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The impact of dietary protein content and lighting programme on breast meat yield in broiler chickens

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Abstract

Effects of the interaction between lighting programme and dietary protein content on broiler performance and meat yield were investigated. The hypothesis was that low breast meat yield from birds managed under short day lengths could be improved by increasing dietary protein content. The treatments consisted of four lighting programmes and four dietary protein levels. They were applied to sexed broilers from one day old to 35 days old. Eight light-tight rooms each contained eight pens with 50 birds, sexes separate, in each pen. Each feed x sex treatment was replicated twice in each room, with the four lighting treatments also being replicated twice. Multiple regression analysis was used to measure responses to the three factors. There was no significant interaction between dietary protein content and lighting programme in feed intake, feed conversion efficiency, bodyweight gain, carcass chemical composition and breast meat yield. Breast meat yield was linearly related to the number of hours of light, the highest yield occurring on the longest day length. Food intake was the same on the shortest day length and the longest, yet breast meat yield was greater on the 23-hour light programme. The decreased breast meat yield in broilers given short day lengths was therefore not the consequence of a shortage of dietary protein, and this hypothesis therefore had to be rejected.

Keywords: breast meat, day length, dietary protein, feed conversion efficiency, feed intake
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Introduction

Lighting programmes and dietary protein content influence broiler performance and meat yield. Lewis *et al.* (2009) conducted an experiment in which a range of constant photoperiods was applied to broiler chickens up to 35 days old. All performance characteristics except breast meat yield (BMY) benefited from a 12L:12D (L: light; D: dark) programme. This was unfortunate because BMY is of paramount importance in broiler production owing to its high value and demand. This may not be an issue where live birds are sold, but in most Western markets breast meat is the primary source of income from poultry carcasses (Mehaffey *et al.*, 2006). To ascertain whether BMY could be enhanced on a 12L:12D schedule by increasing the protein content of the feed supplied to the broilers on this lighting treatment, a follow-up trial was conducted by Mlaba *et al.* (2015). The rationale was that feed intake (FI) by broilers might be lower under short day length regimes than with longer day length, and thus the protein that was ingested not be sufficient ensure maximum BMY. However, the higher protein feeds did not enhance BMY in that trial. The question posed in that investigation was whether short day lengths per se resulted in reduced BMY. To evaluate this possibility, day length was reduced even further in the present investigation using intermittent lighting, which is known to influence the performance of broilers.

Broilers respond to light (Lewis & Morris, 2006), although reports on the effects of various treatments are often contradictory. Lighting treatments during the growing period may be continuous, of different length, increasing or decreasing, and intermittent (repeated short dark cycles over 24 hours) (Schwean-Lardner *et al.*, 2012). Traditionally it was believed that continuous or near-continuous lighting schedules resulted in increased FI and growth rate. Rodrigues and Choct (2019) found that broilers reared under continuous lighting had increased performance (growth rate and FI) compared with broilers on 6-, 12-, and 18-hour day lengths. In another study, bodyweights (BW) of broilers exposed to 23 hours light were heavier than those on 12 hours when they were raised to 42 days old (Ingram *et al.*, 2000). Brickett *et al.* (2007) reported that birds on 12 hours light were more feed efficient than those on longer day lengths, whereas Lewis and Gous (2007)

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found that broilers on eight hours light were more feed efficient than those on 16 hours. In an experiment by Classen (2004), short day lengths resulted in lower BW. The assumption was that darkness reduced the available feeding time. However, Lewis and Gous (2007) showed that BW was unaffected by day lengths greater than six hours. Feed intake was reduced when broilers were maintained on photoperiods less than12 hours, but at 35 days their BW was superior to those reared on day lengths greater than 16 hours. Broilers consumed feed during dark periods as long as these were longer than 8 hours and less than 18 hours (Lewis *et al.*, 2009). The proportion of feed consumed during the dark period increased with time of exposure to darkness (Classen, 2004; Lewis & Gous, 2007; Schwean-Lardner, 2011). These studies showed that BW and FI depended on photoperiod.

The current study was designed to determine whether BMY in broilers reared from one day to 35 days old was related to photoperiod and whether a higher protein feed would increase it to a greater extent on short photoperiods than on those more than 12 hours.

Materials and Methods

Use of animals and approval for all experimental protocols was granted by the University of KwaZulu-Natal Animal Care Committee (reference AREC/061/018M). The trial was conducted at Ukulinga Research Farm, Pietermaritzburg. A total of 3200 one-day-old Ross broiler chicks were reared in 8 light-tight rooms, each room being populated with a total of 400 broilers, 50 chicks being placed in each of the 8 pens (measuring 1.8 x 3.07 m) per room. males and females were penned separately. The floor in all rooms was covered with 10 cm wood shavings. Initially, the room temperature was set at 32 °C. This was decreased gradually to 22 °C by 21 days and kept at this temperature until 35 days, when the trial was ended. In each room, two gas-fired spot-brooders were used to provide heat, each mounted 750 cm from the floor. Minimum ventilation was initially set at 10% and was increased at fixed intervals to reach 100% at 21 days.

Treatments consisted of four levels of dietary protein, four lighting programmes, and two sexes. Two basal starter and finisher feeds (Table 1) were formulated to contain 0.85 and 1.30 of broiler nutrient requirements recommended by Aviagen (2009). The chemical composition of these diets is presented in Table 2. These basal feeds were mixed by a commercial feed company and blended on the farm to produce two intermediate feeds forming a dilution series, with levels of 0.85, 1.00, 1.15, and 1.30 times these recommendations. Starter feeds were fed from one old to 21 days, then finisher feeds from 22 days to 35. The feeds were not pelleted. Chicks were initially fed with open trays (two per pen). However, after seven days two self-feeders were used. Water was supplied in chick fonts for the first seven days, then bell drinkers were used. These four lighting treatments were applied in the trial, namely 23L:1D, 18L:6D, 12L:12D, and 1L:3D repeated 6 times daily. These treatments were introduced after the first 24 hours, with continuous lighting being used initially.

Initial bodyweights (BWs) were measured on the day of arrival by weighing a sample of six boxes (600) of chicks of each sex, subtracting the weight of the boxes, and calculating the mean BW per sex. At 21 and 35 days, birds were bulk weighed per pen, from which their bodyweight gains (BWG) were calculated. Feed intake (FI) was calculated as the difference between the feed allocated and that remaining at the end of each phase, divided by the average number of birds in the pen during the period. Feed conversion efficiency (FCE) (g gain/kg feed) was calculated from average daily gain and FI.

At 35 days, two birds were randomly selected from each pen to measure their chemical and physical properties. Individual BW was measured before electrical stunning and exsanguination. When bleeding had stopped, birds were weighed to measure blood loss and were weighed again after plucking with a drum plucker. Breast meat (without bone), thigh, wing, and drum (with skin and bone) were dissected and weighed separately. The remainder of the body was also weighed, after which all portions were placed in a plastic bag, sealed, labeled and placed in a freezer. Frozen samples were passed twice through a mincing machine, after which approximately 80 g of the mince was sampled for further analysis. Samples were freeze-dried for seven days using Edwards freeze drier, then milled with Retch ultra-centrifugal mill. Freeze-dried samples were then analysed to determine crude protein (CP) with the LECO FP200 nitrogen analyser. For CP analysis, 0.2 g was sampled from the dried sample. Lipid content was determined from the water content of the carcass using the unpublished equation that was generated from broiler carcass data accumulated over many years:

$$\text{Lipid content (\% as is)} = 62.5 - 0.7723 * \text{water content}$$

The responses to lighting programme and dietary protein content and their interaction for both sexes were predicted using multiple linear regression with groups in Genstat (VSN International, 2016). This analysis applied both linear and quadratic terms, with their interactions, with only those showing significance

(*P* <0.05) being used to describe the combined response. In addition, constant terms and regression coefficients were fitted for each sex to determine whether these differed significantly (*P* <0.05).

Table 1 Composition of the high and low protein basal feeds to be fed to broiler chickens

Ingredients, g/kg	HP starter	LP starter	HP finisher	LP finisher
Maize	271	634	526	704
Soybean full fat	360	50.0	250	202
Soybean 48	290	212	151	56.2
Fish meal 65	0	38.4	0	0
L-lysine HCl	1.75	2.76	1.48	0.54
DL methionine	2.75	1.70	2.26	0.82
L_tryptophan	0	0	34.3	0
L-threonine	0.86	0.53	0.46	0
Vit+min premix	1.50	1.50	1.50	1.50
Choline chloride 60%	0	1.07	0	0
Phytase 500	1.00	1.00	1.00	1.00
Limestone	10.2	9.64	12.8	12.7
Salt	2.38	1.06	2.13	2.32
Monocalcium phosphate	14.3	11.5	14.5	16.6
Sodium bicarbonate	3.71	4.65	2.10	1.95
Oil: soya	40.0	30.0	0	0

LP: low protein, HP: hogh protein

Table 2 Chemical composition (g/kg) of high and low protein basal feeds to be fed to broiler chickens

Nutrient	LP starter		HP starter		LP finisher		HP finisher	
	Total	Dig	Total	Dig	Total	Dig	Total	Dig
AME, MJ/kg	13.0		13.0		13.0		13.0	
Crude protein, g/kg	203	176	300	264	163	142	241	216
Lysine, g/kg	13.0	11.6	19.1	17.0	8.65	7.60	12.8	11.4
Methionine, g/kg	5.10	4.70	6.85	6.31	3.45	3.11	5.39	4.97
Methionine + cystine, g/kg	7.84	6.90	11.1	9.70	5.86	5.00	8.46	7.40
Threonine, g/kg	8.12	7.10	12.3	10.7	6.20	5.32	8.53	7.40
Tryptophan, g/kg	2.20	1.81	3.69	3.12	1.74	1.47	36.1	35.7
Arginine, g/kg	12.7	11.8	21.0	19.4	10.3	9.56	14.2	13.2
Isoleucine, g/kg	8.74	7.77	13.9	12.3	6.97	6.16	9.47	8.39
Phenylalanine + tyrosine, g/kg	16.2	14.6	25.1	22.3	13.4	11.9	17.6	15.6
Valine, g/kg	9.52	8.40	14.3	12.6	7.75	6.83	10.1	8.90
Crude fat, g/kg	84.5	76.4	129	111	79.4	71.5	80.3	70.1
Calcium, g/kg	8.00		8.00		8.50	8.50	8.50	8.50
Available phosphorus, g/kg	4.50		4.50		5.00	5.00	4.50	4.50

HP: high protein, LP: low protein, Dig: digestible, AME: apparent metabolizable energy

Results and Discussion

Mean BW, FI and FCE of sexed broilers subjected to four dietary protein levels and four lighting programmes are given in Table 3. There was no significant interaction between light and protein level for any of the three variables. The interaction term and non-significant second-order terms (*P* >0.05) were removed from the regression analysis and are not shown in the tables. Multiple regression coefficients relating these variables to the two treatments are given in Table 4. Bodyweight rose linearly as day length increased and curvilinearly to dietary protein content, with the lowest BW being on the lowest protein content. These terms were common to males and females. However, the constant term differed between the sexes, with males being heavier at 35 days than females. Feed intake responded curvilinearly to light, but dietary protein had no effect on this variable (t = 0.80). Over all treatments, males consumed more feed than females, but the responses to light and protein were the same. The goodness of fit (R^2) was low (16.1%). Feed conversion efficiency declined curvilinearly as day length increased, and rose linearly with dietary protein content, with males and females exhibiting the same responses to light and protein, but with a higher overall FCE for males (higher constant term).

Table 3 Mean bodyweight, feed intake and feed conversion efficiency of sexed broilers at 35 days old subjected to four dietary protein levels and four lighting programmes

	Dietary protein content, relative to Aviagen recommendations								
	0.85x		1.00x		1.15x		1.30x		Lighting regime means
	Females	Males	Females	Males	Females	Males	Females	Males	
Light , hours	Feed intake, g								
6	3350	4016	4044	4422	3976	4295	3972	4037	4014
12	4278	4371	3826	4401	4181	4339	3975	4214	4198
18	4415	4446	4246	4716	4128	4564	4042	4523	4385
23	4440	3747	3772	3996	3837	4076	4029	4003	3988
Sex x diet means	4121	4145	3972	4384	4031	4319	4005	4194	
Protein content means	4133		4178		4175		4099		
	Feed conversion efficiency, g gain/kg feed								
6	704	666	654	637	680	708	678	734	683
12	547	610	646	641	609	670	634	673	629
18	584	648	637	627	655	666	637	660	639
23	579	721	701	738	711	785	673	751	707
Sex x diet means	604	661	659	661	664	707	655	705	
Protein content means	632		660		685		680		
	Bodyweight, g								
6	2384	2714	2679	2853	2745	3082	2732	3001	2774
12	2377	2695	2503	2862	2585	2934	2559	2876	2674
18	2614	2921	2746	2995	2742	3078	2616	3027	2842
23	2568	2725	2662	2988	2750	3234	2731	3003	2833
Sex x diet means	2486	2764	2648	2925	2706	3082	2660	2977	
Protein content means	2625		2786		2894		2818		

It was not expected that feed intakes would differ markedly between treatments, because broilers learn to feed in the dark on day lengths shorter than 18 hours (Lewis *et al.*, 2009) However, intake increased with day length up to 18 hours and then decreased on 23 hours light, which was reported by Lewis *et al.* (2009), but differed from other reports (Downs *et al.*, 2006; Lien *et al.*, 2007), where intake was highest on 23 hours light. Buyse and Decuypere (1988) found that birds on 6 hours intermittent lighting consumed about 80 % of the daily feed intake consumed by the controls on 23.5 hours light. In the present trial, weight gain increased linearly with the number of hours of light, with the highest gain on 23 hours light. In previous trials the gains were the same on all day lengths (Lewis *et a*l., 2009) or higher on 23 hours (Ingram *et al.*, 2000; Rodrigues & Choct, 2019). As a consequence of the higher gain and lower intake, broilers on 23 hours light had the highest FCE of all lighting treatments. These levels of performance were contrary to the results of Lewis & Gous (2007) and Lewis *et al*. (2009). However, Aviagen (2009) suggested that performance was optimized at day lengths between 17 and 20 hours of light.

An increase in dietary protein content resulted in rises in FI, bodyweight gain and FCE, with the performance on the highest protein content (1.3 times requirements) being the same as on the next lower (1.15) level. This asymptotic response was expected and had been demonstrated (Mlaba *et al*., 2015). But as in Mlaba *et al*. (2015) there was no interaction between lighting and dietary protein with the response in FCE being the same under all lighting regimes.

Table 4 Prediction equations relating 35-day bodyweight, food intake to 35 days, and feed conversion efficiency to hours of light,relative dietary protein contents and sex[1]

Variable	Estimate	SE	*t*-statistic (59 df)	*P*-value
35-day bodyweight, g		R^2 = 61.3		
Constant	-928	933	-0.99	0.320
Light	6.02	2.89	2.08	0.040
Protein	61.2	17.7	3.47	<.001
Protein x protein	-0.264	0.082	-3.22	0.002
Sex	312	36.9	8.46	<0.001
Food intake, g		R^2 = 16.1		
Constant	3315	398	8.32	<0.001
Light	131	42.2	3.11	0.003
Light x light	-4.44	1.44	-3.09	0.003
Protein	-0.69	2.71	-0.25	0.800
Sex	229	90.8	2.52	0.015
FCE, g gain/kg feed		R^2 = 42.6		
Constant	670	51.3	13.10	<0.001
Light	-27	5.43	-4.96	<0.001
Light x light	0.977	0.185	5.28	<0.001
Protein	1.123	0.349	3.22	0.002
Sex	38	11.7	3.25	0.002

[1]Protein content was scaled relative to Aviagen (2009) recommendations; sex was coded as female = 0 and male = 1

The weights of physical parts of the broilers, anmely deboned breast, thigh, drum and wing are shown in Table 5. The multiple regression coefficients relating these weights to the two treatments are given in Table 6. No interaction between light and protein content was evident in any of these variables. Second-order terms that were not significant (*P* >0.05) were dropped from the analysis, but all linear terms are given in the table, together with the effect of sex on the constant term, which in all cases was significant, with male weights being heavier than those from females. As with body weight, FI and feed conversion, the physical parts of the broiler responded to light and to dietary protein. Day length was related linearly to both BMY and drum weight, with these weights being numerically lower on the 12 hours light treatment. Thigh and wing weights were unaffected by the length of the photoperiod. The range of day lengths used in this trial was greater than that used by Mlaba *et al.* (2015) (18 hours as opposed to 11), yet the responses were similar, indicating that broilers respond in the same way to intermittent lighting and to constant day lengths. This refuted the suggestion that reduced energy expenditure and stress under intermittent lighting (Onbaşılar *et al.*, 2007) might improve BMY in broilers (Škrbić *et al.*, 2011; Yang *et al.*, 2015). Breast meat yield increased linearly with hours of light and curvilinearly with dietary protein content, whereas thigh weight increased linearly with both light and protein content. Drum weight increased linearly with dietary protein content, but was unaffected by an increase in the number of hours of light. Similarly, dietary protein content had a greater influence on wing weight than day length, although the linear response was not quite significant (t = 0.055).

Table 5 Mean weights of deboned breast meat, thigh, drum and wing weights at 35 days in male and female broilers fed increasing dietary protein levels and raised under four lighting programmes

	Dietary protein, relative to Aviagen recommendations								Lighting regime means
	0.85x		1.00x		1.15x		1.30x		
	Deboned breast meat, g								
Light, hours	Female	Male	Female	Male	Female	Male	Female	Male	
6	433	486	342	488	447	492	453	476	452
12	395	404	413	495	437	454	425	488	439
18	398	482	447	467	470	526	439	498	466
23	429	433	460	535	494	563	436	502	481
Sex x diet means	414	451	415	496	462	509	439	491	
Protein content means	432		456		485		465		
	Thigh, g								
6	210	238	216	240	210	250	232	261	232
12	212	252	213	252	230	254	218	308	242
18	210	229	233	273	215	274	227	269	241
23	200	251	210	259	240	242	227	229	232
Sex x diet means	208	242	218	256	224	255	226	267	
Protein content means	225		237		239		246		
	Drum, g								
6	145	193	152	192	159	204	186	192	174
12	137	172	150	187	164	193	174	205	167
18	142	186	166	185	170	200	170	208	175
23	146	165	160	196	173	187	158	196	171
Sex x diet means	143	179	157	190	167	196	172	200	
Protein content means	161		173		181		186		
	Wing, g								
6	131	161	135	156	137	159	151	150	147
12	129	144	134	155	139	150	140	160	142
18	133	161	146	154	138	164	137	167	148
23	140	147	147	164	141	164	134	157	148
Sex x diet means	133	153	141	157	139	159	141	159	
Protein content means	133		141		139		141		

Broiler producers continually seek methods of improving profitability by increasing performance or by reducing the cost of production. The cost of electricity is such that considerable savings could be made by reducing the number of hours of light used in a broiler house, provided that performance was not affected adversely. Conventionally, a 23 L:1D programme was used in broiler houses on the assumption that birds required light to find the feeders and drinkers (Lewis & Morris, 2006). This changed with the European Union Council (2007) directive, enforceable from 30 June 2010, which stipulated that after seven days old broilers must be given a lighting regime that followed a 24-hour rhythm and had at least 6 hours total darkness, of which at least 4 hours must be uninterrupted. This led to a number of studies in which various day lengths were applied to ascertain their effect on the performance of commercial broilers. Among many trials, Lewis *et* *al.* (2009) demonstrated advantages in growth rate, feed efficiency, bone strength, and liveability when using 12-hour photoperiods, but this treatment reduced BMY significantly compared with a 23-hour lighting regime.

Table 6 Prediction equations relating relating deboned breast meat, thigh, drum and wing weights of broilers at 35 days to hours of light. relative dietary protein content and sex[1]

Variables	Estimate	SE	*t*-statistic (61 df)	*P*-value
Breast meat	R^2 = 29.8			
Constant	-237	232	-1.02	0.308
Light	1.99	0.719	2.76	0.007
Protein	11.3	4.39	2.58	0.011
Protein x protein	-0.049	0.020	-2.39	0.018
Sex	54.4	9.17	5.93	<0.001
Thigh	R^2 = 43.0			
Constant	152	15.3	9.93	<0.001
Light	0.713	0.344	2.07	0.040
Protein	0.511	0.131	3.90	<0.001
Sex	39.1	4.39	8.90	<0.001
Drum	R^2 = 29.4			
Constant	102	12.5	8.1	<0.001
Light	-0.161	0.283	-0.57	0.569
Protein	0.561	0.107	5.22	<0.001
Sex	31.9	3.60	8.84	<0.001
Wing	R^2 = 38.3			
Constant	121	7.56	16.05	<0.001
Light	0.218	0.170	1.28	0.204
Protein	0.126	0.065	1.94	0.055
Sex	19.0	2.17	8.74	<0.001

[1]Protein content was scaled relative to Aviagen (2009) recommendations; sex was coded as female = 0 and male = 1

Breast meat yield is of paramount importance in broiler production. So it was deemed worthwhile to ascertain whether this problem could be overcome with higher dietary protein feed, since FI was lowered on a short day length, thus reducing the supply of dietary protein for body protein synthesis. Mlaba *et al.* (2015) confirmed the benefits of a 12-hour day length on performance, but did not improve BMY by feeding additional protein to broilers on 12 hours light. The current study was designed to determine whether BMY was related to photoperiod per se by introducing an intermittent lighting programme that provided just 6 hours light/day, and whether a higher protein feed would increase BMY to a greater extent on short photoperiods than on those longer than 12 hours. Because this was a response trial, in which the levels of the two factors were not independent, the trends or responses to the imposition of dietary protein level and day length were important, and not whether there were differences between treatment means (Morris, 1983; 1999).

Body water, protein and lipid contents (g/kg) of the sampled broilers at 35 days are given in Table 7. These three chemical components all responded linearly to dietary protein content, but not to the number of hours of light. There was no interaction between light and dietary protein content. Since the lipid contents were calculated from body water content, the lipid contents were affected in the same way as the water, except that the correlation was negative.

The following equations describe the response in body water (BW, g/kg), protein (BP, g/kg) and lipid (BL, g/kg) to the relative protein content of the diet (DPC) and sex (female = 0, male = 1):

$$BP = 148 (\pm 8.29) + 37.4 (\pm 7.64) \times DPC \quad (R^2 = 10.8)$$
$$BW = 551 (\pm 7.89) + 50.6 (\pm 7.17) \times DPC + 6.42 \times sex \quad (R^2 = 22.3)$$
$$BL = 199 (\pm 6.09) - 38.9 (\pm 5.53) \times DPC - 4.92 \times sex \quad (R^2 = 22.2)$$

Table 7 Mean body water, lipid, and protein content (g/kg) of broiler chickens fed four levels of dietary protein and subjected to four lighting schedules to 35 days old

	Dietary protein content, relative to Aviagen recommendations								Lighting regime means
	0.85x		1.00x		1.15x		1.30x		
	Female	Male	Female	Male	Female	Male	Female	Male	
Light, hours	Body water, g/kg								
6	601	616	594	589	584	588	599	607	611
12	603	603	587	614	618	594	596	606	607
18	619	626	608	621	608	617	618	619	606
23	601	619	628	619	609	628	615	624	611
Sex x diet means	595	600	601	604	613	621	613	622	
Protein content means	597		603		617		618		
Body protein									
6	172	179	188	173	192	175	172	178	187
12	181	197	187	185	179	183	198	188	188
18	186	190	194	192	188	188	181	204	188
23	194	197	199	189	207	191	186	205	189
Sex x diet means	181	176	186	188	187	194	197	196	
Protein content means	179		187		191		196		
Body lipid									
6	161	150	166	170	174	171	162	156	153
12	159	159	172	151	147	167	165	157	156
18	148	142	156	145	155	149	148	147	157
23	161	147	140	147	155	140	150	143	154
Sex x diet means	166	162	161	158	152	146	151	144	
Protein content means	164		160		149		148		

Day length did not have any influence on the chemical composition of the broilers in this trial. This was contrary to reports by Apeldoorn *et al.* (1999), who used a 6-hour programme, and Yang *et al.* (2015), who used two intermittent lighting regimes (2L:2D and 4L:4D). In both cases fat content was low compared with the continuous lighting. Conversely, an intermittent programme of 1L:2D used by Ohtani & Leeson (2000) resulted in higher abdominal fat content compared with continuous lighting.

Dietary protein content had a greater effect on the growth of the physical parts than day length. Breast meat yield rose curvilinearly with an increase in protein content, whereas thigh, drum and wing weights all rose linearly, corresponding to increases in body protein and water contents. Danisman & Gous (2011; 2013) demonstrated that there were allometric relationships between the physical parts of the body and body protein content, with the weights of the physical parts increasing with body protein content. Because more lipid is deposited in the body on low protein feeds as opposed to high (Gous et al., 1990) the weights of the physical parts would be expected to increase on low protein feeds at a given body protein content, because of this increase in lipid content, thus increasing the constant term in the allometric regression. This was corroborated by Mlaba et al. (2009) because the body lipid content increased as dietary protein content decreased. This would account for the observation by Brickett *et al.* (2007) that birds fed low protein feeds had heavier wing and drum weights at 35 days as a result of the intramuscular fat that had been deposited.

Conclusion

The responses in feed intake, weight gain, carcass composition and in the weights of the physical parts of the broiler were greater over the range of dietary protein level fed than from the range of constant day lengths imposed on the birds. There were no interactions between dietary protein and lighting programme in any of the variables. Although the birds consumed less food with 6 hours of light compared to those having light for 12 and 18 hours, birds on the regime providing 23 hours of light consumed the same amount of food but grew faster and had heavier breasts than broilers on the 6-hour intermittent lighting programme. The decreased breast meat yield in broilers given short day lengths was not the consequence of a shortage of dietary protein, and thus this hypothesis was rejected.

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Authors' Contributions

PS was responsible for conducting the experiment, data collection, analysis of results, and write up. ZR was responsible for supervising and editing the written paper, ensuring that the paper followed the guidelines. RG oversaw project planning and statistical analysis of the results and assisted in editing the paper.

Conflicts of Interest Declaration

The authors state under confidence that there are no conflicts of interest with regard to the publication of the manuscript.

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