.12[a]	1.86[ab]	0.86[b]	0.76[b]	0.0493	0.334	Y = 17.24-1.45X
Walking	0.50[a]	0.07[b]	0[b]	0[b]	0.0037	0.066	Y = 5.08-0.50X
Preening	0.90[a]	0.74[a]	0[b]	0[b]	0.0004	0.120	Y = 3.97-0.28X
Stretching	0	0	0	0	NS	0	-
Env. Pecking[4]	0	0	0	0	NS	0	-
Feather pecking	0	0	0	0	NS	0	-
Strutting	0	0	0	0	NS	0	-
Aggression	0	0	0	0	NS	0	-
Other[5]	0	0	0	0	NS	0	-

[a,b,c] Means with common letters within a main effect do not differ significantly ($P \leq 0.05$).
[1] Means represent the average response of four replicate rooms each containing three pens of males (20 birds)/daylength treatment.
[2] Pooled standard error of the mean.
[3] Regression considered significant if $P \leq 0.05$.
[4] Env. Pecking = environmental pecking (cage, wall, litter).
[5] Other = behaviours at low frequency (dustbathing, wing flapping, feather ruffle, and scratching).