BROILER

ROSS TECH

Lighting for Broilers

2010

ROSS

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DR. HANK CLASSEN - Hank Classen was born and raised in rural Saskatchewan, Canada. He received his undergraduate degree at the University of Saskatchewan and then completed master's and doctorate degrees at the University of Massachusetts in the United States. After a brief stay on faculty at The Pennsylvania State University, he returned to the Department of Animal and Poultry Science at the University of Saskatchewan where he is currently professor and department head.

Dr. Classen's teaching and research responsibilities are primarily in the areas of poultry nutrition and management. His nutritional research has focused on feed ingredients and feeding programs for broilers and laying hens. Management research has emphasized animal welfare issues including the impact of light (broilers), beak trimming (laying hens), nutritional manipulation of behavior (laying hens, broiler breeders) and transportation (broilers).

As a result of his research and interaction with the industry, he has received the Award for Distinction in Outreach and Engagement (2008), the designation as Fellow of the Poultry Science Association (2007), the Award of Innovation (2004), the Alberta Poultry Serviceman of the Year (1994) and the American Feed Industry Association Nutrition Research Award (1993).

Dr. Classen has served as president of the World's Poultry Science Association - Canada Branch and the Poultry Science Association as well as serving as a director for both organizations.

SUMMARY

Traditionally, it has been assumed that using long daylengths for broilers will maximize growth rate. However, recent research examining the relationship between daylength and a range of characteristics in commercial broilers has shown that this is not always correct. This document gives updated information on the response of broilers (production, meat yield and welfare parameters) to daylength.

The key points are:

- **The response to daylength does not differ between strains or sexes.**
- **Broiler performance is not optimized by providing 23 hours of light and this lighting program is not recommended.**
- **Providing broilers with 23 hours of light has a negative effect on**
  - **growth rate**
  - **feed intake**
  - **mortality**
  - **processing performance**
  - **broiler welfare**
- **Broiler performance and welfare are optimized when between 17 and 20 hours of light are given.**

Please Note: The following abbreviation applies to this document.

L = Hours of Light

INTRODUCTION

Light is an important management technique in broiler production and is composed of at least three aspects, light wavelength, light intensity and photoperiod length and distribution. The latter aspects can be considered independently but are known to have interactive effects. By far the most research on broiler lighting has been devoted to the impact of photoperiod length and distribution. Traditionally, it has been assumed that using long daylengths in management schemes allowed maximum feeding time and, as a consequence, maximum growth rate. A joint research program between Aviagen and the University of Saskatchewan examined the relationship between darkness exposure and a range of characteristics in commercial broilers. The documents associated with this research will describe the impact of 14 (14L), 17 (17L), 20 (20L) and 23 (23L) hours of light per day with all darkness provided in one period on broiler production and meat yield parameters, welfare and bird health.

MATERIALS AND METHODS

Four trials were conducted to study the effect of daylength, broiler sex and strain and their interactions on production parameters in broilers. **Table 1** summarizes the final ages and stocking densities used in the trials. A total of just over 16,000 broilers were included in these trials. Two strains were tested (Ross x Ross 308 and Ross x Ross 708) in each trial and sexes were housed separately. Statistical analysis failed to demonstrate major strain by lighting program or strain by sex interactions on traits measured. The lack of interactions indicates that the two strains and sexes react similarly to lighting changes and therefore, this report focuses primarily on lighting effects.

Table 1: Experimental details.

Trial Number	Total Bird Numbers	Slaughter Age	Maximum Final Stocking Density
1	5040	31 or 39 days	24 kg/m^2
2	4464	39 or 49 days	30 kg/m^2
3	3712	39 days	30 kg/m^2
4	2912	48 days	30 kg/m^2

Lighting program treatments consisted of graded amounts of daylength to allow the description of relationships between daylength and particular production traits. The lighting treatments were 14 (14L), 17 (17L), 20 (20L) and 23 (23L) hours of light per day with all darkness provided in one period. All birds were exposed to 23L with 20 lux (2 foot candles[fc]) light intensity until 7 days of age when they were placed on experimental lighting treatments. The light intensity was reduced to 8 lux (0.8 fc) at the same time. Light intensity was measured at bird height at the center of the middle pen within each room on the day of chick placement and again at the initiation of lighting programs at 7 days of age. Experimental rooms had light traps on fans and inlets to eliminate light entry. The light source was incandescent bulbs.

The research was completed in eight environmentally independent rooms each subdivided into 12 pens (6 pens of males (53 males per pen) and 6 pens of females (63 females per pen)) and environmental conditions were similar to commercial settings. Each lighting program was replicated in two rooms in each trial. The broiler chicks were hatched in a commercial hatchery. Wheat straw was used as litter material in cleaned and disinfected pens in trials 1 and 2, while reused wheat straw based litter was used in trials 3 (reused 2 times) and 4 (reused 3 times). Room temperature followed standard industry practice with a gradual reduction from brooding temperatures to 22°C (72°F). Feed (1 tube feeder per pen; 0 to 24 days – 110 cm (44 inch) circumference; 24 days to market – 137.5 cm (55 inch) circumference) and water (Lubing 4087 nipple drinkers with 6 nipples per pen) were provided on an ad libitum basis. Feed allocation was based on the number of birds placed and provided 0.5 kg (1.1 lb) Starter (crumbled form), 2 kg (4.4 lb) Grower (crumble) and the balance of feed as Finisher 1 (pellet). For birds grown to 49 days of age, 1.6 kg (3.5 lb) of Finisher 1 was fed, and Finisher 2 was subsequently fed until the end of the trial. All diets were primarily based on corn and soybean meal. See **Table 2** for diet and nutrient specifications for trials 1 and 2, and **Table 3** for trials 3 and 4.

Table 2: Composition of diets used in trials 1 and 2 of the lighting research.

Ingredients: (%)	Starter	Grower	Finisher 1	Finisher 2
Corn	54.16	58.77	64.17	67.83
Soybean meal	37.60	32.70	27.50	24.80
Canola oil	3.25	4.00	4.00	3.35
Di-calcium phosphate	1.92	1.72	1.62	1.40
Limestone	1.56	1.41	1.36	1.24
Salt	0.35	0.37	0.36	0.33
Vitamin/Mineral premix[1,2]	0.19	0.19	0.19	0.14
Choline chloride[3]	0.07	0.09	0.11	0.12
DL-Methionine	0.28	0.23	0.17	0.20
L-Threonine	0.02	0.01	0.00	0.03
L-Lysine HCL	0.17	0.11	0.11	0.15
Pro-Bond (Pea starch)	0.26	0.15	0.15	0.15
Sodium bicarbonate	0.22	0.20	0.21	0.22
Bio-cox 120	0.06	0.06	0.06	0.06
Rovomix E50[4]	0.0004	0.0004	0.0004	0
Nutrients: (%)	**Starter**	**Grower**	**Finisher 1**	**Finisher 2**
AME (kcal/kg)[5]	3050	3149	3200	3200
Crude protein	22.0	20.0	18.0	17.1
Calcium	1.00	0.90	0.85	0.76
Non-phytate phosphorus	0.50	0.45	0.42	0.37
Sodium	0.21	0.21	0.21	0.20
Arginine	1.51	1.36	1.20	1.121
Lysine	1.38	1.20	1.06	1.021
Methionine	0.62	0.55	0.47	0.481
Total sulphur amino acids	1.030	0.920	0.840	0.760
Threonine	0.88	0.79	0.70	0.691
Tryptophan	0.31	0.28	0.24	0.223

[1] Supplied per kilogram of diet: vitamin A, 9425 IU; vitamin D, 3055 IU; vitamin E, 50 IU; vitamin K, 1.43 mg; thiamine, 1.95 mg; riboflavin, 6.5 mg; niacin, 65 mg; pyridoxine, 3.25 mg; vitamin B12, 0.013 mg; pantothenic acid,13.0 mg; folic acid, 1.1 mg; biotin, 0.163 mg and antioxidant, 0.081 mg.
[2] Supplied per kilogram of diet: iron, 55 mg; zinc, 60.5 mg; manganese, 74 mg; copper, 5.5 mg; iodine, 0.72 mg; and selenium, 0.3 mg.
[3] The concentration of choline in the choline chloride premix is 60%.
[4] The E concentration of Rovomix E50 is 500 IU/gram.
[5] National Research Council 1994.

Table 3: Composition of diets used in trials 3 and 4 of the lighting research.

Ingredients: (%)	**Starter**	**Grower**	**Finisher 1**	**Finisher 2**
Corn	54.3	58.7	64.3	67.29
Soybean meal	37.5	32.62	27.47	25.40
Canola oil	3.3	4.15	4.10	3.35
Di-calcium phosphate	1.92	1.72	1.57	1.39
Limestone	1.58	1.40	1.39	1.24
Salt	0.361	0.368	0.346	0.330
Vitamin/Mineral Premix[1,2]	0.126	0.127	0.127	0.127
Choline chloride[3]	0.018	0.086	0.098	0.119
DL-Methionine	0.324	0.264	0.234	0.198
L-Threonine	0.083	0.051	0.041	0.031
L-Lysine HCL	0.173	0.112	0.007	0.146
Pro-Bond (Pea starch)	0.150	0.150	0.150	0.150
Sodium bicarbonate	0.210	0.200	0.200	0.220
Rovomix E50[4]	0.004	0.004	0.004	0.004
Nutrients: (%)	**Starter**	**Grower**	**Finisher 1**	**Finisher 2**
AME (kcal/kg)[5]	3060	3163	3212	3200
Crude protein	21.7	19.7	17.6	17.1
Calcium	1.00	0.89	0.85	0.76
Non-phytate phosphorus	0.50	0.45	0.41	0.37
Sodium	0.211	0.210	0.201	0.20
Arginine	1.511	1.358	1.200	1.121
Lysine	1.380	1.200	0.980	1.021
Methionine	0.665	0.582	0.528	0.481
Total sulphur amino acids	1.030	0.920	0.840	0.760
Threonine	0.940	0.830	0.740	0.691
Tryptophan	0.309	0.275	0.241	0.223

[1] Supplied per kilogram of diet: vitamin A, 9425 IU; vitamin D, 3055 IU; vitamin E, 50 IU; vitamin K, 1.43 mg; thiamine, 1.95 mg; riboflavin, 6.5 mg; niacin, 65 mg; pyridoxine, 3.25 mg; vitamin B12, 0.013 mg; pantothenic acid,13.0 mg; folic acid, 1.1 mg; biotin, 0.163 mg and antioxidant, 0.081 mg.
[2] Supplied per kilogram of diet: iron, 55 mg; zinc, 60.5 mg; manganese, 74 mg; copper, 5.5 mg; iodine, 0.72 mg; and selenium, 0.3 mg.
[3] The concentration of choline in the choline chloride premix is 60%.
[4] The E concentration of Rovomix E50 is 500 IU/gram.
[5] National Research Council 1994.

Body weights and remaining feed were recorded at 0, 7, 31/32, 38/39 and for trials lasting longer, at 48/49 days of age, allowing feed efficiency, both with and without mortality correction, to be calculated. The flocks were examined on a daily basis and birds exhibiting signs of pain were euthanized. Mortality was collected twice per day, weighed, and along with culled birds, submitted for necropsy to determine the cause of death or morbidity.

For meat yield evaluation, randomly selected birds were double wing banded and individually weighed after feed (4 hours) and water (additional 2 hours) withdrawal. They were then sent to a commercial processing company for slaughter. Carcasses were retrieved at the processing plant, packed in ice and sent back to the University of Saskatchewan for the determination of meat yield. For each evaluation (within an age and experiment), 28 to 32 males and 28 to 32 females per genotype x lighting treatment subclass were dissected. Meat yield examination included measurement of breast (skin, Pectoralis major and Pectoralis minor), intact right thigh, left thigh (skin, meat, bone), intact right drum, left drum (skin, meat, bone), wings, abdominal fat and back/rack (remainder of carcass).

The statistical approach used in analyzing the data from this research was a 4 (daylength) x 2 (gender) x 2 (genotype) factorial arrangement with experiments considered blocks; lighting treatments were nested within room. A General Linear Model in SAS (Proc GLM of SAS) was used for analysis of variance, Duncan's Mean Test for mean separation and Regression (Proc Reg) and Response Surface Regression (Proc RSReg) for regression analysis. Percentage data was (log+1) transformed prior to analysis to normalize distribution. Differences were considered significant when the probability was less than 5% unless otherwise specified.

Key Points

- Four trials were conducted to determine the effect of daylength, broiler sex and strain on production parameters in broilers.
- Two strains were tested (Ross 308 and Ross 708) and sexes were housed separately.
- The lighting treatments were 14 hours of light, 17 hours of light, 20 hours of light and 23 hours of light per day, with all darkness provided in one period.
- All birds received 23 hours of light at 20 lux for the first 7 days.
- Diets were primarily a corn/soybean meal mix. The Starter was crumbled, the Grower was a crumble and the Finisher was pellets.
- Body weights and feed intake were recorded at 0, 7, 31/32, 38/39 and 48/49 days of age.
- FCR (feed:gain) was calculated with and without correction for mortality.
- Meat yield evaluation was completed at the University of Saskatchewan after the birds had been slaughtered at a commercial processing plant.
- There was no difference in the way the two strains or the sexes responded to lighting. The focus of this report is the influence of lighting on 'average' broiler performance.

INFLUENCE OF DAYLENGTH ON BROILER PRODUCTION AND MEAT YIELD

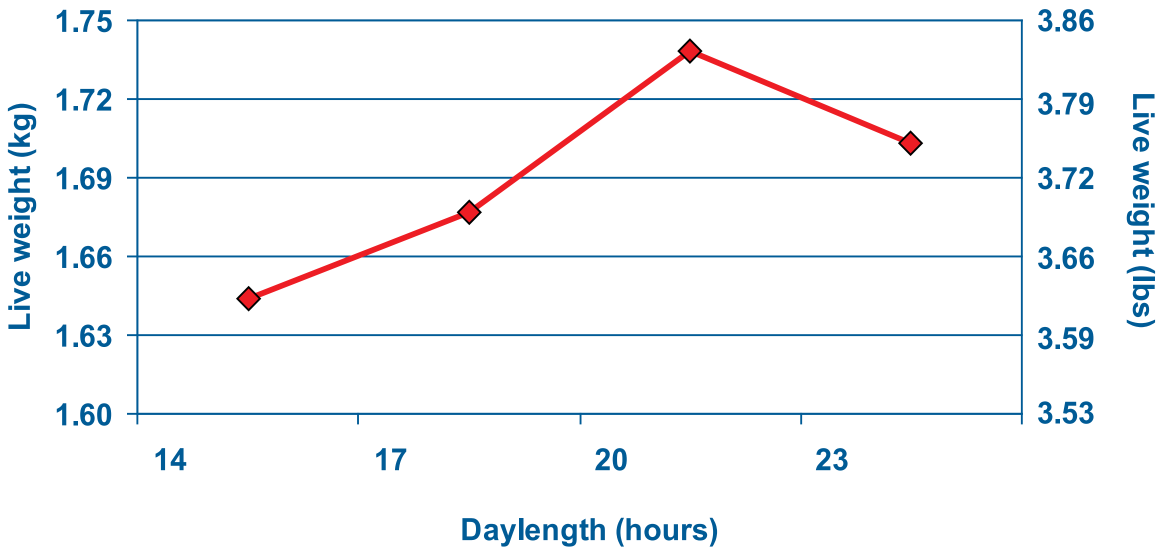
This section will describe the impact of 14 (14L), 17 (17L), 20 (20L) and 23 (23L) hours of light per day with all darkness provided in one period on production and meat yield parameters.

Growth Rate

Chicks used in these experiments had an average initial weight of 42 grams across lighting treatments and experiments. Growth rate was high in all experiments with values approximately 15% higher than published Ross broiler performance objectives.

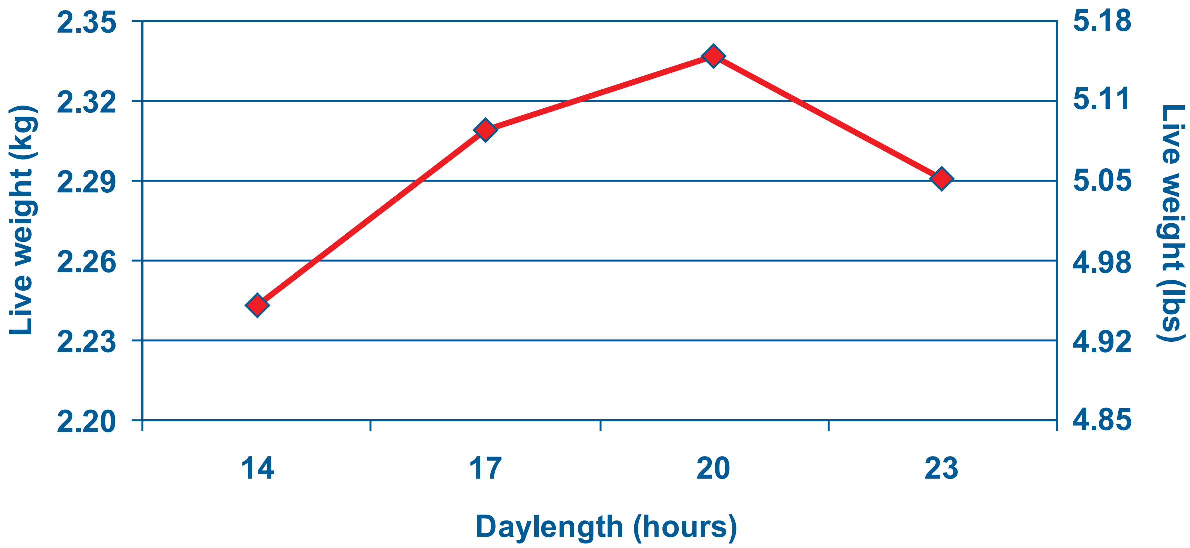
The number of hours of daylength had an important impact on growth rate and the effects were dependent on age at marketing. At 31/32 days, body weight responded to daylength in a quadratic manner - with a significant peak in body weight at 20L (**Figure 1**). This challenges the paradigm that constant or near-constant light results in highest body weights for birds marketed at younger ages. Decreasing daylength to less than 20L reduces body weight. Even at this early market age, broilers given 17L were not significantly different in growth rate in comparison to birds given 23L.

Figure 1: Effect of daylength on body weight at 31/32 days of age.



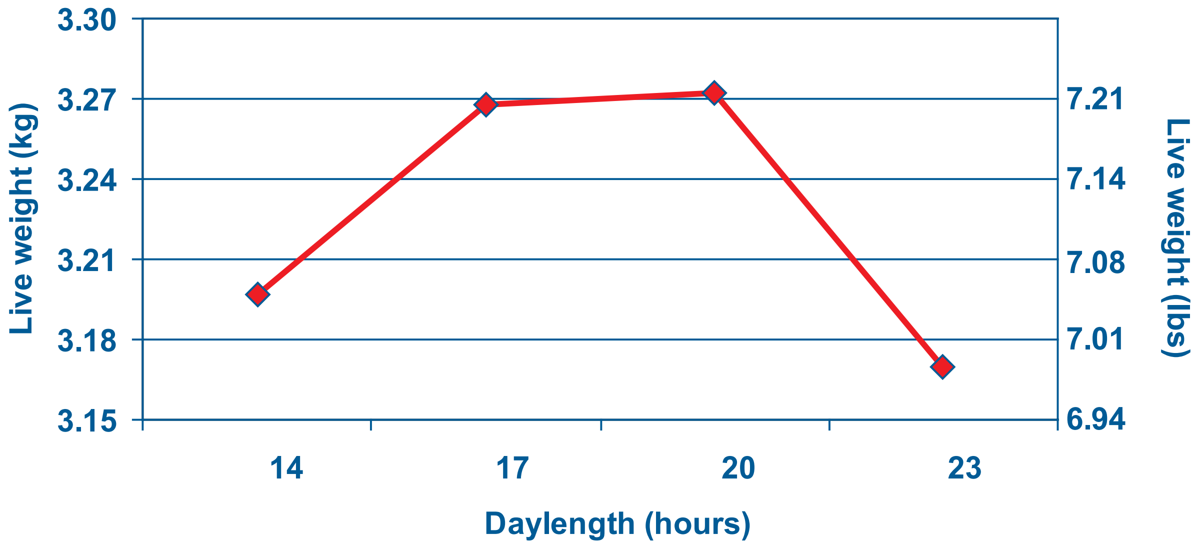
For birds reared to 38/39 days, a similar trend exists (**Figure 2**). Again quadratic in nature, the heaviest weights were achieved with 20L with lower values on either side of this point. The 23L treatment actually resulted in numerically lower weights than those provided with 17L - indicating that as birds age they adapt, given sufficient time and can modify their feeding behavior to compensate for shorter days and longer dark periods.

Figure 2: Effect of daylength on body weight at 38/39 days of age.



When birds were grown to heavier weights, (approx. 3.2 kg at 48/49 days), increasing the length of the dark period was beneficial. Maximum body weight was achieved for broilers given 17L and 20L treatments. Birds given 14L demonstrated compensatory growth and were equal in weight to those raised on 23L (**Figure 3**). In conclusion, broilers raised to older market weights have more opportunity to compensate for a reduction in growth rate earlier in life due to shorter daylength.

Figure 3: Effect of daylength on body weight at 48/49 days of age.



Key Points

- Hours of daylength have an important impact on growth rate with the effects being dependent upon marketing age.
- Providing broilers with 20 hours of light a day gave the highest growth rate at all ages.
- As birds age they are able to adapt to shorter daylengths. Broilers marketed at older ages perform relatively better on shorter daylengths than birds marketed at younger ages.
- Short daylengths (i.e. 14 hours of light) lead to a reduced growth rate regardless of market age.
- Increasing daylength to 23 hours a day also has a negative impact on growth rate. The data from this trial do not support the idea that providing near constant light (23 hours) will achieve the highest growth rates.

Feed Consumption

Feed consumption is also affected by daylength (**Table 4**). In general, the feed consumption response looks very much like that for growth rate. For all marketing ages, broilers given 20L ate more than other treatments. As with growth rate, the comparison of 20L to 23L does not support the belief of many that more time for feeding always results in more feed intake. Since broilers prefer to eat during the day, it is expected that broilers given days shorter than 20L would eat less and the data support this concept. As mentioned for growth rate, the results also show that broilers adjust their eating behavior to compensate for the shorter daylength as they get older. Although the concept of bigger birds eating more and smaller birds eating less is shown at smaller market ages (0-31/32 days), this is not necessarily the case in birds marketed later. For example, birds given 14L gained the same weight from 0 to 48/49 days as 23L birds, but ate significantly less feed. For the same marketing age, the 17L birds ate less than 20L broilers despite the fact that they gained the same weight. This difference relates to better feed efficiency for broilers given a shorter day and longer night period.

Table 4: Effect of daylength on feed consumption (kg/bird).

	Lighting Program				SEM
	14L:10D	17L:7D	20L:4D	23L:1D	
0-31/32 days	2.43^{D}	2.57^{C}	2.68^{A}	2.61^{B}	0.013
0-38/39 days	3.58^{C}	3.75^{B}	3.87^{A}	3.78^{B}	0.020
0-48/49 days	5.69^{C}	5.94^{B}	6.15^{A}	5.89^{B}	0.057

^{ABCD} Means with different superscripts within an age are significantly different ($P < 0.05$)

Key Points

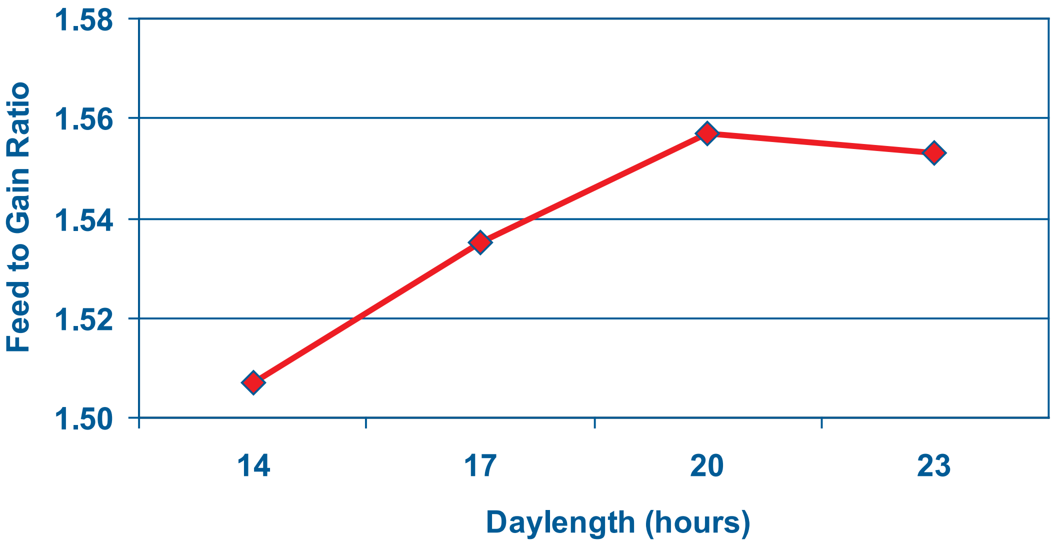
- Feed intake was highest in broilers given 20 hours of light a day. There was a marked and significant reduction in feed intake when daylength was decreased below or increased above this.
- Broilers adjust eating behavior to compensate for shorter daylengths as they get older.
- In birds marketed at older ages (48/49 days) differences in feed intake are not related to body weight gain, but are the result of improved feed efficiency when shorter days and longer nights are given (see below).
- Feed intake data does not provide support for the idea that near constant light (23 hours of light a day) will result in an increased feed intake by allowing maximum feeding time.

Feed Efficiency

Feed to Gain Ratio

Feed to gain ratio (F:G) is a common method of assessing feed efficiency in the broiler industry and the effects of daylength on this characteristic, without mortality or body weight correction, are shown on **Figures 4**, **5** and **6**. F:G for 0-31/32 days improved quadratically with decreasing daylength, so that the most efficient birds were raised under 14L (**Figure 4**). F:G of birds on 20L and 23L are similar.

Figure 4: Effect of daylength on feed to gain ratio of broilers from 0 to 31/32 days of age.



The data for 0-38/39 days are similar (**Figure 5**). The response is again quadratic and decreasing daylength improves F:G. The effect of daylength is not related to body-weight gain as birds raised on 23L were the same weight as birds given 17L, yet 17L results in a significant improvement in F:G.

Figure 5: Effect of daylength on feed to gain ratio of broilers from 0 to 38/39 days of age.

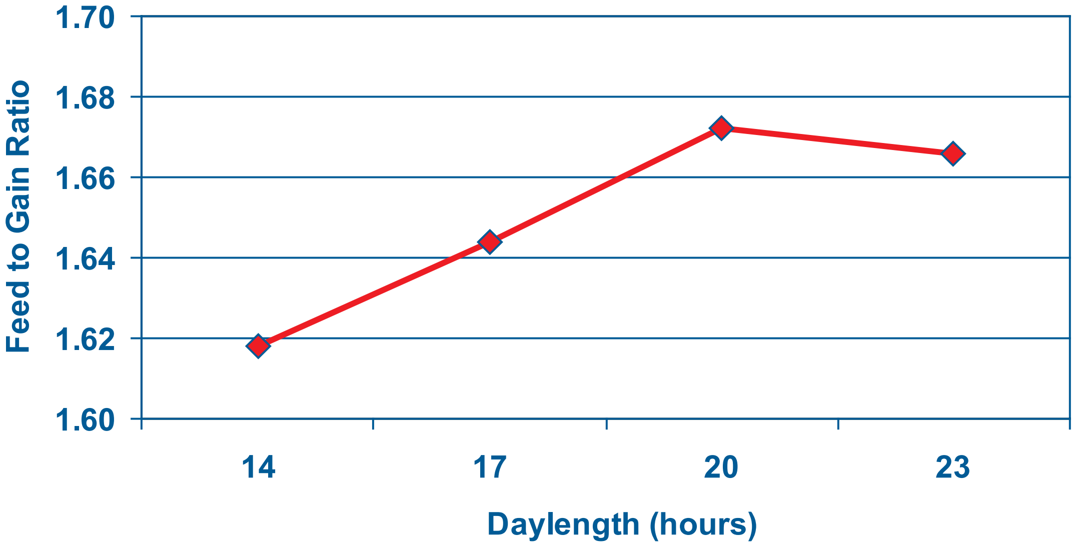
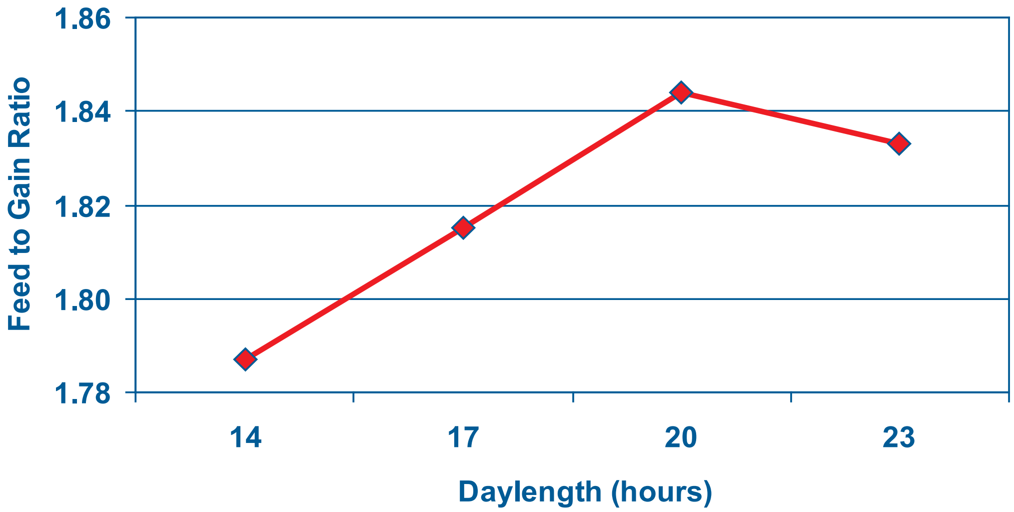


Figure 6 shows the data for the market age of 0-48/49 days. The shape of the curve is similar to other market ages and again the improvement in F:G for shorter daylengths is not due to a difference in growth rate as both 14L and 17L broilers were equal to or greater in weight than the 23L birds.

Figure 6: Effect of daylength on feed to gain ratio of broilers from 0 to 48/49 days of age.



This research did not establish the reason for the beneficial effect of short daylength on F:G but it can help define potential mechanisms which include an impact on mortality, changes in maintenance requirements associated with activity and changes in bird metabolism during the dark period. Mortality effects are described below and are partially responsible for the beneficial effect of daylength on F:G. However, the beneficial effect remains even after the results are corrected for the weight of dead and culled birds. Based on the findings of other data collected in this research (see welfare section), the effect is not due to bird activity. Even when darkness was included in the total behavioral assessment, birds on short daylength are in fact more active than those on longer days. Another possible reason for the improved F:G is the reduced maintenance requirement associated with lower metabolism that is known to occur during darkness.

Key Points:

- **Feed efficiency is improved with decreasing daylength (longer night periods); the best feed efficiency occurred when broilers were given 14 hours of light regardless of market age.**
- **This improvement in feed efficiency is not due to differences in body-weight gain but may be due to reduced maintenance requirements as a result of the lower metabolism that occurs during darkness.**

Feed to Gain (mortality corrected)

Feed to gain ratio is the primary method of assessing feed efficiency in industry but in science, it can be useful to look at F:G corrected for the weight of mortality and culling. In this method, the weight of dead and culled birds is added to the live-weight gain and therefore results in an assessment of F:G that is independent of the incidence of mortality. The data for F:G mortality corrected are shown in **Figures 7**, **8** and **9** and are very similar to that for F:G. These results demonstrate that the broilers exposed to shorter daylength are more efficient independent of mortality.

Figure 7: Effect of daylength on feed to gain ratio (mortality corrected) of broilers from 0 to 31/32 days of age.

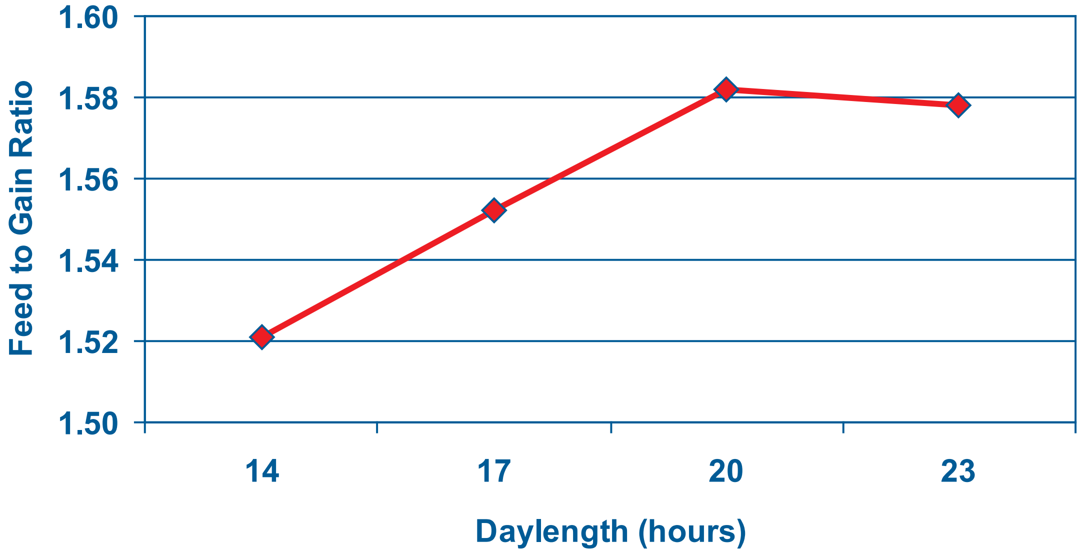


Figure 8: Effect of daylength on feed to gain ratio (mortality corrected) of broilers from 0 to 38/39 days of age.

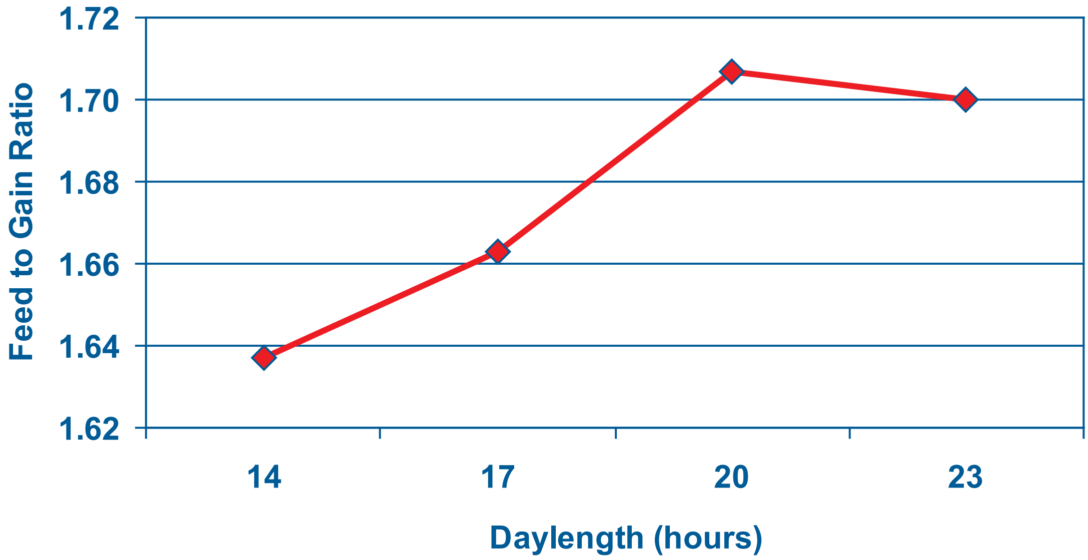
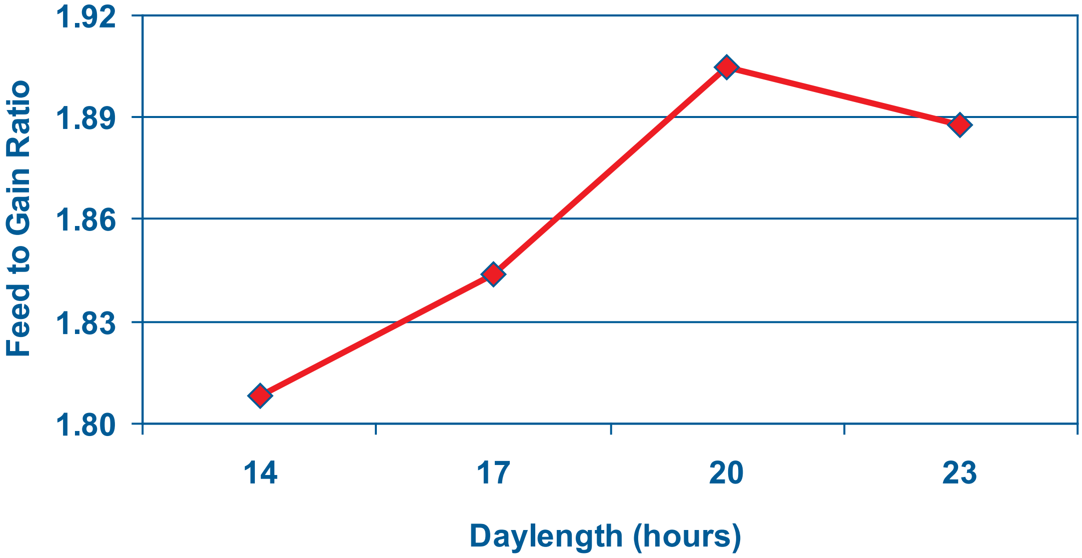


Figure 9: Effect of daylength on feed to gain ratio (mortality corrected) of broilers from 0 to 48/49 days of age.



Key Point

- **The benefits of shorter days on feed conversion efficiency are independent of mortality.**

Mortality

The effect of daylength on the percentage of mortality and culls from 7 to 31/32, 38/39 and 48/49 days are shown in **Figures 10**, **11** and **12**. The data show that daylength has a linear impact on mortality and culls in a broiler flock. Reducing daylength results in less mortality and culls, regardless of slaughter age. It is noteworthy that reducing daylength below 17L did not result in a further reduction in mortality. Differences in mortality are primarily due to the incidence of sudden death syndrome, leg weakness and to a lesser degree bacterial infectious processes.

Figure 10: Effect of daylength on the incidence (%) of mortality and culls from 7 to 31/32 days of age.

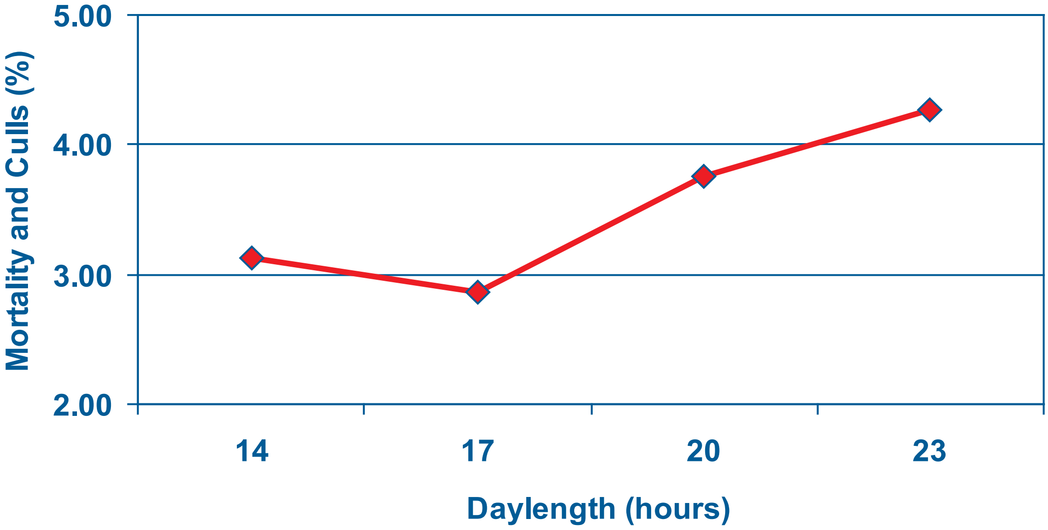


Figure 11: Effect of daylength on the incidence (%) mortality and culls from 7 to 38/39 days of age.

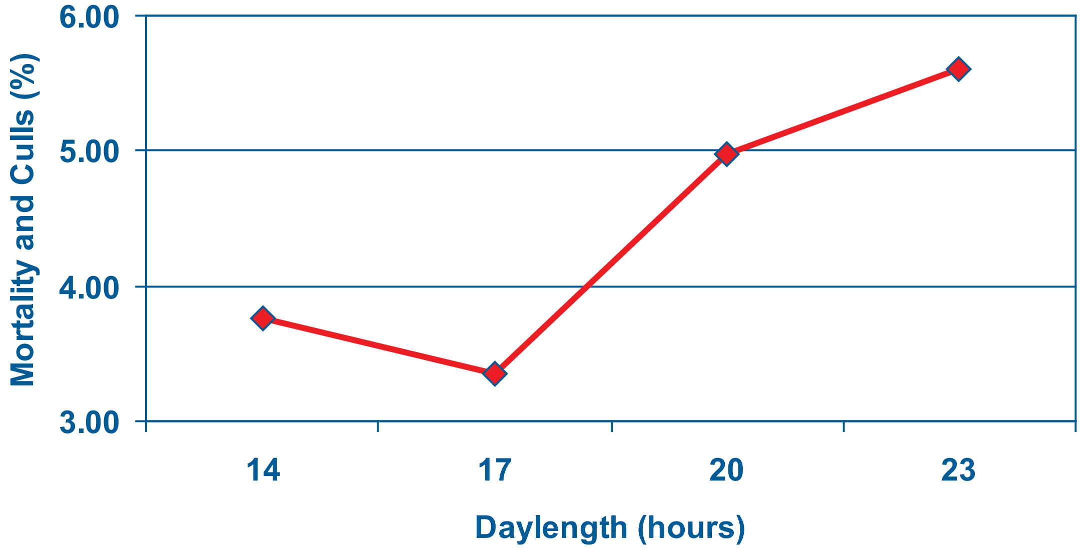
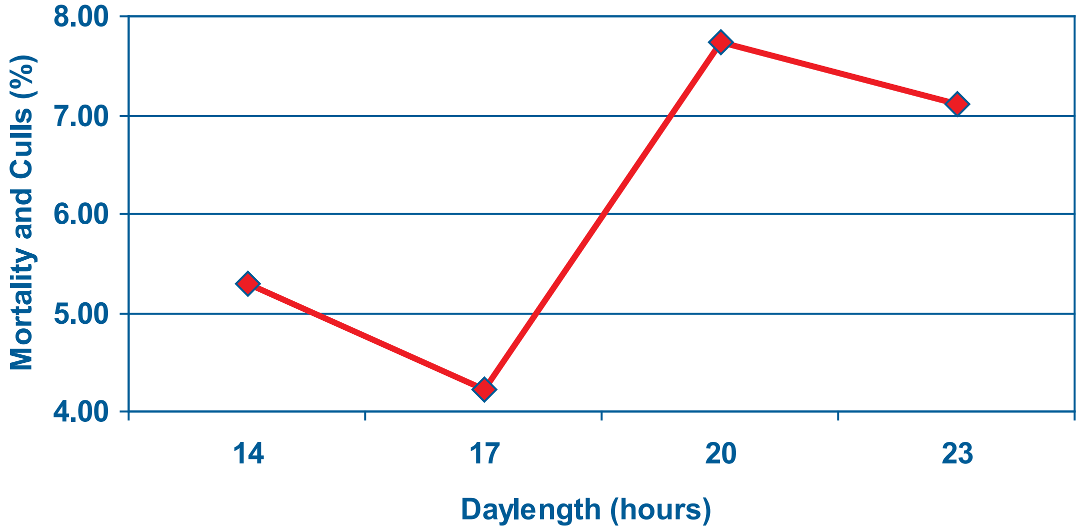


Figure 12: Effect of daylength on the incidence (%) of mortality and culls from 7 to 48/49 days of age.



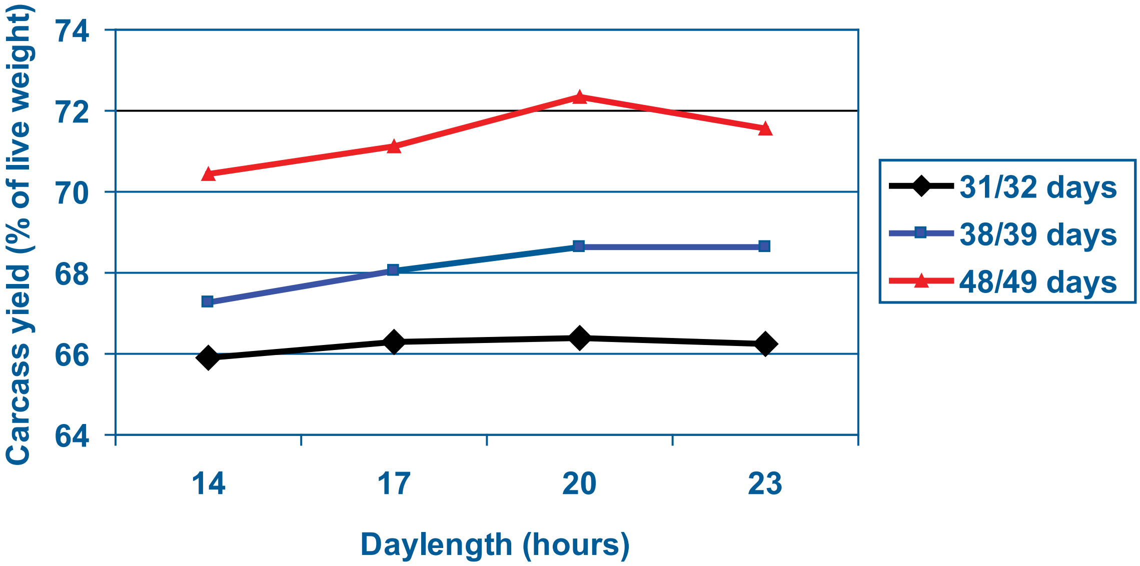
Key Points

- **Reducing daylength results in less mortality regardless of slaughter age.**
- **However, there are no further benefits to mortality of reducing daylength to less than 17 hours of light.**

Meat Yield

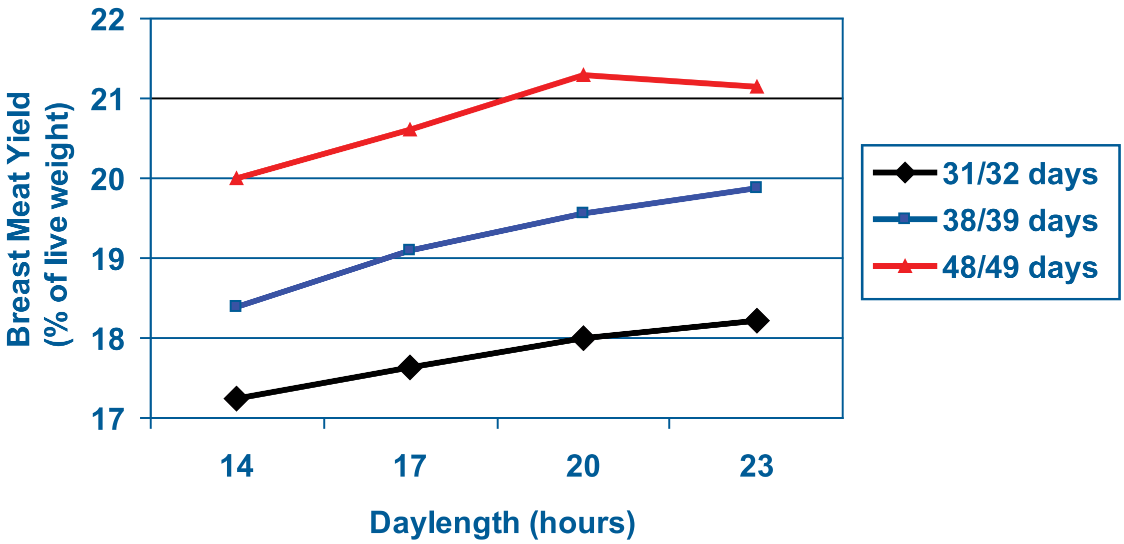
Lighting had a major impact on meat yield with the impact partially age dependent. At 31/32 days of age lighting did not affect carcass yield but it increased with increasing daylength at 38/39 (linear) and 48/49 (quadratic) days of the age (**Figure 13**). The data also clearly demonstrate that carcass yield increases with broiler age.

Figure 13: Effect of daylength and age on carcass yield (% of live weight) of broiler chickens.



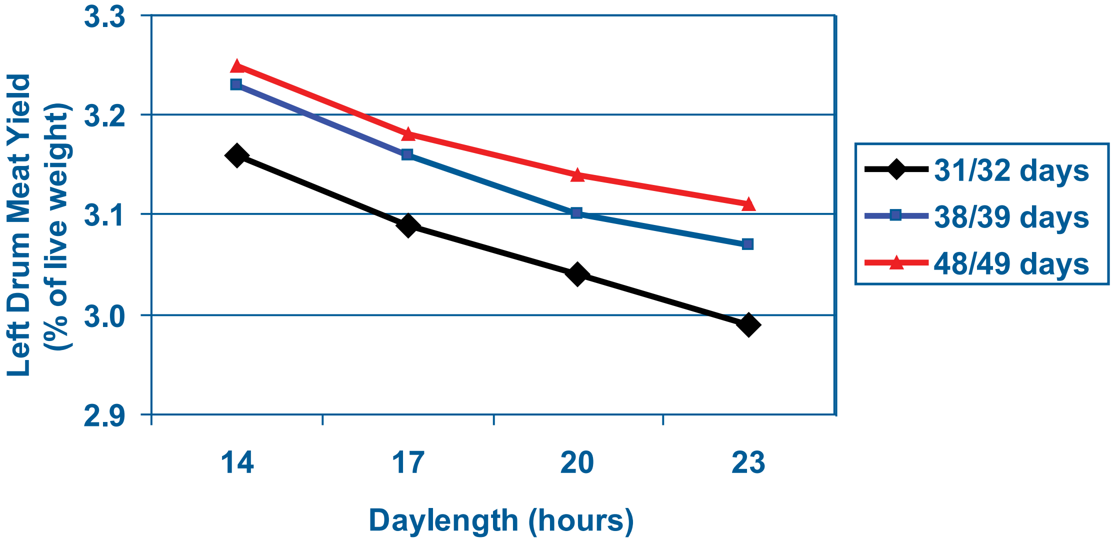
An important and consistent effect of daylength on meat yield was found for breast meat (Pectoralis major, Pectoralis minor and total). For all ages examined, breast meat yield increased with daylength (**Figure 14**). As with carcass yield, the relationship changed with age. At 31/32 and 38/39 days, the relationship is linear while at 48/49 days it is quadratic with broilers given 20 and 23 hours of daylength equal in yield. Breast meat yield increased with broiler age.

Figure 14: Effect of daylength and age on breast meat yield (% of live weight) of broiler chickens.



Although not as definitive as the increase in breast meat yield, increasing daylength tended to reduce the percentage of leg portions and in particular left drum meat yield which reduced linearly at all ages (**Figure 15**).

Figure 15: Effect of daylength and age on left drum meat yield (% of live weight) of broiler chickens.



Carcass fat is also an important characteristic but the current data do not allow for an easy assessment. As noted in the **Materials and Methods** section, abdominal fat is not a good indicator because of the processing technique, but other yield criteria can be used for interpretation. Some of the fat deposited by broilers is subcutaneous and this fat is mostly retained with the skin during the meat yield process. Therefore, proportionally heavier breast skin should be an indicator of a fatter carcass. Examination of the value for breast skin indicates that females have heavier weight than males. It is well established that females are slightly fatter than males and therefore this finding is what would be expected. This suggests that breast skin is a reasonable alternative for abdominal fat. Daylength does not affect breast skin and this can be interpreted that daylength does not have a major effect on carcass fat.

Key Points

- **Carcass yield was not affected by daylength in broilers marketed early (31/32 days). At older marketing ages (38/39 and 48/49 days) carcass yield was found to increase with increasing daylength.**
- **Breast yield was increased with daylength. But in older birds (those marketed at 48/49 days) there was no benefit of increasing daylength beyond 20 hours of light.**
- **Increasing daylength led to a linear reduction in drum meat yield.**
- **Daylength did not affect carcass fat content.**

Conclusions - Influence of Daylength on Broiler Production and Meat Yield

The daylength used in lighting programs can have important consequences on the growth and meat yield of broiler chickens. It can also affect welfare as indicated by the increase in the incidence of mortality and culls with increasing daylength. Broiler performance is not optimized at 23 hours of daylength regardless of the nature of the performance indicator and is not recommended. Growth is maximized at 20L at younger ages but in older broilers, the optimum appears to be between 17 and 20 hours. Feed efficiency is improved with more darkness within the range studied in this research. Shorter daylengths reduce mortality and the data indicate no improvement when 14 hours of daylength is compared to 17 hours. Meat yield is negatively affected by shorter daylength with particularly important effects on carcass and breast meat yield. The diversity of daylength effects makes selection of one lighting program for all broiler production situations impossible. Selection of lighting programs based on performance and meat yield indices must therefore consider a number of factors before a decision is reached.

Many factors need to be considered when selecting the right lighting program. The nature of the market (e.g. whole carcass, cut up, further processed) and age when birds are marketed are key factors. For example, the economic consequences of lighting on broilers slaughtered at a young age for cut up markets will be quite different than for birds raised an older market age for further processing. The cost of feed is another important factor with higher costs making the impact of daylength on feed efficiency much more important. The level and cost of mortality can vary among production systems and again can play an important role in establishing the right daylength.

Lighting programs also have the potential to interact with other management decisions and thus should preferably be considered together. A key aspect relates to feed intake. Since daylength has important physiological effects and can affect feed intake, factors that also affect feed intake need to be considered. For example, the negative effect of limited feeder space or higher than recommended housing density on feed intake may produce even poorer results when combined with short daylength. Similarly feeding a low energy feed or fed in mash form requires that birds have additional feeding time that should be considered when selecting a lighting program. The impact of lighting on health will also be more affected in rapidly growing birds than in those fed nutritionally limiting diets or in systems that slow growth below the Ross broiler performance objectives.

Key Points

- **Response to daylength will not differ between strains or sexes.**
- **Growth and feed intake are maximized at 20 hours of light.**
- **Birds marketed at older ages (48/49 days) are able to adapt to shorter daylengths and daylength can be reduced to 17 hours of light with no effect on the growth rate of these broilers.**
- **In birds slaughtered at younger ages (31/32 days) shorter daylengths (below 20 hours of light) will have a clear negative impact on growth rate and feed intake.**
- **Feed efficiency is improved with shorter daylengths.**
- **Mortality is improved with shorter daylengths but there is no benefit in reducing daylength beyond 17 hours of light.**
- **Longer daylengths have a positive effect on meat yield.**
- **Ultimately, it is difficult to recommend one lighting program for all broiler production situations but the data from this trial shows that:**
    - **broiler performance is likely to be optimized at a daylength of between 17 and 20 hours of light.**
    - **broiler performance is not optimized by providing 23 hours of light and this lighting program is not recommended as it has a negative effect on growth rate, feed intake, mortality and processing performance.**
    - **When considering lighting programs the following need to be taken into account:**
    - **market (whole carcass, cut up, etc.).**
    - **age at slaughter.**
    - **cost of feed and impact of daylength on feed efficiency.**
    - **feed intake and the negative effect of limited feeder space or high stocking densities will be compounded by a short daylength.**
    - **feed type - low density/mash feeds require increased feeding time and short daylengths will inhibit this and may reduce feed intake.**

INFLUENCE OF DAYLENGTH ON BROILER WELFARE

This section will describe the impact of 14 (14L), 17 (17L), 20 (20L) and 23 (23L) hours of light per day with all darkness provided in one period on broiler welfare and health.

Broiler Welfare

The domestication of animals and the historically more recent intensification of their production for human use bring with it the responsibility to care for animals in ways that provide for their welfare. This is recognized by those that produce animals as well as by consumers and society as a whole. As a result, codes of practice and in some cases governmental legislation are used to guide animal production towards higher standards of husbandry and welfare. It is generally accepted that science should guide codes and regulations but in many cases, research is not sufficiently detailed to assist with this process. As with other types of livestock, guidelines are also required for intensively grown broilers. Therefore, it is important to understand both the production and welfare effects of broiler management practices such as use of lighting programs. This section presents research that evaluates the impact of daylength on broiler welfare.

It is important to understand what is meant by “welfare”. There are many definitions but welfare assessment often has been suggested to fall into three main areas:

- Failure of an animal to cope with its environment
- Animal feelings
- Deviation from “normal” behavior

An animal’s welfare is said to be affected when it can no longer cope with its environment or other stressors. An inability to cope can manifest itself by physiological changes in the body and can include disease or stress responses. It can also show itself through behavioral changes. Specifically, when behaviors that are motivated to occur in the animal no longer occur or change in frequency, this can indicate that welfare is compromised. An animal’s feelings include pain, fear and stress, and can be difficult to measure but behavioral assessment can be useful for estimating an animal’s feelings. Finally, welfare has been said to be compromised if an animal does not perform behaviors that its wild ancestors did. For example, if a bird no longer forages, then this implies that the welfare is affected negatively. With a wide range of welfare definitions, it is not surprising that measuring welfare can be difficult. In most cases, a single indicator is insufficient to establish welfare and a more accurate assessment is derived from the evaluation of multiple criteria, including production, physiological and behavioral parameters.

The research in this report was designed to help establish the effect of daylength on broiler welfare using a variety of welfare measurements. Practical graded levels of daylength were chosen to allow prediction of daylength effects on broiler welfare. Experimental daylengths were 14 (14L), 17 (17L), 20 (20L) and 23 (23L) of light with all darkness provided in one period.

Key Points

- **It is important to understand the effects of lighting programs on both production and welfare if broiler management is to be optimized.**
- **The aim of this part of the research was to help establish the effect of daylength on broiler welfare using a variety of welfare measurements including production, physiological and behavioral parameters.**

Production

Assessing welfare should never be completely based on production alone. However, identifying declining production that occurs unexpectedly may be indicative of less than optimum welfare. The production information for these experiments has been discussed in detail in the previous section titled Influence of Daylength on Broiler Production and Meat Yield but it is important to include a brief description here.

Chickens prefer to eat during the day and will not eat during darkness unless the daylength is very short or another environmental or other factor causes a shift in eating behavior. Therefore, limiting the time that birds have visual access of feeders and waterers by using shorter daylengths has generally been found to reduce growth rate, especially at younger ages and our data concurs with this finding. For example, birds given 14 hours of daylength weighed less than birds on other daylengths at 31/32 days of age. In this situation, the reduction in growth rate can be explained by less time to eat and is not likely a welfare concern.

Constant or near-constant photoperiods were introduced into broiler production because the long daylength allowed virtually constant access to feed and water and as a consequence it was logically concluded that broiler growth would be maximum in comparison to birds given shorter days. This did not occur in our work. In our experiments, which gathered production data over four experiments at various ages on close to 16,000 broilers, birds raised on near-constant (23L) photoperiods never grew the fastest. The older broilers got, the more darkness could be added to the lighting program and still outperform the near-constant photoperiod (**Table 5**). See **Figures 1**, **2** and 3 in the Production and Meat Yield section. The failure of birds given 23L to grow as fast as birds given 20L at any age or 17L at 48/49 days of age is not expected because the birds were able to see feeders and drinkers and had free access. No other limiting factor in the 23L lighting program is obvious and therefore, the reduced body weight may be indicative of reduced welfare.

Table 5: Effect of daylength on broiler body weight (kg).

Market age (days)	Daylength (hours)			
	14	17	20	23
31/32	1.644^{C}	1.677^{B}	1.738^{A}	1.703^{B}
38/39	2.243^{C}	2.309^{B}	2.337^{A}	2.291^{B}
48/49	3.197^{B}	3.268^{A}	3.272^{A}	3.170^{B}

^{ABC} Means with different superscripts within an age are significantly different ($P<0.05$).

Key Points:

- **An unexpected/unexplained drop in production may indicate reduced welfare.**
- **Limiting the amount of time that birds have visual access to the feeders by reducing daylength generally leads to a reduction in growth rate. This effect is most obvious in young birds and can be explained by the birds having less time to eat.**
- **As they age broilers adapt to shorter daylengths and in older broilers (48/49 days) daylength can be reduced to 17 hours of light without negatively affecting growth rate.**
- **Giving near constant light (23 hours) despite providing virtually constant access to feed and water does not produce the best growth rates at any age.**
- **As there were no other limiting factors, it is concluded that the reduction in performance on 23 hours of light is indicative of poor welfare.**

Flock Mortality

An undeniable indicator of welfare in a commercial flock is mortality. In this work, as daylength increased, overall mortality increased linearly, regardless of the target weight or age of marketing (see **Figures 10**, **11** and **12** in the Production and Meat Yield section). Mortality then, is a clear indicator of a reduction in welfare with long lighting programs.

Combining the production data from above with the mortality data reveals an important association; birds reaching the heaviest weight did not have the highest mortality. Often, growth rate in broilers has been used to explain increasing mortality levels but these data show that rapid growth in itself is not the only factor affecting mortality in a high health flock and indicates that metabolic factors play a role as well.

Key Points

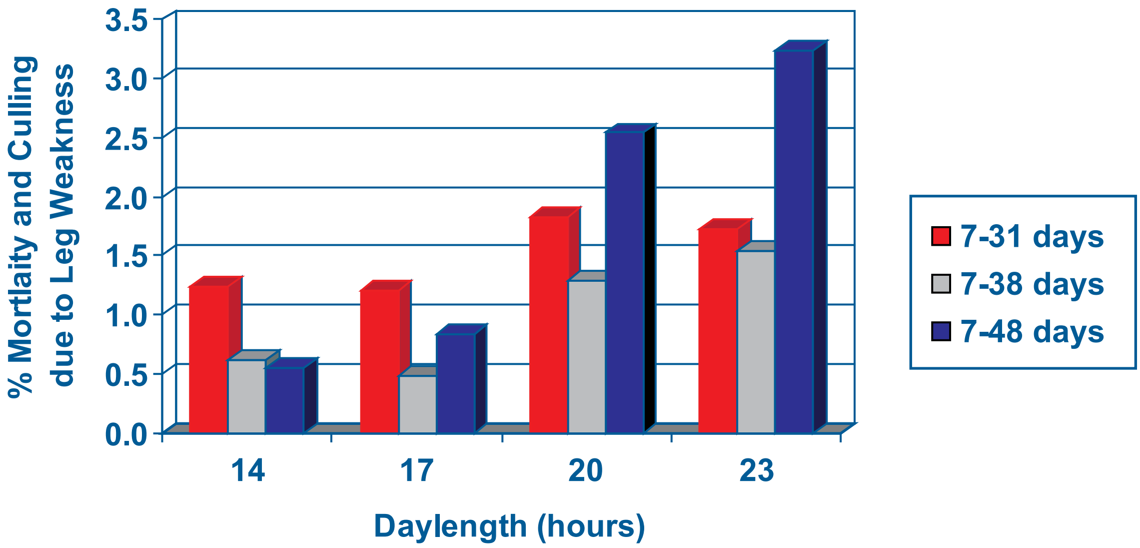
- **Morality increased with increasing daylength regardless of target weight or marketing age, indicating a negative impact of long days on bird welfare.**
- **Birds that grew the fastest were not those with the highest mortality.**

Leg Weakness

Leg weakness is considered by many to be the most important welfare issue in commercial broiler production and it is recognized that birds with moderate to severe leg problems are in pain. Leg weakness may also affect the ability of broilers to feed and drink and this is also a welfare concern.

The incidence of leg weakness can be estimated by a number of techniques. The incidence of birds that are culled for leg issues or are found as mortalities in a flock is an important indicator. **Figure 16** shows the levels of mortality and culls due to leg weakness increased linearly with increasing daylength. Birds raised under 23L have the highest incidence even though they do not grow the fastest, and in the case of the 48-49 day old birds, 23L birds grow at the same rate as broilers given 14L which had much lower levels of mortality or culls due to leg weakness.

Figure 16: Effect of daylength on the incidence (%) of mortality and culling due to leg weakness.



While mortality and cull levels are important in determining leg weakness, there are likely to be birds remaining in a flock that do not die or are not culled but are still in pain. A method currently used to monitor this is "gait scoring". This is a technique that involves two individuals watching individual birds walk and then scoring their ability to walk based on published descriptions. The gait scoring system used in this work is demonstrated in **Table 6**. Previous research has shown that birds falling in the categories of 3, 4 and 5 are in pain so are considered a welfare concern.

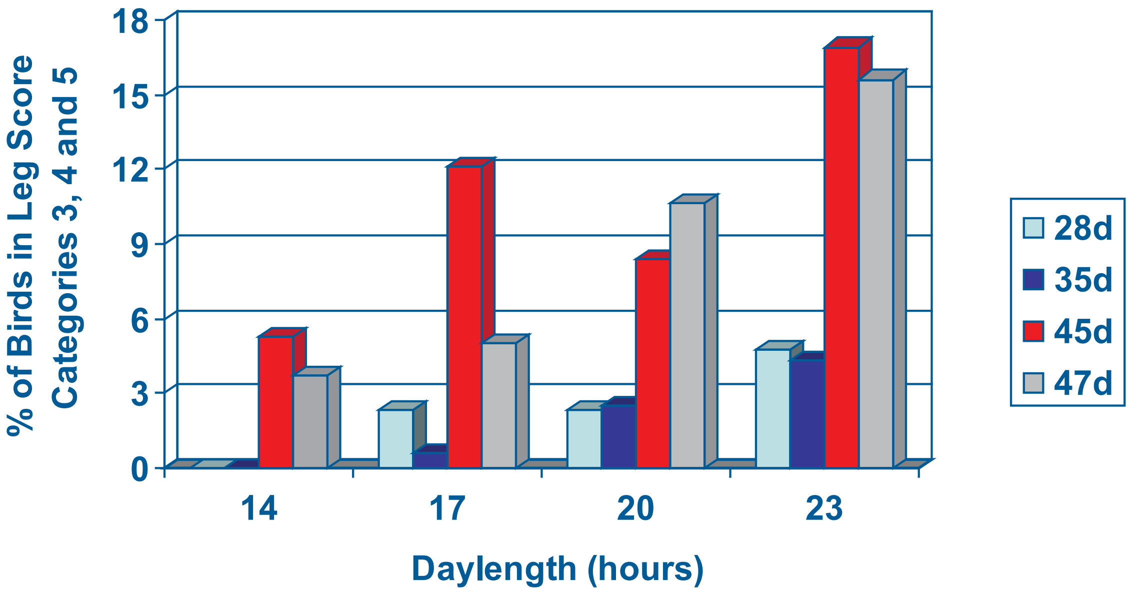
Table 6: Summary of gait scoring technique (Garner et al. 2002).

Gait Score	Description
0	**Normally walking bird**
1	**Detectable but unidentifiable abnormality**
2	**Identifiable abnormality, little impact on overall function**
3	**Identifiable abnormality which impairs function**
4	**Severe impairment of function but still capable of walking**
5	**Complete lameness**

Garner, J.P., Falcone, C., Wakenell, P., Martin, M. and Mench, J.A. 2002. Reliability and validity of a modified gait scoring system and its use in assessing tibial dyschondroplasia in broilers. Br. Poult. Sci. 43: 355-363.

A total of 3200 individual birds were observed at various ages (**Figure 17**). Similar to leg weakness mortality and culls, the relationship between daylength and percentage of birds falling in the upper categories (3 + 4 + 5) was linear and can be interpreted that long daylength is associated with more birds experiencing pain.

Figure 17: Effect of daylength on the sum of gait scores categories 3, 4, plus 5.



Key Points

- **Mortality and culls due to leg weakness are increased with increasing daylength.**
- **Broilers given 23 hours of light had the highest incidence of leg weakness despite not having the fastest growth rate.**
- **Broilers given 23 hours of light also had a higher incidence of leg weakness compared to birds given a shorter daylength but with the same growth rate.**
- **Leg scoring data (scoring birds on a scale of 0 to 5, where birds with scores of 3, 4 or 5 are considered to be in pain) showed that the number of birds considered to be in pain increased with increasing daylength.**

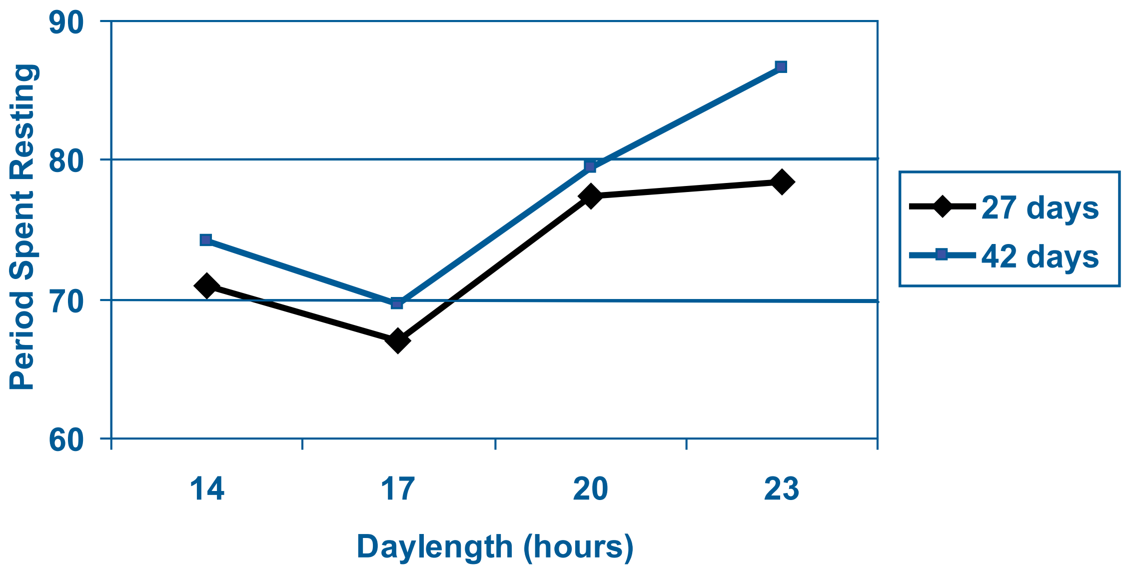
Behavior

Observations of animal behavior can be one of the most important tools in understanding how that animal copes with its environment. In this work, behavior was observed in birds at 27/28 days of age, and in a separate experiment, at 42/43 days of age. With the use of infrared capable cameras and infrared light sources, behavior was observed in both the light and dark period. The figures presented below represent a summarization of data collected by examining behavior at 10 minute intervals over a 24 hour period of time. In other words, the data shown below are the overall behavioral patterns (combination of light and dark periods). The effect of light on bird behavior daytime only is given in **Appendix 2**.

Resting and Sleeping

Resting was classified as birds that were lying on the straw. This classification included birds that were sleeping because it was not possible to accurately separate those that were sleeping from those that were not. At both 27/28 and 42/43 days of age, daylength affected the proportion of time that birds were resting with the proportion increasing with longer daylengths (**Figure 18**). At 42 days of age, birds on near constant light (23L) are actually inactive and resting for over 85% of the 24 hour period. These findings are quite significant because nearly all birds were classified as resting during dark periods. Therefore, the overall values for 14L, 17L, and 20L include 10, 7, and 4 hours of darkness, respectively, where the birds were nearly all resting. The increase in darkness and therefore resting behavior account for the slightly higher proportion of time birds given 14L spent resting in contrast to 17L broilers.

Figure 18: Effect of daylength on the percentage of time in a 24 hour period that birds spend resting.



Key Points

- **Time spent resting and sleeping increased with increasing daylength.**
- **Broilers given 23 hours of light a day spent a significant amount of time being inactive.**

Mobility Behaviors

Mobility behaviors are important indicators of bird health and well being and are essential for the proper growth and development of broiler chickens. For example, mobility is necessary for movement around the barn, accessing feeders and waterers and interacting with other birds. Further, research has suggested that lack of mobility plays a role in bone disease and leg weakness. The ability to perform mobility behaviors is also indicative of bird vigor.

Walking and running times (percent of 24 hours) were also affected by photoperiod (**Figures 19** and **20**) with the highest values for 17L birds and a significant decline as daylength increased. Regardless of the age, birds on the near-constant daylength spend very little time walking, and running was not observed. The finding that birds on the long photoperiods perform these behaviors at low levels or not at all is a welfare concern. But why does a long daylength cause these effects? Behavioral observation can't differentiate between the ability to move and a lack of initiative (desire) to move. As noted above, birds given the 23L had more mortality and culling due to leg weakness and poorer gait scores. While this may account for some of the difference in walking and running, the fact that a very high proportion of birds still had acceptable gait scores suggests that the reduced behavioral expression is related to a factor(s) that reduces the desire to move. While not proven, it is of interest to speculate on the role of sleep in affecting behavior in long daylengths. In other species, sleep deprivation is known to affect physiological and metabolic parameters as well as behavioral expression. The question that arises is whether birds under near-constant light can sleep enough in total or in long enough continuous periods. Previous research has shown that sleep is disrupted in the commercial broiler setting by bird movement.

Figure 19: Effect of daylength on the percentage of time in a 24 hour period that birds spend walking.

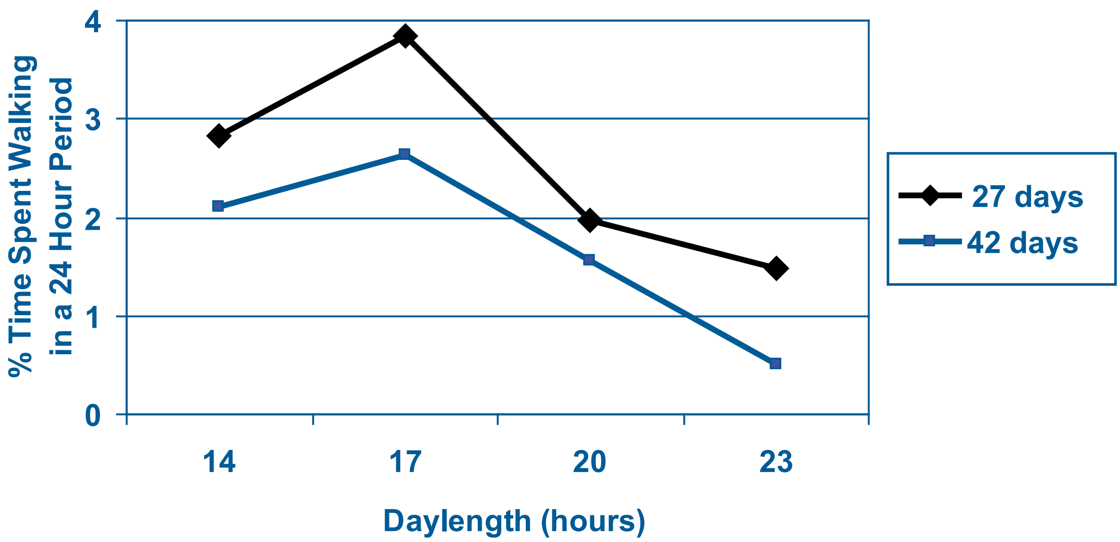
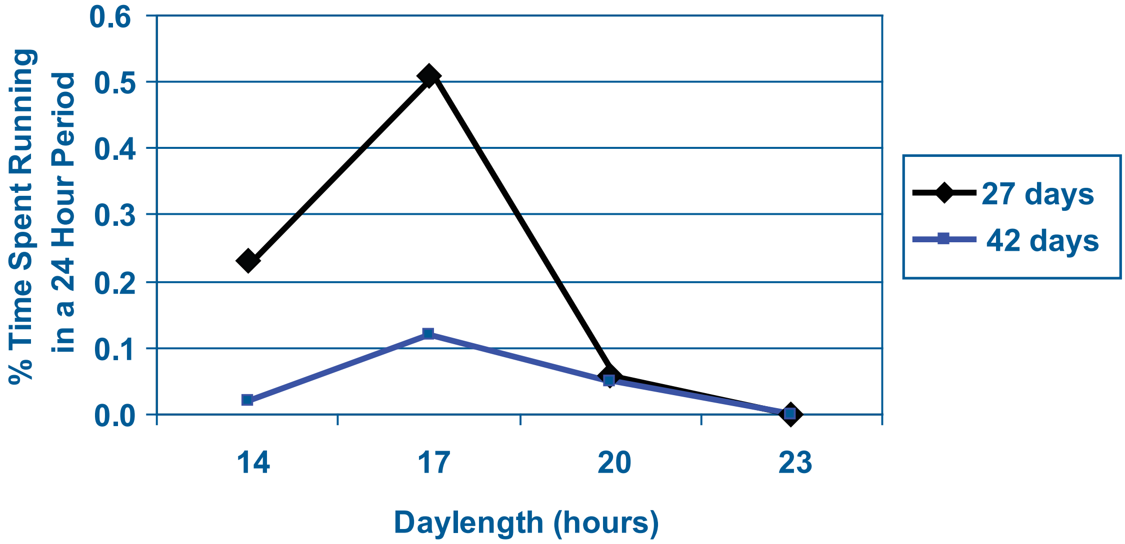


Figure 20: Effect of daylength on the percentage of time in a 24 hour period that birds spend running.



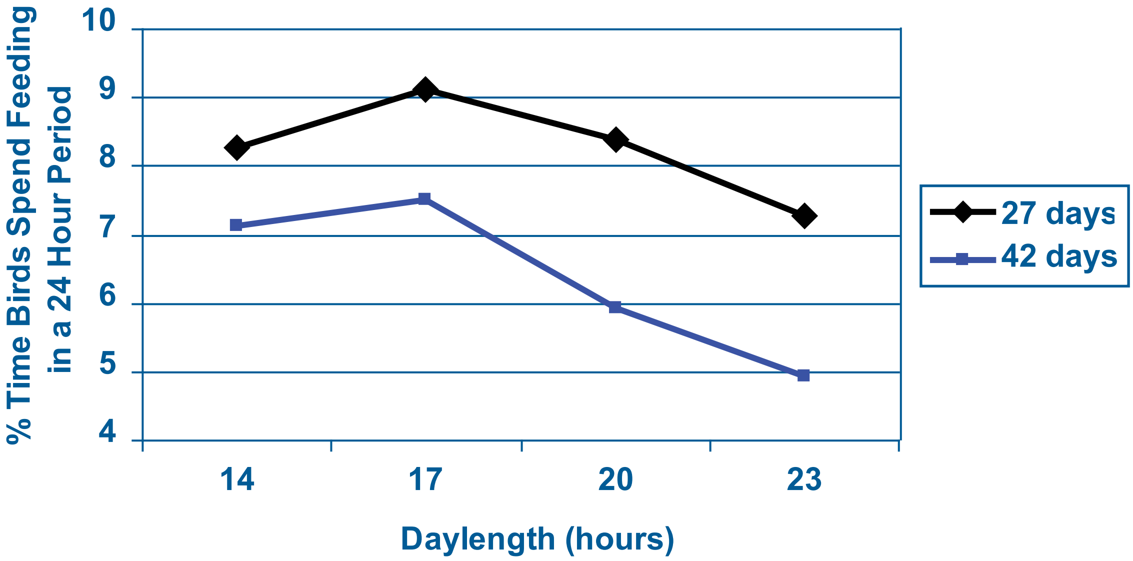
Key Points

- **Walking and running activity was highest in broilers given 17 hours of light.**
- **Increasing daylength beyond 17 hours led to a significant decline in walking and running activity with walking and running activity being lowest in birds given 23 hours of light.**
- **The data suggests that this lack of movement is related more to a lack of "desire" to move than to an inability to move (leg weakness).**

Ingestion Behaviors

Ingestion behaviors are eating and drinking and because of their importance for providing nutrients essential for life they have strong motivation. This motivation is particularly strong in broilers that have been selected for rapid growth rate and a high demand for nutrients. Daylength affected time spent eating with a maximum time for the 17L treatment and a linear reduction in time as daylength increased (**Figure 21**). Feeding time for 14L birds was less than for 17L treatment but again this is explained by the increase in the length of the dark period. Of interest, the length of time feeding did not correspond with the amount of eaten. Broilers given 17L ate less than 20L and 23L birds. This demonstrates that behavioral observation allows the assessment of time spent at the feeder but not the level of feed intake. Understanding what caused the difference in time spent eating would be of interest. Are broilers given longer daylength less able to move to the feeder and therefore they eat more at each visit? Or, are broilers given shorter daylength demonstrating more investigative or play behavior by spending more time at the feeder than expected based on feed intake? Both questions suggest better welfare for the birds given shorter daylength. Additionally, the reality that longer daylengths allow maximum visual access to feeders, yet result in a reduction in the percent of time spent at the feeder may well indicate a problem.

Figure 21: Effect of daylength on the percentage of time in a 24 hour period that birds spend feeding.



Key Points

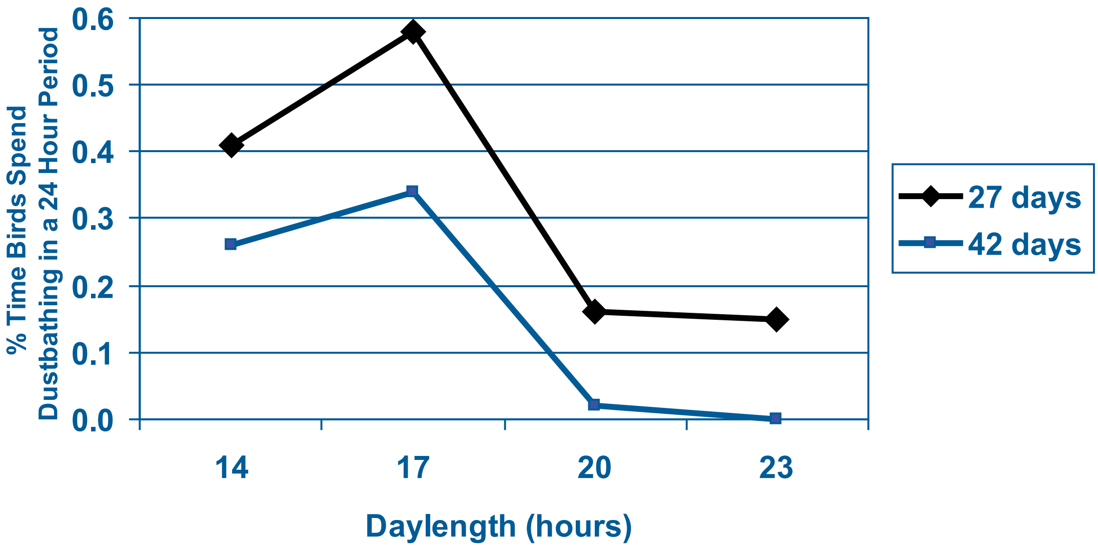
- Length of time spent eating did not correspond with feed intake. For example, broilers given 17 hours of light ate less than those given 20 or 23 hours of light but they spent more time at the feeder.
- Maximum time spent eating occurred in birds given 17 hours of light.
- Increasing daylength beyond 17 hours led to a significant decrease in eating time.
- The data suggest that shorter day lengths are better for bird welfare in terms of ingestion/feeding behavior.

Comfort and Exploratory Behaviors

Comfort behaviors are considered among the more important behaviors observed in terms of welfare. Their importance comes from the fact that they are usually performed when all other basic needs have been met and are therefore more subject to change in frequency than necessary behaviors such as eating and drinking. Comfort behaviors are typically expressed when distress and suffering are not present and when basic needs are met. Comfort behaviors include dustbathing, feather ruffling, preening, stretching and wing flapping.

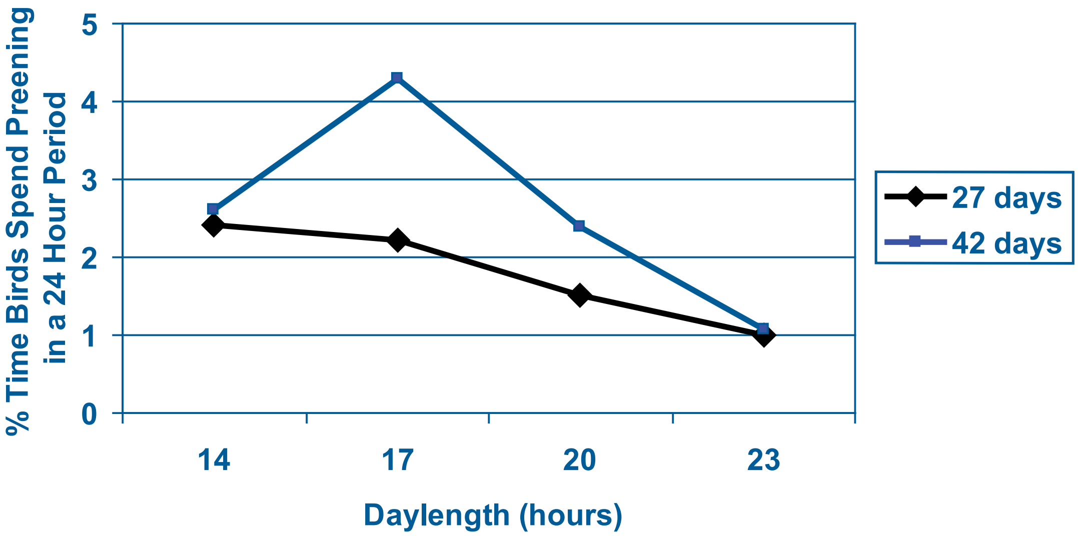
Dustbathing is comfort behavior and its motivational factors are still not totally established. Scientists have debated as to whether it is an internally motivated (coming from within the body) or externally motivated (triggered by something in the environment) behavior. Both may play a role but the evidence is very strong that birds dust-bathe in a daily rhythm that is set by light. This would suggest a strong motivation. Daylength affected dustbathing with the highest percentage for the 17L treatment and then decreasing to a point where it virtually disappeared for 20L and 23L (**Figure 22**). The near-elimination of this behavior is a welfare concern.

Figure 22: Effect of daylength on the percentage of time in a 24 hour period that birds spend dustbathing.



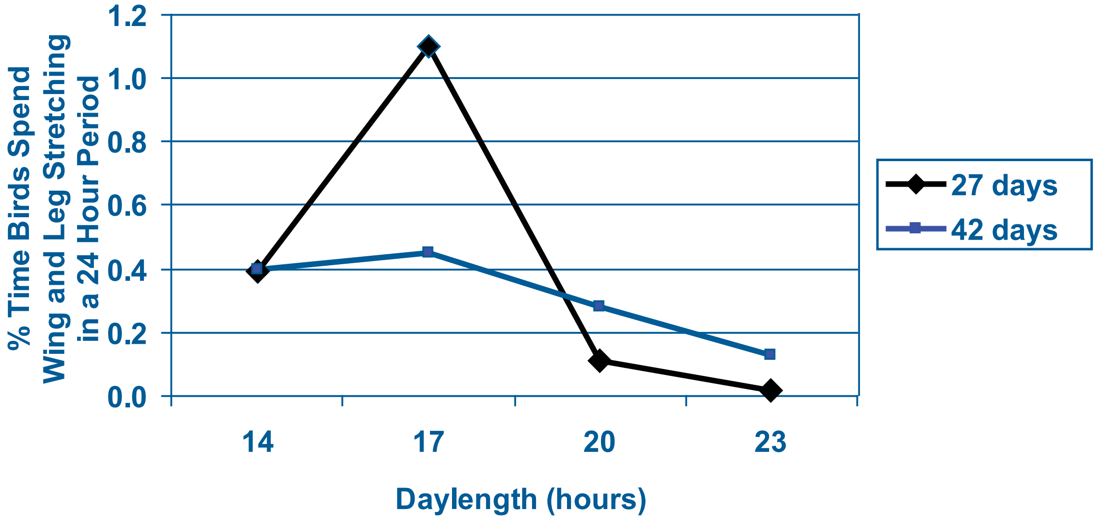
Preening is a comfort behavior that also has a physiological function as it aids in feather maintenance. Daylength does affect the level of preening. When the daylength became longer, the percentage of time spent preening decreased linearly at 27 days of age and in a quadratic fashion at 42 days (**Figure 23**).

Figure 23: Effect of daylength on the percentage of time in a 24 hour period that birds spend preening.



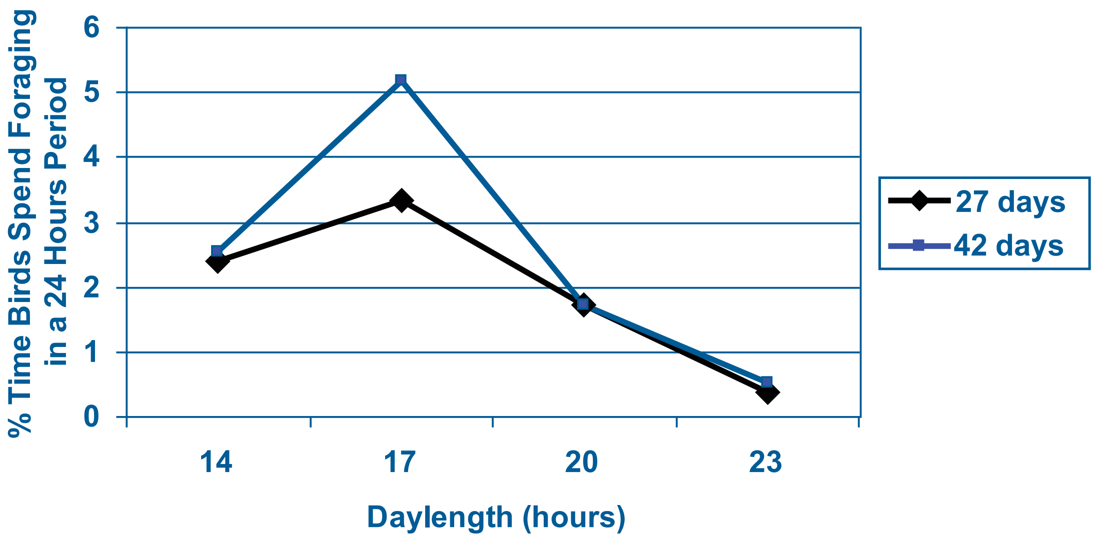
Leg stretching or wing stretching are other "comfort" behaviors (**Figure 24**). Similar to those already discussed, the time allocated to these behaviors also declines as days get longer and occurred at very low levels under 23 hours of daylength.

Figure 24: Effect of daylength on the percentage of time in a 24 hour period that birds spend wing and leg stretching.



Foraging is a behavior that poultry ancestors relied on as a feeding mechanism, and in general, behaviors that were once important still occur in current livestock. Foraging, or pecking at the litter, was also affected by daylength (**Figure 25**). The pattern is very similar to comfort behaviors in that it nearly disappears in the broilers given 23 hours of daylength. Again, this is indicative of a welfare concern with long daylengths.

Figure 25: Effect of daylength on the percentage of time in a 24 hour period that birds spend foraging.



Key Points

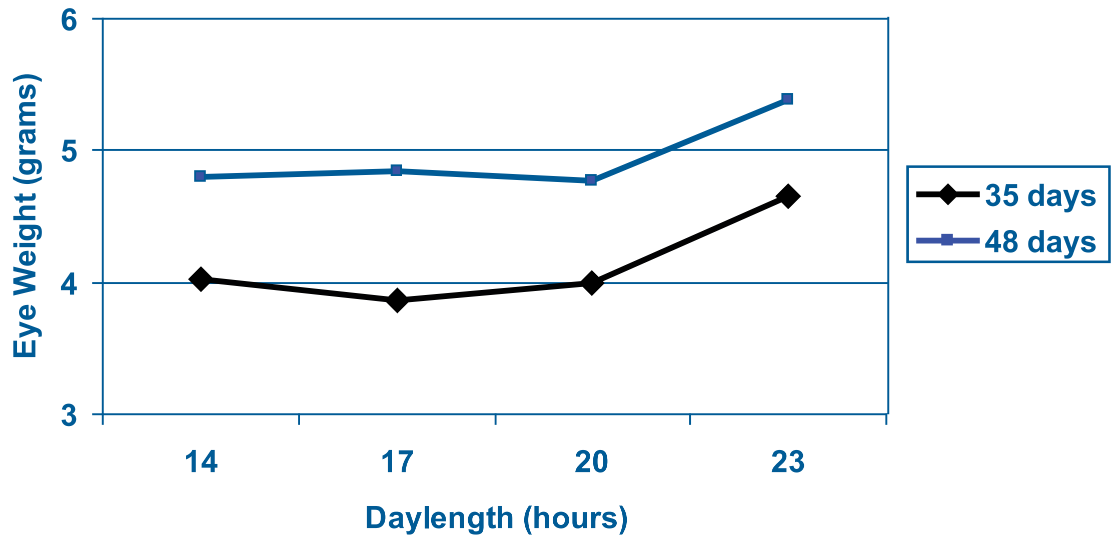
- Comfort behaviors such as dustbathing, feather ruffling, preening, stretching and wing flapping are expressed in the absence of distress and suffering and when all other basic needs are met. They are therefore considered to be important indicators of welfare.
- All comfort behaviors were decreased when daylength was increased beyond 17 hours of light. In many cases comfort behaviors virtually disappeared in birds given 23 hours of light.

Eye Development

Eyes grow in a diurnal pattern with growth occurring during the light period and growth stopping during the dark period. The amount of darkness required for a "normal" growth pattern is unknown but previous research has shown that continuous light results in enlarged eyes. In humans, enlargement of this type can result in pressure on the optic nerve, which may be painful and can lead to glaucoma.

The effect of daylength on eye weights is shown in **Figure 26**. Eye weights under 14, 17 or 20 hour daylengths are the same indicating that as little as 4 hours of darkness is enough to induce a normal diurnal growth pattern. However, mean eye weight for birds receiving 23 hours of daylength was heavier than birds under any other lighting program. While the welfare effects of enlarged eyes in broiler chickens is not established, this finding is a concern and needs to be considered with other evidence when establishing the welfare implications of daylength.

Figure 26: Effect of daylength on eye weights.



Key Points

- **Eye growth occurs only in daylight, therefore providing increased levels of daylight may lead to excessive eye growth and a potential welfare issue. Continuous lighting has been shown to result in enlarged eyes which may result in pain.**
- **It is not known if this effect is seen in chickens but the data from this trial show that the eyes of broilers given 23 hours light were larger than those given shorter daylengths.**

Melatonin

Melatonin is a hormone that is produced naturally in the body. The hormone is produced in a diurnal fashion, with higher levels during the dark period and lower levels during the light period. Melatonin plays an important role in signalling changes that optimize body function. These functions include reproduction, immune function, feed intake, learning and mental status. A diurnal pattern in melatonin levels is considered to be an important aspect of well being and therefore was of interest in this study.

Blood samples were collected from 21 day-old broilers during a 24 hour period for melatonin analysis. The expected diurnal pattern in melatonin levels with high values during the night and low values during the day were seen for broilers given daylengths of 14, 17 and 20 hours. Broilers given 23 hours of daylight did not show a diurnal pattern with all values throughout the 24 hour study period being approximately the same. The lack of a diurnal pattern for these birds suggests the possibility of a wide range of negative physiological consequences and is therefore a concern.

Key Points

- **Melatonin is important for a number of physiological functions including reproduction and immune status. It is normally produced in a diurnal pattern.**
- **Broilers given 23 hours of light did not show a diurnal pattern of melatonin production. This could lead to a wide range of negative physiological consequences.**

Conclusion - Influence of Daylength on Broiler Welfare and Health

Does photoperiod have an effect on the welfare of broilers? The objective of this research was to evaluate multiple methods of welfare assessment to help provide a clear answer. Based on a summarization of the results of welfare assessment in this research, the answer is yes (**Table 7**). In **Table 7**, a score is given to each parameter in terms of the daylength effect on welfare. A "zero" is given to the daylength(s) which appear to be the most advantageous in terms of welfare, a "three" is given to the lighting program(s) with the perceived poorest welfare, and "one" and "two" are given to daylengths producing intermediate responses. The points are then averaged for each of the main assessment methods (productivity, health, behavior and physiology), and the averages totalled for a TOTAL WELFARE SCORE. The daylength which produces the highest total is suggested to have the poorest welfare and that which produces the lowest value the best welfare. Although the method of point allocation can be debated, it is a useful method of giving an overall assessment of broiler welfare.

The data strongly suggest that near-constant light (23L) is not acceptable from a welfare perspective as its total score is much higher than any other daylengths. In addition, the negative effect on broiler welfare is consistent regardless of the assessment method (productivity, health, behavior or physiology). Near-constant light appears to result in physiological changes within the bird, resulting in an unexplainable drop in growth rate and feed intake, changes in eye growth and the disruption of the diurnal rhythms and melatonin production. It also results in changes to behavior that include increased lethargy and a decline in comfort, exercise and nutritive behaviors. The birds also stopped doing behaviors which are normal for their repertoire. Therefore, we believe that near-constant or constant photoperiods should not be used for broiler production.

Adding a few hours of darkness (20L) results in an improvement in all welfare parameters tested. In addition, growth rate is better for this daylength regardless of age at marketing. So, even though birds are given less visual access to feeders and drinkers, their growth rate has improved. Health improves with this addition of 3 hours of darkness as seen by generally less overall mortality and leg weakness (cull levels and gait scores). Behavior also shows an improvement. Birds under 20L are performing more exercise behaviors, more comfort behaviors and more exploratory behaviors than birds given 23 hours of daylength. Overall, even the addition of 3 hours of total darkness to a lighting program improves the welfare of broilers as compared to near-constant lighting programs.

Table 7: Summarization of the effects of daylength on broiler welfare.

	Daylength (hours)			
	14	**17**	**20**	**23**
Growth Rate	**0**	**0**	**0**	**3**
Health				
Mortality	1	0	2	3
Leg Disorders - Culls	0	1	2	3
Gait Scores	0	1	2	3
Health Average Score	**0.33**	**0.67**	**2.00**	**3**
Behavior				
Resting	1	0	2	3
Walking	1	0	2	3
Running	1	0	2	3
Feeding	0	0	3	3
Preening	1	0	2	3
Leg/Wing Stretching	1	0	2	3
Dustbathing	0	0	3	3
Foraging	1	0	2	3
Behavior Average Score	**0.75**	**0**	**2.25**	**3**
Physiology				
Eye Development	0	0	0	3
Melatonin Cycles	0	0	0	3
Physiology Average Score	**0**	**0**	**0**	**3**
Total Welfare Score	**1.08**	**0.67**	**4.25**	**12.00**

Comparing 14 and 17 hour daylengths in terms of broiler welfare shows minor differences. Growth rate is reduced in broilers given 14L, but this should be expected, as darkness reduces feed intake. Mortality levels are similar for the two lighting regimes but there are lower levels of culling for leg disorders and improved gait scores for the 14L (although the differences are small). Levels of exercise, comfort behaviors and exploratory behaviors are actually higher for 17L than 14L. Under both programs, melatonin cycles in a diurnal pattern and eye development is similar. There appears to be little advantage of using 14 rather than 17 hours of daylength from broiler chickens.

In conclusion, this data clearly shows that near-constant or constant daylength is not acceptable when considering the welfare of broilers and this adds to the demonstration that these lighting programs are also not as good in terms of production. Welfare is maximized when darkness is given to the birds and it appears that a 17 hour daylength is near optimum from a welfare perspective.

Key Points

- Daylength has a clear effect on broiler welfare.
- The data from this trial strongly suggests that near constant light (23 hours) leads to reduced bird welfare, resulting in:
    - physiological changes within the bird, which lead to an unexplainable drop in growth rate and feed intake, changes in eye growth and the disruption of the diurnal rhythms and melatonin production.
    - changes to behavior that include increased lethargy and a decline in comfort, exercise and nutritive behaviors.
    - birds also stopping behaviors which are normal for their repertoire.
- Data shows that although significant improvements in bird welfare will occur with just a 3 hour increase in darkness (from 23L to 20L), bird welfare is best when between 14 and 17 hours of light are given. Although there is no added benefit to broiler welfare of using 14 hours of light compared to 17 hours of light.
- Data looking at the effects of lighting on broiler production shows that the best production occurs in broilers given between 17 and 20 hours of light.
- Taking the information on both broiler production and welfare the optimal daylength for broilers appears to be between 17 and 20 hours of light a day.

Appendix 1. Effect of Daylength, Sex and Strain on Meat Yield

The data for meat yield is presented according to age at 31/32, 38/39 and 48/49 days of age in the following three tables. Data is presented as a percentage of live weight and is shown for experimental main effects of daylength, bird gender and bird genotype (Ross x Ross 308; Ross x Ross 708). Carcass yield was only affected by gender at 38/39 days of age where females had a higher yield than males. As expected, Ross x Ross 708 broilers had superior carcass yield in comparison to the Ross x Ross 308 birds. Females demonstrated increased breast muscling in comparison to males with the effect significant at 38/39 and 48/49 days of age but only significant for the Pectoralis minor at 31 days. Ross x Ross 708 broilers had more breast yield than the Ross x Ross 308 at all ages. Gender had an important and consistent effect on broiler leg portions. Males had larger portions of thigh meat, thigh bone, whole drum, drum meat and drum bone. Other gender effects were not consistent. Ross x Ross 708 broilers had at least as much leg portion meat and less drum and thigh bone in comparison to Ross x Ross 308. The portion of the carcass remaining after meat yield was also smaller for Ross x Ross 708 at 38/39 days of age. The changes in leg bones and remaining carcass suggest a proportionally smaller skeleton in Ross x Ross 708 broilers. Breast skin (an indicator of carcass fat) was not affected by genotype.

Effect of daylength, gender and strain on broiler carcass characteristics at 31/32 days of age (% of live weight).

	Daylength (hours)					Gender			Strain		
	14	**17**	**20**	**23**	**P**	**Male**	**Female**	**P**	**308**	**708**	**P**
Carcass	65.90	66.27	66.38	66.25	NS	65.91	66.48	0.0730	66.05	66.35	NS
Pectoralis major	14.11^{B}	14.48^{AB}	14.74^{A}	14.94^{A}	0.0424	14.62	14.52	NS	14.12^{B}	15.02^{A}	0.0001
Pectoralis minor	3.13^{B}	3.16^{B}	3.25^{A}	3.27^{A}	0.0164	3.09^{B}	3.32^{A}	0.0001	3.14^{B}	3.27^{A}	0.0009
Total breast	17.24^{C}	17.64^{BC}	17.99^{AB}	18.21^{A}	0.0183	17.71	17.83	NS	17.26^{B}	18.28^{A}	0.0001
Breast skin	2.81	2.82	2.83	2.79	NS	2.70^{B}	2.93^{A}	0.0002	2.84	2.79	NS
Right thigh whole	6.35	6.30	6.39	6.29	NS	6.32	6.34	NS	6.32	6.34	NS
Left thigh meat	4.40	4.37	4.45	4.32	NS	4.42^{A}	4.35^{B}	0.0125	4.39	4.38	NS
Left thigh skin	0.94	0.96	0.96	0.93	NS	0.87^{B}	1.03^{A}	0.0001	0.97	0.93	0.0898
Left thigh bone	0.85	0.84	0.85	0.85	NS	0.88^{A}	0.82^{B}	0.0013	0.86	0.84	NS
Right drum whole	4.76	4.71	4.68	4.59	NS	4.76^{A}	4.61^{B}	0.0001	4.69	4.67	NS
Left drum meat	3.16^{A}	3.09^{AB}	3.04^{B}	2.99^{B}	0.0454	3.12^{A}	3.01^{B}	0.0014	3.06	3.07	NS
Left drum skin	0.52	0.52	0.51	0.51	NS	0.52	0.51	NS	0.52	0.51	NS
Left drum bone	1.19	1.21	1.20	1.23	NS	1.24^{A}	1.18^{B}	0.0051	1.22	1.19	0.0619
Wings	7.48	7.52	7.49	7.46	NS	7.47	7.51	NS	7.49	7.49	NS
Remaining carcass	15.36	15.50	15.16	15.25	NS	15.15^{B}	15.49^{A}	0.0491	15.42	15.21	NS

^{ABC} Means with different superscripts within daylength, gender and strain are significantly different ($P < 0.05$).
NS = Not significant ($P < 0.10$). P values ranging from 0.05 to 0.10, while not significant, are noted.

Effect of daylength, gender and strain on broiler carcass characteristics at 38/39 days of age (% live weight).

	Daylength (hours)					Gender			Strain		
	14	**17**	**20**	**23**	**P**	**Male**	**Female**	**P**	**308**	**708**	**P**
Carcass	67.25^{C}	68.04^{B}	68.63^{A}	68.63^{A}	0.0003	67.91^{B}	68.36^{A}	0.0015	67.55^{B}	68.72^{A}	0.0001
Pectoralis major	14.92^{D}	15.51^{C}	15.93^{B}	16.19^{A}	0.0001	15.54^{B}	15.74^{A}	0.0053	14.99B	16.28^{A}	0.0001
Pectoralis minor	3.47^{C}	3.58^{B}	3.63^{AB}	3.70^{A}	0.0185	3.45^{B}	3.73^{A}	0.0001	3.51^{B}	3.67^{A}	0.0001
Total breast	18.39^{D}	19.09^{C}	19.56^{B}	19.89^{A}	0.0001	18.98^{B}	19.47^{A}	0.0001	18.51^{B}	19.96^{A}	0.0001
Breast skin	2.99	3.12	3.07	3.05	0.0907	2.97^{B}	3.14^{A}	0.0001	3.06	3.05	NS
Right thigh whole	6.23	6.34	6.29	6.23	0.0521	6.25	6.29	0.0705	6.27	6.27	NS
Left thigh meat	4.43	4.48	4.43	4.38	0.0618	4.48^{A}	4.37^{B}	0.0001	4.40^{B}	4.46^{A}	0.0289
Left thigh skin	0.86	0.90	0.91	0.88	NS	0.82^{B}	0.95^{A}	0.0001	0.90^{A}	0.87^{B}	0.0344
Left thigh bone	0.79	0.78	0.79	0.79	NS	0.81^{A}	0.77^{B}	0.0001	0.80^{A}	0.78^{B}	0.0012
Right drum whole	4.97	4.80	4.75	4.70	0.0506	4.87^{A}	4.74^{B}	0.0016	4.86	4.75	0.0548
Left drum meat	3.23^{A}	3.16^{B}	3.10^{C}	3.07^{C}	0.0002	3.20^{A}	3.09^{B}	0.0001	3.14^{B}	3.15^{A}	0.0001
Left drum skin	0.52	0.50	0.52	0.52	NS	0.51^{B}	0.53^{A}	0.0101	0.52	0.51	NS
Left drum bone	1.20	1.22	1.20	1.20	NS	1.25^{A}	1.16^{B}	0.0001	1.22^{A}	1.19^{B}	0.0001
Wings	7.58	7.59	7.59	7.63	NS	7.55^{B}	7.64^{A}	0.0009	7.59	7.60	NS
Remaining carcass	16.24	16.31	16.47	16.36	NS	16.36	16.33	NS	16.44^{A}	16.25^{B}	0.0046

^{ABC} Means with different superscripts within daylength, gender and strain are significantly different ($P < 0.05$).
NS = Not significant ($P < 0.10$). P values ranging from 0.05 to 0.10, while not significant, are noted.

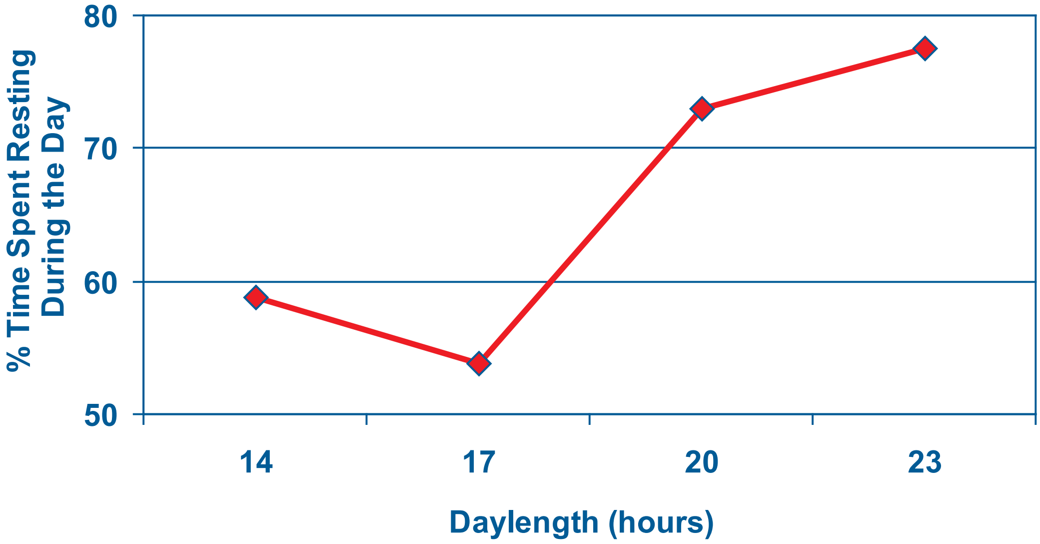
Effect of daylength, gender and strain on broiler carcass characteristics at 48/49 days of age (% of live weight).

	Daylength (hours)					Gender			Strain		
	14	**17**	**20**	**23**	**P**	**Male**	**Female**	**P**	**308**	**708**	**P**
Carcass	70.42^{C}	71.14^{BC}	72.34^{A}	71.58^{AB}	0.0040	71.26	71.48	NS	70.97^{B}	71.76^{A}	0.0144
Pectoralis major	16.19^{C}	16.81^{B}	17.44^{A}	17.18^{AB}	0.0003	16.79^{B}	17.02^{A}	0.0457	16.27B	17.54^{A}	0.0001
Pectoralis minor	3.80^{B}	3.81^{B}	3.85^{AB}	3.96^{A}	0.0420	3.68^{B}	4.03^{A}	0.0001	3.79^{B}	3.92^{A}	0.0034
Total breast	19.99^{C}	20.62^{B}	21.29^{A}	21.14^{A}	0.0001	20.47^{B}	21.05^{A}	0.0001	20.06^{B}	21.46^{A}	0.0001
Breast skin	3.03	3.02	3.10	2.97	NS	2.90^{B}	3.16^{A}	0.0001	3.03	3.03	NS
Right thigh whole	6.52	6.47	6.57	6.49	NS	6.50	6.53	NS	6.55	6.48	0.0742
Left thigh meat	4.58	4.56	4.53	4.42	NS	4.62^{A}	4.43^{B}	0.0001	4.52	4.52	NS
Left thigh skin	0.96^{B}	0.97^{B}	1.02^{A}	0.94^{B}	0.0069	0.88^{B}	1.06^{A}	0.0001	1.00^{A}	0.95^{B}	0.0085
Left thigh bone	0.76	0.74	0.74	0.75	NS	0.79^{A}	0.71^{B}	0.0001	0.76^{A}	0.74^{B}	0.0014
Right drum whole	4.92	4.86	4.85	4.84	NS	5.00^{A}	4.73^{B}	0.0001	4.93A	4.81B	0.0001
Left drum meat	3.25^{A}	3.18^{B}	3.14^{B}	3.11^{B}	0.0108	3.25^{A}	3.09^{B}	0.0001	3.19^{A}	3.15^{B}	0.0475
Left drum skin	0.57	0.56	0.58	0.58	NS	0.56	0.58	NS	0.57	0.57	NS
Left drum bone	1.13	1.15	1.17	1.17	NS	1.23^{A}	1.08^{B}	0.0001	1.18^{A}	1.14^{B}	0.0006
Wings	7.53	7.58	7.72	7.67	NS	7.65	7.60	NS	7.65	7.60	NS
Remaining carcass	17.27^{B}	17.57^{A}	17.72^{A}	17.67^{A}	0.0356	17.63	17.49	NS	17.65	17.46	NS

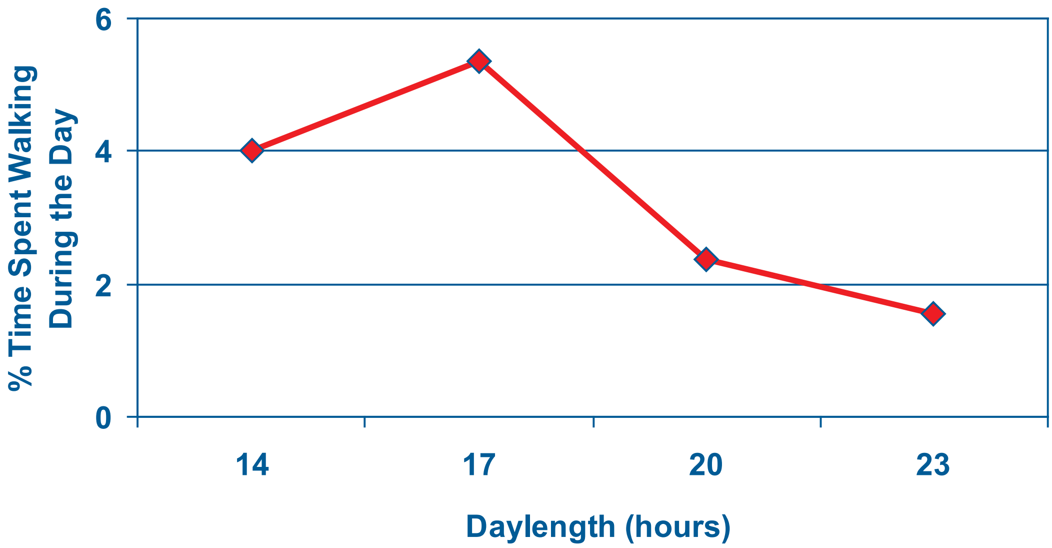
^{ABC} Means with different superscripts within daylength, gender and strain are significantly different ($P < 0.05$).
NS = Not significant ($P < 0.10$). P values ranging from 0.05 to 0.10, while not significant, are noted.

Appendix 2. Effect of Daylength on Bird Behavior Exclusive of Night

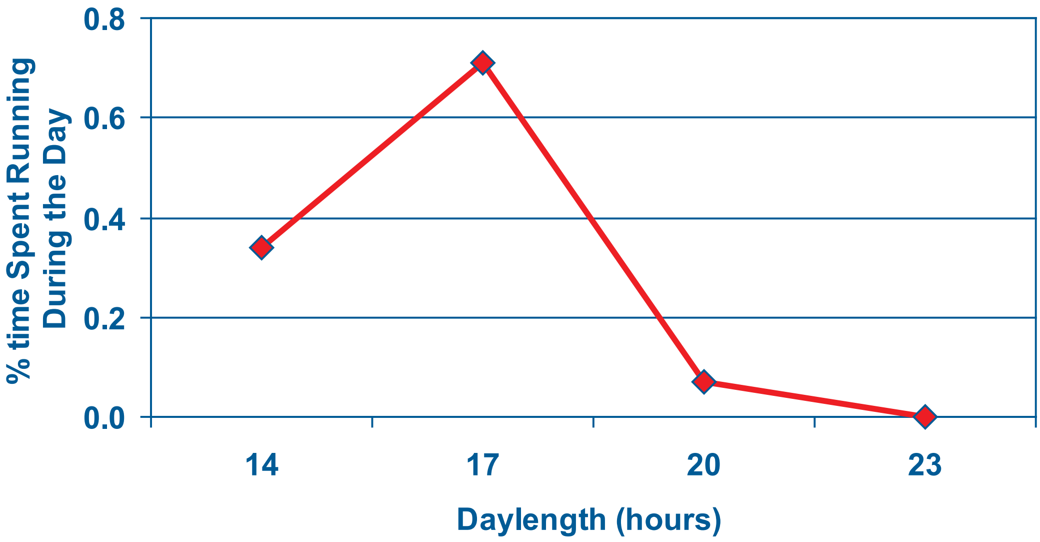
Overall effect of daylength on precentage of time resting during the day (photoperiod) exclusive of night.



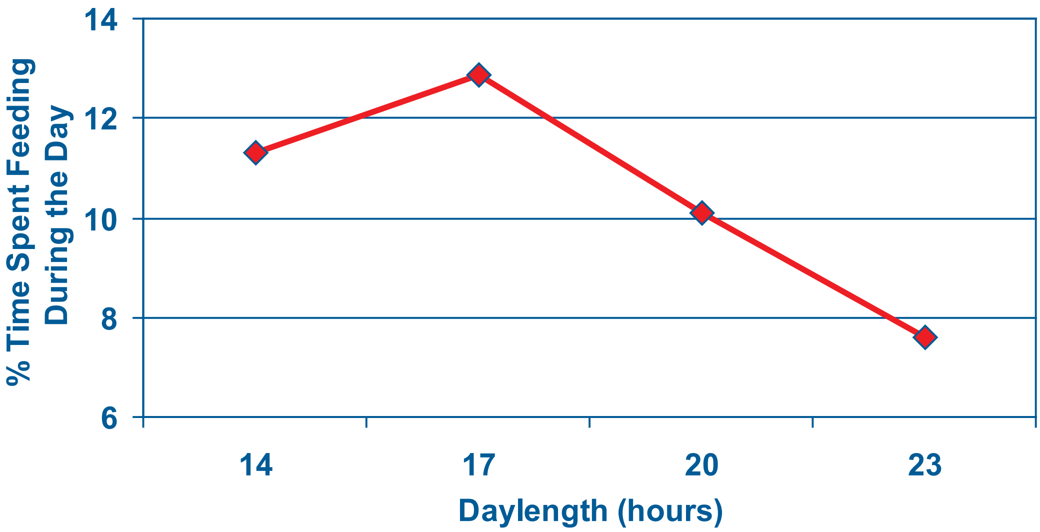
Overall effect of daylength on percentage of time walking during the day (photoperiod) exclusive of night.



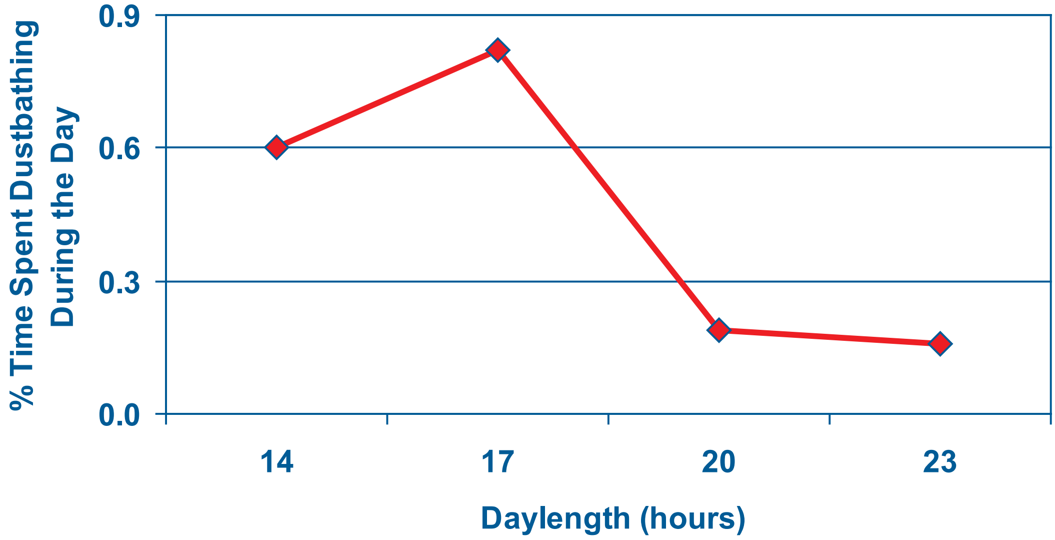
Overall effect of daylength on percentage of time running during the day (photoperiod) exclusive of night.



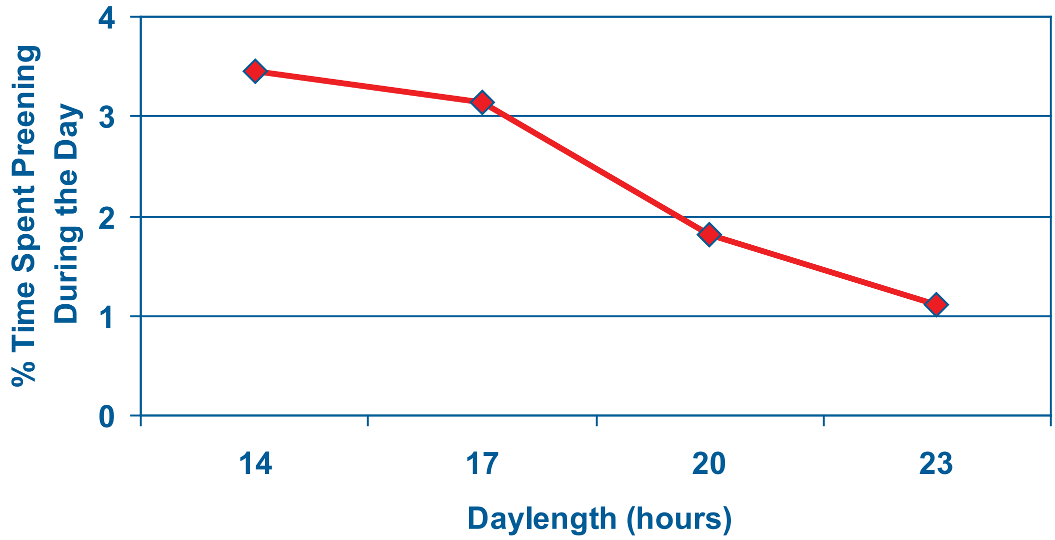
Overal effect of daylength on percentage of time feeding during the day (photoperiod) exclusive of night.



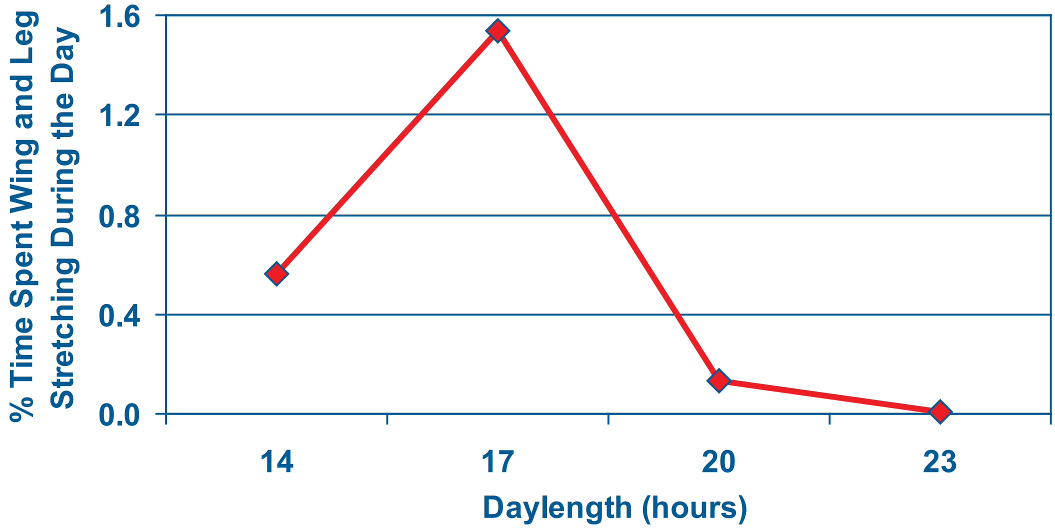
Overall effect of daylength on percentage of time dustbathing during the day (photoperiod) exclusive of night.



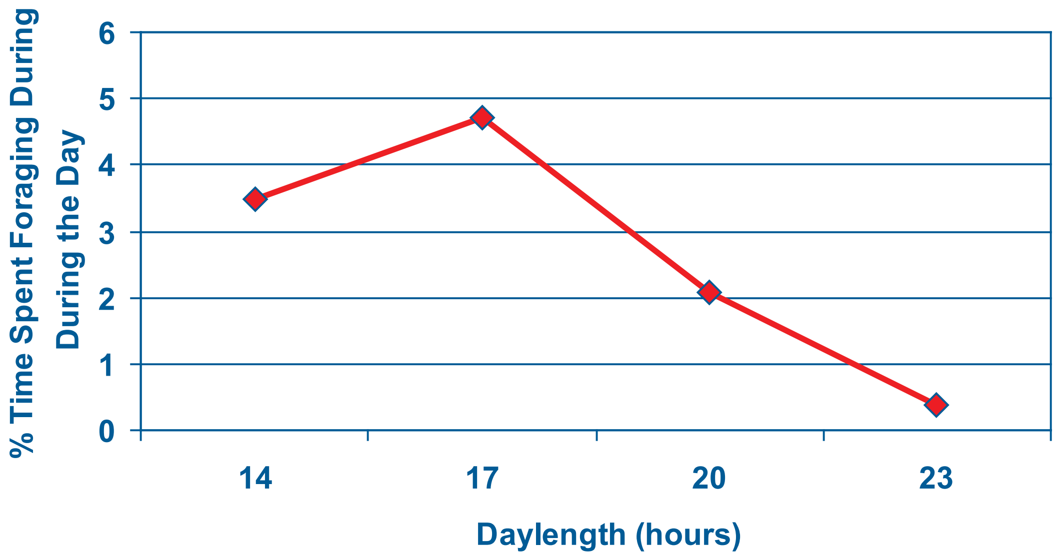
Overal effect of daylength on percentage of time preening during the day (photoperiod) exclusive of night.



Overall effect of daylength on percentage of time wing and leg stretching during the day (photoperiod) exclusive of night.



Overall effect of daylength on percentage of time foraging during the day (photoperiod) exclusive of night.



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