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Original Research Article

Feed intake pattern of broiler chickens under intermittent lighting: Do birds eat in the dark?

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A R T I C L E I N F O

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A B S T R A C T

This paper reflects the results of a short experiment conducted in parallel with a larger trial which aimed to test the assumption that 'consumption of feed by broiler chickens during periods of darkness is largely negligible'. To that effect, on d 31, feeders of birds raised under intermittent lighting (IL), i.e. 1 h of light [1L]:3 h of dark (3D):1L:3D:1L:3D:1L:3D:2L:6D, were weighed at the onset and at the end of each period of darkness (or scotoperiod). Moreover, in order to compare the feeding behavior of IL birds with that of broilers raised under continuous lighting (CL, i.e. 18L:6D), their feeders were weighed in parallel and at the same time points. On d 31, feed intake of IL birds during scotoperiods represented 45% of their 24 h feed intake. Both CL and IL birds presented anticipatory feed intake prior to the long nocturnal period of darkness (6D), as well as higher feed intake right at the onset of lighting at 06:00. Feed intake of CL birds during the 6D nocturnal scotoperiod was negligible at around 2% of their total feed intake. Intermittent lighting birds exhibited excitement at the start of each hour-length scotoperiod and, within that time, ingested around 2.5 times the amount of feed ingested by CL birds. Although short, this study revealed several interesting observations which might be worth further exploring in a larger, lengthier, behavior-focused experiment. Amongst other factors, it might be interesting to understand whether the high feed intake observed during scotoperiods for IL birds in reflective of the whole flock or rather a coping mechanism developed mainly by hierarchically lower-ranking birds to achieve their daily feed intakes requirements.

1. Introduction

Meat-type chickens, commonly referred to as 'broilers', are the most efficient terrestrial animals in converting nutrients present in the feed into muscle. Back in 1985, under good husbandry and good nutrition practices, a 1.4 kg broiler would be produced with 3.2 kg of feed. This represents a feed conversion ratio (FCR) of 2.3 at 35 d. In 2010, at the same age, a 2.4 kg bird could be reared with as little as 3.7 kg of feed, showcasing a 65% lower FCR (Siegel, 2014). As highlighted by Lewis and Gous (2007), broiler chickens have been reared in commercial operations throughout the past decades on either continuous (24 h of light [24L]) or near continuous illumination (23L and 1 h of dark [1D]) in the certainty that this practice maximizes feed intake and growth rate. Indeed, voluntary feed intake is the main driver of growth in broilers (Scott, 2005); however, *ad libitum* feeding along with long-day lengths may have negative consequences to birds, namely: 1) overconsumption of feed (Hetland and Svihus, 2001) which negatively impacts feed efficiency, nutrient digestibility and ultimately financial returns; 2) induction of physiological growth-related problems, such as leg problems, acute metabolic (i.e. sudden death syndrome) and chronic problems (i.e. ascites) (Buyse et al., 1996b; Buys et al., 1998; Schwean-Lardner et al., 2013); 3) impairment of the immune system of birds (Abbas et al., 2008); and 4) promotion of a series of ocular-related problems (Buyse et al., 1996b). A short dark period in otherwise continuous lighting (CL) programs was first introduced to accustom birds to darkness and to minimize panic in case of power failure (Ketelaars et al., 1986). Throughout the past decades, a number of scientists have challenged usual commercial practices and researched the effect of intermittent lighting (IL) on performance, behavior, carcass characteristics, health and mortality of

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broilers. Reviews of such work are available (Buyse et al., 1996b; Rodrigues and Choct, 2018). One general assumption made by these researchers is that 'broiler chickens generally only eat during the photoperiod' (Buyse et al., 1996b). In an attempt to verify the accuracy of such assumption, and in parallel with a larger experiment, we investigated whether broiler chickens raised under IL would indeed refrain from feeding throughout the entirety of the dark period (scotoperiod). Also, we compared the feed intake of IL birds during scotoperiods to that of birds raised under a CL program (18L:6D).

2. Materials and methods

2.1. Experimental design and animal husbandry

A detailed description of the experimental design, including the ingredient composition of diets, is available in a previous publication (Rodrigues et al., 2018). In this parallel study, the effects of lighting program (CL, 18L:6D vs. IL, 1L:3D:1L:3D:1L:3D:1L:3D:2L:6D) on daily feed intake patterns were ascertained. Until d 7 birds were provided with 23 h of light and 1 h of dark (23L:1D) at an intensity of 20 lux and plastic plates complemented bell feeders to stimulate feed consumption. On d 7, 168 Cobb 500 same-hatch, mixed sex, 7-day-old chicks (154.8 ± 1.4 g) were randomly allocated into 14 floor pen-replicates (0.7 m × 0.70 m, 12 birds per pen) distributed between two, side by side, negative pressure climate-controlled experimental rooms (7 pens per room). Pens were bedded with fresh softwood shavings and were equipped with a bell feeder (diameter: 370 mm) and 2 water cup drinkers. Daily monitoring of birds and environment ensured similar settings between rooms. Water and feed were provided *ad libitum*. Also on d 7, chicks were introduced to 1 of 2 lighting programs until the end of the main experiment on d 35, according to the room they were in. Birds in the 2 rooms had no visual or physical contact throughout the trial to avoid influencing behavior. The first lighting program (Room 1) provided 18L at an intensity of 10 to 12 lux and 6 dark (18L:6D). Lights were introduced at 06:00 and removed at midnight. This program is referred to as CL. The second lighting program (Room 2), referred to as IL, provided a total of 6 h of light (10 to 12 lux) and 18 h of dark (6L:18D) divided into 10 lignt-to-dark periods, i.e. 1L:3D:1L:3D:1L:3D:1L:3D:2L:6D. In this room, lights were on from 06:00 to 7:00, 10:00 to 11:00, 14:00 to 15:00, 18:00 to 19:00 and 22:00 to midnight (24:00). There was no physical removal of feed during periods of darkness. Blackout masking tape and plastic sheets were placed at light entrance points (i.e. windows and door frames) to ensure complete darkness was attained during daytime. In both rooms, light was provided by fluorescent lamps. This experiment was approved by the Animal Ethics Committee of the University of New England (Approval No.: AEC17-002). Care of animals, sampling procedures and euthanasia of animals throughout this experiment were performed according to ethical regulations in place at the University of New England (NHMRC, 2013).

2.2. Measurements

Data recording was done from d 7. Birds were monitored at least twice daily and the number and weight of dead birds found at each inspection were recorded. Average daily gain (ADG), feed intake, body weight gain (BWG), feed conversion ratio corrected for mortality (FCRc, calculated by adding weight of dead birds), and livability were calculated on d 14, 21, 28 and 35. Feed conversion ratio standardized to a slaughter weight of 2,000 g was calculated using the formula proposed by Pesti and Rogers (1997). At d 31, weight of feeders was measured in a total period of 24 h, at the start and end of each scotoperiod for IL birds, i.e. at 22:00, 24:00, 06:00, 07:00, 10:00, 11:00, 14:00, 15:00; 18:00, 19:00 and, 24 h later, at 22:00. Weights of feeders for CL birds were recorded in parallel and at the same time points. Relative feed intake was calculated as a percentage of the feed intake for the respective time interval divided by total feed intake for the 24 h period.

2.3. Statistical analysis

Pen served as the experimental unit. Data were analyzed using the fit model platform of JMP 8.0 (SAS Institute Inc. Cary, NC) with lighting program and time points as factors. The normality of all data was tested prior to fitting the statistical model. After model fitting one pen was identified as an extreme outlier (data points above ± 2 times the root mean square error for performance parameters) and analyses were re-run after its exclusion. When interactions were observed ($P < 0.05$), Tukey's honest significance test was used to compare treatment means.

3. Results

Performance results for the grower (d 7 to 21) and finisher (d 22 to 35) are shown in Table 1. Throughout the trial, livability remained high (>99%) and unrelated to the tested factor ($P > 0.05$, Table 1). BW at d 35 averaged 2,138 ± 22 g and was unaffected by lighting program ($P > 0.05$). During the grower period feed intake was reduced with IL ($P < 0.05$) which resulted in an overall reduction of feed intake from d 7 to 35 ($P < 0.05$, Rodrigues et al. (2018)). At d 31, the 24 h feed intake per bird was not influenced by lighting program ($P > 0.05$) and averaged (153.9 ± 2.7) g. Birds under IL consumed 10% of their daily feed intake (approx. 15 g of feed per bird) during the 6 h scotoperiod from 24:00 to 06:00 whereas CL birds consumed less (approx. 3.4 g of feed per bird, $P < 0.0001$) (Table 2). The first feeding from 06:00 to 07:00 was

Table 1
Performance of broiler chickens during the grower (d 7 to 21) and finisher (d 22 to 35) periods.[1]

Item	d 7 to 21				d 22 to 35				d 7 to 35	
	ADG, g	BWG, g	FI, g	FCRc	ADG, g	BWG, g	FI, g	FCRc	Livability, %	$FCR_{2,000}$
CL[2]	48.4 ± 0.9	679 ± 11.7	928 ± 19.6[a]	1.367 ± 0.01[a]	93.9 ± 1.7	1,315 ± 24.1	2,071 ± 33.3	1.575 ± 0.02	99.4 ± 0.22	1.370 ± 0.01
IL[3]	46.7 ± 0.9	653 ± 12.6	861 ± 21.2[b]	1.319 ± 0.01[b]	94.0 ± 1.8	1,318 ± 26.0	2,056 ± 36.0	1.561 ± 0.02	100.0 ± 0.24	1.351 ± 0.01
P-value	0.185	0.157	0.040	0.021	0.955	0.941	0.773	0.592	0.105	0.344

ADG = average daily gain; BWG = body weight gain; CL = continuous lighting (18 h of light [18L]:6 h of dark [6D]); FCRc = mortality-corrected feed conversion ratio; $FCR_{2,000}$ = feed conversion ratio corrected for a final body weight of 2,000 g; FI = feed intake; IL = intermittent lighting (1L:3D:1L:3D:1L:3D:1L:3D:2L:6D).
[a, b] Means with different superscripts differ significantly ($P < 0.05$).
[1] Data were analysed using the fit model platform of JMP 8.0 (SAS Institute Inc. Cary, NC). When interactions were observed ($P < 0.05$), Tukey's honest significance test was used to compare treatment means.
[2] Values are means of 7 replicates ($n = 7$) ± standard error.
[3] Values are means of 6 replicates ($n = 6$) ± standard error.

Table 2
Feed intake and relative feed intake of birds as measured at d 31.[1]

Time intervals[2]	Feed intake, g/bird[2]		Relative feed intake, %[2]	
	CL	IL	CL	IL
22:00 to 24:00	22.09 ± 1.25[abc]	22.22 ± 1.25[abc]	14.53 ± 0.77[ab]	14.24 ± 0.77[ab]
24:00 to 06:00	3.36 ± 1.25[g]	15.21 ± 1.25[de]	2.21 ± 0.77[f]	9.67 ± 0.77[cd]
06:00 to 07:00	14.10 ± 1.25[ef]	16.85 ± 1.25[cde]	9.37 ± 0.77[cd]	10.83 ± 0.77[bcd]
07:00 to 10:00	25.19 ± 1.25[a]	7.67 ± 1.25[fg]	16.57 ± 0.77[a]	4.88 ± 0.77[ef]
10:00 to 11:00	5.91 ± 1.25[g]	14.69 ± 1.25[e]	3.93 ± 0.77[f]	9.42 ± 0.77[cd]
11:00 to 14:00	23.12 ± 1.25[abc]	14.29 ± 1.25[e]	15.30 ± 0.77[a]	9.12 ± 0.77[cd]
14:00 to 15:00	7.20 ± 1.25[g]	17.67 ± 1.25[bcde]	4.72 ± 0.77[f]	11.33 ± 0.77[bcd]
15:00 to 18:00	21.19 ± 1.25[abcd]	13.78 ± 1.25[ef]	14.08 ± 0.77[ab]	8.75 ± 0.77[de]
18:00 to 19:00	5.23 ± 1.25[g]	14.02 ± 1.25[ef]	3.46 ± 0.77[f]	9.02 ± 0.77[cd]
19:00 to 22:00	24.06 ± 1.25[ab]	19.97 ± 1.25[abcde]	15.83 ± 0.77[a]	12.73 ± 0.77[abc]
P-value				
LP	NS		NS	
T	<0.0001		<0.0001	
LP × T	<0.0001		<0.0001	

CL = continuous lighting (18 h of light [18L]:6 h of dark [6D]); IL = intermittent lighting (1L:3D:1L:3D:1L:3D:1L:3D:2L:6D); LP = lighting program; NS = not significant; T = time.
[a, b, c, d, e, f, g] Means with different superscripts differ significantly ($P < 0.0001$).
[1] Data were analysed using the fit model platform of JMP 8.0 (SAS Institute Inc. Cary, NC). When interactions were observed ($P < 0.05$), Tukey's honest significance test was used to compare treatment means. Values are means of 7 replicates ($n = 7$) for each treatment ± standard error.
[2] Grey areas represent intervals when lights were off (scotoperiods).

the largest for CL birds with approx. 14 g of feed ingested in 1 h, whereas throughout the rest of the day until 22:00 they ingested similar amounts from 5.2 to 8.4 g per hour ($P > 0.05$). In the 2 h preceding the 6D, CL birds ingested comparable amounts to those observed in the first feeding bout (Fig. 1). Birds raised under IL consumed less feed than CL birds during the various scotoperiods ($P < 0.0001$), except on the last dark period of the day, from 07:00 to 10:00, when they consumed similar amounts to birds under CL. On the other hand, during the various photoperiods of the day, except the first (from 06:00 to 07:00) and the last (from 22:00 to 24:00), they consistently ingested around 2.5 times the amount consumed by birds under CL ($P < 0.0001$).

4. Discussion

Overall, performance of birds was in line with the breed standards (Rodrigues et al., 2018). At d 31, 24 h feed intake was not affected by lighting program but was around 9% lower than expected (154 vs. 169 g), which could probably be explained by the frequent disruption caused by weighing the feeders. This short study was performed at d 31 to avoid both the depression of feed intake and the subsequent compensatory growth characteristic in birds following a change in lighting program. As reviewed by Buyse et al. (1996b) and Rodrigues and Choct (2018), depression of both feed intake and growth is normally observed in the couple of weeks following the change from continuous or near-continuous to IL.

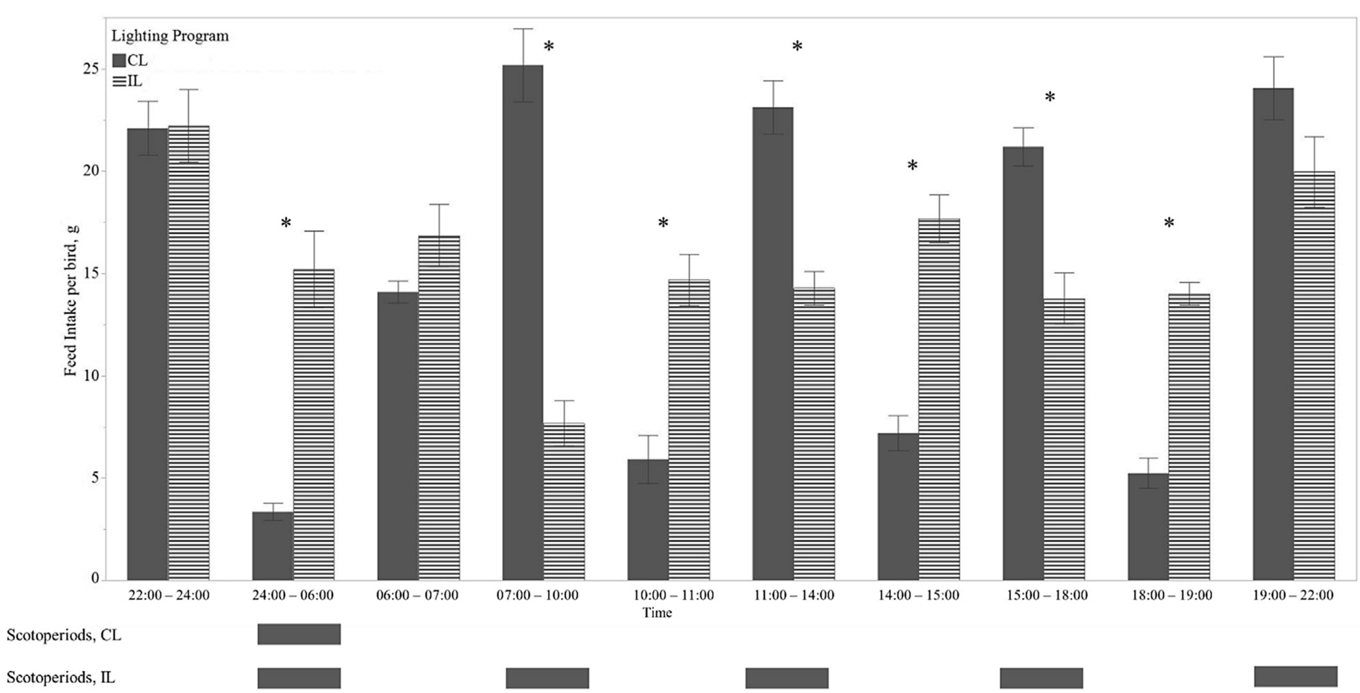

Fig. 1. Feeding pattern for birds raised under CL or IL throughout a 24-h period at d 31. CL = continuous lighting (18 h of light [18L]:6 h of dark [6D]); IL = intermittent lighting (1L:3D:1L:3D:1L:3D:1L:3D:2L:6D). Values are means of 7 replicates ($n = 7$) for each treatment. Error bars are constructed using one standard error from the mean. Asterisks (*) denote means which differ within the same time interval ($P < 0.0001$).

That period is usually followed by the adaptation to the lighting program which results in compensatory growth and similar final body weights. This ongoing adaptation was indeed observed as light intermittency negatively impacted feed intake and tended to impact BWG in the grower but not in the finisher period.

Although the feed intake pattern of birds raised under CL programs consists of short, very frequent and regular feeding bouts, as frequent as twice per hour (Buyse and Decuypere, 2003; Svihus et al., 2013; Neves et al., 2014), there are marked diurnal/nocturnal differences in feed intake. The reported feeding behavior of birds and their pattern of eating immediately when lights come on was observed in this study for both birds under CL and IL. This is birds' response to hunger, and then again just prior to lights going off in anticipation of the dark period (Buyse et al., 1993; May and Lott, 1994; Hughes, 2004; Neves et al., 2014; Schwean-Lardner et al., 2014). Interestingly, in the last short dark period of the day, from 19:00 to 22:00, the fact that birds under IL were in almost complete darkness did not impede them from consuming similar amounts of feed to that of birds under CL. This, as well as the fact that birds under IL ingested around 45% of their total daily feed intake during the various scotoperiods throughout the day, confirms that IL birds, or some of them, indeed learnt to eat in the dark, as suggested by Lewis and Gous (2007). Such observation markedly contrasts that of Buyse and Decuypere (1988) who stated that birds on IL limit feeding to the photoperiod of each light:dark cycle. Despite this ability apparently developed for IL but not for CL birds, IL birds still exhibited a vigorous rush of intake at the initiation of each feeding bout, unlike the apparent little excitement of CL birds during feeding. Such feeding behavior has been previously reported for birds on 1L:2D and led to heavier abdominal fat pads vs. the 24L controls (Ohtani and Leeson, 2000). The present study did not include abdominal fat pad weighing; however, a similar experiment conducted by our research group reported less abdominal fat accumulation for IL birds ($P < 0.05$, data not shown), which is in line with previous reports with similar light:dark intervals (Buyse and Decuypere, 1988; Buyse et al., 1996a). Also, limited data gathered through infra-red recording of IL birds during the scotoperiods showed that the great majority of birds rested throughout with only few birds visiting feeders at occasions. Such observation appears contradictory to the abovementioned high feed intake of IL birds during scotoperiods thus suggesting that feeding behavior during periods of darkness might be restricted to some birds, hypothetically lower-ranking ones in the flock's hierarchy. Agonistic behavior comparable to those observed in young layer stock has been observed in broiler chickens with limited access to feed (Mench, 1988). It might well be that the restricted time allocated for feeding activities in IL birds activated such hierarchical behaviors. Due to geographical limitations mixed-sex broilers were used in this study; however, it would be interesting to understand whether males and females exhibit different feeding behavior, especially when feed is restricted. Although feeder space was not a limitation in the present study (<70 birds/feeder diameter of 380 to 400 mm), concerns over feeder space for birds raised under IL have been previously raised as they seem to perform at the same level of, or better than, CL birds in particular when feeder space is increased (Nakaue, 1981; Weaver et al., 1982).

5. Conclusion

The main objective of this study was to understand whether feed consumption during scotoperiods of birds raised under IL (1L:3D:1L:3D:1L:3D:1L:3D:2L:6D) is negligible. For that purpose, at 31 d, weight of feeders was recorded at the start and at the end of each scotoperiod for IL birds. In order to understand feed consumption pattern of birds raised under CL (18L:6D) and to compare it with that of IL birds, their feeders were weighed in parallel.

Not only was feed intake of IL birds during the various scotoperiods throughout the day not negligible, it represented around 45% of their total feed intake. Both CL and IL birds presented anticipatory feed intake prior to the long nocturnal period of darkness (6D), as well as higher feed intake right at the onset of lighting at 6:00. IL birds exhibited excitement at the start of each hour-length scotoperiod and, within that time, ingested around 2.5 times the amount of feed ingested by CL birds.

Although short, this study revealed several interesting observations which might be worth further exploring in a larger, lengthier, behavior-focused experiment. It might be interesting to understand whether the high feed intake observed during scotoperiods for IL birds in reflective of the whole flock or rather a coping mechanism developed mainly by lower-ranking birds to achieve their daily feed intakes requirements. Also, it would be worth exploring whether: 1) the observed scotoperiod feeding behavior is homogeneous throughout the growing period; 2) the pattern of water intake in the dark follows that of feeding; 3) feeding behavior during scotoperiods is markedly influenced by genetics (i.e. slow vs. fast growing genotypes and/or different broiler strains) and; 4) early feeding and initial learning (first 3 to 7 d) influence feeding behavior of broilers in the dark.

Conflict of interest

We declare that we have no financial and personal relationships with other people or organizations that can inappropriately influence our work, there is no professional or other personal interest of any nature or kind in any product, service and/or company that could be construed as influencing the content of this paper.

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