Interaction Between Step-Up Versus Step-Down Lighting from Four to Sixteen Weeks on Growth and Development in Turkey Hens from Two Commercial Strains[1]

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ABSTRACT British United Turkeys (BUT) and Nicholas (NIC) hens were exposed to a step-up (10 to 16 h/day) or a step-down (16 to 10 h/day) light program from 4 to 16 wk of age. Lights were increased or decreased by .5 h/wk. From 1 to 20 wk, weekly BW data were used to calculate growth curve parameters according to the Gompertz equation. Compared with BUT hens, the slope of the growth curve was greater, but the BW and age at the point of inflection (POI) was decreased in NIC hens. The step-down light program significantly increased the slope of the growth curve, but decreased the BW and age at POI compared with the step-up program. A sample of hens from each strain and program was processed at 16 wk. The relative weight of the *Pectoralis minor* (*P. minor*) was increased in BUT hens compared with NIC hens. The absolute and relative weights of the *Pectoralis major* and the absolute weight of the *P. minor* were increased in hens from the step-down program compared with the step-up program. The step-up program significantly increased the relative weight of the abdominal fat pad compared with the step-down program, and NIC hens had more abdominal fat than BUT hens. Total carcass lipid was significantly increased by the step-up program, compared with the step-down program, and NIC hens had significantly more carcass lipid than BUT hens.

(*Key words*: turkeys, hens, photoperiod, body weight, breast muscle)

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INTRODUCTION

The commercial turkey industry has changed considerably over the past decade, particularly with respect to growth and development of commercial birds. Consumer awareness with respect to diet has greatly increased the consumption of all poultry meat. With the increased proportion of turkey meat going into further processed food products, there is a need for basic research that increases the understanding of overall carcass development and not just the variables BW gain and feed efficiency.

The effect of photoperiod on different aspects of growth in turkeys has received considerable attention. McCartney (1956) reported that growing turkeys needed a minimum of 13 h of light/day for maximum feed intake and BW gain and that 15 h were optimal. Shoffner *et al.* (1962) reported that 6 h of light/day or exposure

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to natural daylength significantly improved growth compared with a continuous light treatment. Aukland (1978a,b) studied the effects of constant 23-, 14-, or 8-h days compared with a step-down 22- to 14-h treatment and found no significant light treatment effects on BW or feed efficiency in toms and hens. Hester *et al.* (1983) reported that a high-intensity, step-up (HISU) lighting program resulted in a significant decrease in BW in hens compared with a low intensity, step-down (LISD) program. The LISD program, however, was actually a 12 h light (L):12 h dark (D) light regimen from 2 through 19 wk. Peng *et al.* (1985) reported that the LISD light program significantly increased breast muscle weight and percentage compared with the HISU light program. Klingensmith *et al.* (1986) reported the HISU light program caused earlier sexual maturity and epiphyseal plate closure in toms compared with the LISD program.

The demand for turkey meat for incorporation into further processed products makes it necessary for the industry to use a significant number of hens, in addition to a majority of the toms, for deboning. Larsen *et al.* (1988) studied the comparative growth and carcass component yields of hens from three commercial strains from 12 to 21 wk of age. Their results showed that economically important muscle groups continue to grow in hens through 21 wk of age, and there are significant strain differences independent of differences in BW.

As discussed by Larsen *et al.* (1988), there is a considerable interest in the relative differences among commercial genotypes in the pattern of growth and carcass development. Peng *et al.* (1985) reported that the HISU light program significantly increased carcass fat compared with the LISD program. Hens have a greater predisposition for fat accretion than toms and any increases in carcass fat in response to an increasing photoperiod in heavy hens might exacerbate the situation. The objectives of the present study were to characterize the growth curves and carcass component weights of hens from two commercial strains, and secondly, to study the effects of different photoperiod regimens on the same growth and carcass parameters.

MATERIALS AND METHODS

Hatching eggs from similar aged British United Turkeys (BUT) and Nicholas (NIC) breeder hens were hatched at the Ohio Agricultural Research and Development Center, Wooster, OH. All the birds were sexed, wing-banded, and debeaked in the hatchery prior to placement. An equal number of hen poults were randomly assigned to one of four environmentally controlled rooms in a solid-walled rearing house. Each room was equipped with an independent lighting system. The two strains were reared intermingled among the four rooms for the entire study. During the initial brooding period (0 to 4 wk), the birds were kept in one section of each room. The size of this section was calculated to allow for .035 m^2 per poult. From 4 to 12 wk of age, the hens in each room were randomly allotted to two replicate pens per room and the floor space was increased to .52 m^2 per bird. For the latter portion of the study (12 to 20 wk of age), the hens in each room were randomly reallocated to three replicate pens per room and the floor space was increased to .85 m^2 per hen. All hens were fed diets formulated to National Research Council (1984) specifications (Table 1).

Photoperiods by week among the four rooms for the first 4 wk of the study were the following; 24L:0D, 23L:1D, 20L:4D, and 16L:8D (Table 2). Beginning at 4 wk of age, the photoperiod in two rooms was decreased to 10 h and then increased by .5 h/wk to a maximum of 16 h at 16 wk of age (step-up). In the other two rooms, the lights were decreased from 16 to 10 h by .5 h/wk (step-down). The initiation of the lighting programs at 4 wk coincided with the initial division of each room into multiple, replicate pens.

At 7 days of age, 100 poults from each strain (50 per light program after 4 wk; 25 per each strain per room) were identified by wing-band and individually weighed. These hens were individually marked and reared intermingled with the other birds. They were weighed at weekly intervals through 20 wk of age. The weekly BW data were fitted for Gompertz growth analysis as described by Anthony *et al.* (1986). Growth curve parameters were

TABLE 1. Composition of experimental diets

Ingredients and composition	Age, wk				
	0 to 4	4 to 8	8 to 12	12 to 16	16 to 20
	(g)				
Corn	44.50	46.00	61.00	65.50	68.00
Corn gluten meal, 60% CP	3.80	2.30	. . .	. . .	. . .
Alfalfa, 17% CP	4.00	4.00	. . .	. . .	. . .
Soybean meal, 48% CP	37.90	38.00	30.80	28.00	. . .
44% CP	. . .	. . .	. . .	. . .	23.50
Fish meal, menhaden, 60% CP	5.00	3.00	2.50	. . .	. . .
Animal-vegetable fat	. . .	1.80	1.00	2.00	4.00
Salt	.20	.30	.20	.25	.25
Ground limestone	.50	.60	.60	.50	.50
Defluorinated phosphate	2.05	2.00	1.80	1.70	1.70
DL-methionine	.05	. . .	. . .	.05	.05
Lysine HCl	. . .	. . .	.10	. . .	. . .
Vitamin and mineral premix[1,2,3]	2.00	2.00	2.00	2.00	2.00
Composition					
Crude protein, %					
Calculated	28.4	26.4	21.7	19.25	16.37
Analyzed	27.2	25.7	22.6	19.80	17.20
ME, kcal/kg	2,796	2,890	2,994	3,091	3,190
Lysine, %	1.62	1.52	1.32	1.05	.85
Methionine, %	.58	.47	.39	.38	.34
TSAA, %	1.05	.90	.74	.68	.61

[1]The premix contributed the following (grams per 100 kg feed): ground corn, 422; choline chloride (60%), 100; amprolium (25%), 22.7; selenium premix (200 mg/kg Se), 45.4; DL-methionine (99%), 45.4; trace mineral premix, 45.4; vitamin premix, 227.

[2]The vitamin premix contributed the following per kilogram of diet: vitamin A, 8,745 IU; cholecalciferol, 3,745 IU; vitamin E, 60 U; vitamin K (menadione sodium bisulfite), 2.91 mg; thiamine HCl, 2.2 mg; riboflavin, 6.6 mg; niacin, 99 mg; pantothenic acid, 15.4 mg; folic acid, 1.2 mg; pyridoxine, 2.2 mg; biotin, 165 mg; vitamin B_{12}, 15 mg; ethoxyguin, 113.5 mg.

[3]The trace-mineral premix contributed the following per kilogram of diet: zinc oxide (72% Zn), 147 mg; manganous oxide (55% Mn), 152 mg; copper sulfate (25.2% Cu), 35 mg; ferrous sulfate monohydrate (31% Fe), 72 mg; potassium iodide, 1.5 mg.

TABLE 2. Lighting schedule for hens in the step-down and step-up programs

Age	Step-down program			Step-up program		
	Light per day	Lights on	Lights off	Light per day	Lights on	Lights off
(wk)	(h)					
0 to 1	24	. . .	. . .	24	. . .	. . .
1 to 2	23	0100	2400	23	0100	2400
2 to 3	20	0200	2200	20	0200	2200
3 to 4	16	0400	2000	16	0400	2000
4 to 5	16	0400	2000	10	0700	1700
5 to 6	15.5	0430	2000	10.5	0700	1730
6 to 7	15	0430	1930	11	0630	1730
7 to 8	14.5	0500	1930	11.5	0630	1800
8 to 9	14	0500	1900	12	0600	1800
9 to 10	13.5	0530	1900	12.5	0600	1830
10 to 11	13	0530	1830	13	0530	1830
11 to 12	12.5	0600	1830	13.5	0530	1900
12 to 13	12	0600	1800	14	0500	1900
13 to 14	11.5	0630	1800	14.5	0500	1930
14 to 15	11	0630	1730	15	0430	1930
15 to 16	10.5	0700	1730	15.5	0430	2000
16 to 20	10	0700	1700	16	0400	2000

analyzed using the General Linear Model (GLM) procedure of the base SAS® software system (SAS Institute, 1985). The main effects tested were strain and light program and the interaction of strain by light program. All the hens in each room were weighed at 4, 8, 12, and 16 wk.

At 16 wk, 30 hens from each strain and light program (n = 120) that were not part of the growth curve study were randomly selected, individually weighed (live weight), and killed by exsanguination. After scalding, feather removal, evisceration (head and neck, shanks, and viscera), and abdominal fat removal, the hens were again weighed (eviscerated weight). The viscera was considered to be all internal organs including heart and lungs but excluding the kidneys. Abdominal leaf fat was removed prior to viscera removal and included all the fat surrounding the abdominal cavity but not any fat associated with the gizzard or intestine. Eviscerated carcasses were stored in an ice-water slush overnight and individually reweighed prior to dissection (chilled weight). From one half of each carcass, the *Pectoralis major* (*P. major*) and *Pectoralis minor* (*P. minor*) muscles were individually dissected and weighed. The tibia plus associated muscles (drum), and femur plus associated muscles (thigh) were also dissected from the same half-carcass and weighed. One person was responsible for each stage of the cut-up process. The lengths of the femur and tibia were also recorded. Relative carcass parts data are expressed as a percentage of live BW prior to processing.

The chilled carcasses from eight hens per strain and light program combination (n = 32 total) were cut in half lengthwise on a band saw after parts and muscle dissection. The undissected portion was frozen at –20 C for determination of total carcass protein and lipid. Each half was thawed, ground, and several subsamples were mixed, frozen, and lyophilized as described by Bacon *et al.* (1986). The composite samples weighed approximately 500 g prior to drying. Two subsamples from each dried carcass sample were analyzed for total protein and three subsamples were analyzed for total lipid also as described by Bacon *et al.* (1986). The carcass data were analyzed by analysis of variance using GLM (SAS Institute, 1985) with strain and lighting program as main effects.

TABLE 3. The influence of strain and lighting program on growth curve parameters[1]

Variable	Point of inflection		
	Weight	Age	Slope
	(g)	(days)	(ΔCF/day^2)
Strain[3]			
BUT	5,598 ± 88[a]	84.4 ± .8[a]	.0120 ± .0002[b]
NIC	5,286 ± 84[b]	78.3 ± .8[b]	.0130 ± .0002[a]
Lighting program			
Step-up	5,773 ± 89[a]	83.9 ± .9[a]	.0121 ± .0002[b]
Step-down	5,087 ± 67[b]	78.7 ± .7[b]	.0130 ± .0002[a]

[a–b]Means ± SE within strains and programs with no common superscripts are different ($P<.05$).

[1]Gompertz equation was used to fit growth curves.

[2]Slope was expressed as the change in the conversion factor (ΔCF) over time. The conversion factor is that value that when substituted for BW and expressed over time will yield a straight line (Richlefs, 1967).

[3]BUT = British United Turkeys; NIC = Nicholas.

RESULTS

Growth Curve Analysis

The magnitude or slope of the growth curve was significantly increased in the NIC compared with BUT hens (Table 3). The slope is represented by the conversion factor, a value that when substituted for BW and expressed over time will result in a straight line. Although the slope of the growth curve was greater, a decline in linear growth as represented by the point of inflection (POI), was reached at a significantly earlier age and lighter body weight in the NIC compared with BUT hens. The step-down lighting program also resulted in a significant increase in the slope of the growth curve compared with the step-up program. The step-down program, however, also resulted in a significantly earlier age and BW at the POI compared with the step-up program.

There were significant strain differences in intermediate and final BW (Table 4). Nicholas hens were significantly heavier at

TABLE 4. Effect of lighting program and strain on live body weight in commercial hens

Variable	Age, wk 4	8	12	16
	(kg)			
Strain[1]				
BUT	.962	2.714	5.362	8.414
NIC	1.077	2.992	5.706	8.212
Lighting program				
Step-down	1.031	2.861	5.594	8.243
Step-up	1.007	2.845	5.474	8.384
SEM	.016	.038	.059	.051
Source of variation	Probability			
Strain	.0001	.0001	.0015	.0087
Lighting program	.1265	.556	.164	.054

[1]BUT = British United Turkeys; NIC = Nicholas.

TABLE 5. Effect of lighting program on feed consumption in growing turkey hens

Lighting program	Feed intake 4 to 8 wk	8 to 12 wk	12 to 16 wk
	(kg per bird)		
Step-down	3.96[a]	7.93	9.40[b]
Step-up	3.45[b]	8.03	10.74[a]
SEM	.11	.20	.23

[a–b]Means within an age with no common superscripts are different (P<.05).

4, 8, and 12 wk whereas BUT hens were heaviest at 16 wk. The step-up lighting program resulted in increased BW at 16 wk (P<.053) and there were no strain by lighting program interactions at any age. Hens in the step-down light program consumed significantly more feed than those in the step-up program from 4 to 8 wk after the initiation of the light study (Table 5). There were no significant lighting program differences in consumption from 8 to 12 wk, but from 12 to 16 wk the step-up program resulted in a significant increase in feed intake compared with the step-down light program.

The NIC hens randomly chosen for processing were significantly heavier than the BUT hens (P<.049; Table 6) but there were no significant strain differences in eviscerated or chilled carcass weight. There were also no significant differences in the absolute weights of the *P. major* and *P. minor* breast muscles. The hens chosen from the step-down light program were significantly heavier than the hens randomly selected from the step-up program. The weights of the eviscerated carcass, chilled carcass, *P. major*, and *P. minor* were also significantly increased in hens from the step-down program compared with the step-up program. The relative weights of the eviscerated carcass, chilled carcass, and *P. major* were similar in NIC and BUT hens (Table 7). The relative weight of the *P. minor*, however, was significantly increased in BUT hens compared with NIC hens. The relative weight of the eviscerated carcass, chilled carcass, and *P. minor* were similar in hens from the step-down and step-up light programs. The relative weight of the *P. major*, however, was significantly greater in hens from the step-down program.

The femur and tibia were significantly longer in BUT hens compared with NIC hens (Table 8) but there were no strain differences in the weight of the thigh or drum. There were no lighting program effects on the length of the tibia or femur but the step-down program resulted in increased thigh and drum weights compared with the step-up program. There were no significant strain or lighting program effects on the relative weight of the thigh or program effects on the relative weight of the drum (Table 9). The relative weight of the drum, however, was significantly increased in BUT hens compared with NIC hens. The abdominal fat pad was significantly heavier in NIC hens compared with BUT hens. The relative weight of the abdominal fat pad was also significantly increased in NIC hens compared with BUT hens (Table 9). The step-up light program also resulted in a significant increase in the relative weight of abdominal fat relative to the step-down program.

Nicholas hens had significantly more carcass lipid than BUT hens, and the step-up program also resulted in significantly more carcass lipid than the step-down program (Table 10). Neither strain nor light program had an effect on carcass protein.

DISCUSSION

Results from the present experiment support what is observed commercially;

TABLE 6. Influence of lighting program and strain on carcass characteristics of turkey hens at 16 wk of age. 1. Absolute weight

Variable	Live weight	Eviscerated weight	Chilled carcass weight	*Pectoralis major*[1]	*Pectoralis minor*[1]
	(kg)				
Strain[2]					
BUT	8.125	6.560	6.715	.736	.221
NIC	8.340	6.720	6.870	.751	.211
Lighting program					
Step-down	8.370	6.76	6.940	.771	.224
Step-up	8.090	6.52	6.645	.716	.208
SEM	.080	.07	.07	.011	.004
Source of variation	Probability				
Strain	.049	.097	.116	.328	.136
Lighting program	.014	.013	.004	.0004	.018

[1]The values represent muscles taken from one half of the breast.
[2]BUT = British United Turkeys; NIC = Nicholas.

there are significant differences between commercial strains in growth rate and carcass composition (C. Link, Cooper Farms, Inc., Ft. Recovery, OH 45846, personal communication). The growth curve data suggested that NIC hens have a greater magnitude of early growth but their linear growth reaches a plateau at a significantly younger, physiological age and lighter BW. The BUT hens, on the other hand, would have a lower, but longer rate of linear growth. Anthony *et al.* (1991a) reported that hen turkeys also had an increased magnitude of early growth but a significantly decreased age and BW at POI compared with faster growing toms. In comparisons made among growth-selected and control strains of quail, chickens, and turkeys (Anthony *et al.*, 1991b), an increased slope of the growth curve was always associated with a decreased age at POI. The growth curve observations from the present experiment were supported by the overall flock body weight data; the NIC hens were significantly heavier at 4, 8, and 12 wk, whereas BUT hens were heaviest at 16 wk. As growth reaches a plateau, nutrient require-

TABLE 7. Influence of lighting program and strain on carcass characteristics of turkey hens at 16 wk of age. 2. Relative weight (grams per gram BW × 100)

Variable	Eviscerated weight	Chilled carcass weight	*Pectoralis major*[1]	*Pectoralis minor*[1]
	(% live weight)			
Strain[2]				
BUT	80.75	82.88	9.06	2.72
NIC	80.43	82.29	8.95	2.54
Lighting program				
Step-down	80.64	82.79	9.16	2.70
Step-up	80.54	82.38	8.85	2.57
SEM	.22	.34	.09	.21
Source of variation	Probability			
Strain	.328	.499	.395	.019
Lighting program	.737	.201	.021	.118

[1]The values represent muscles taken from one half of the breast.
[2]BUT = British United Turkeys; NIC = Nicholas.

TABLE 8. Effects of lighting program and strain on thigh and drum characteristics and abdominal fat (Fat) in turkey hens at 16 wk of age. 1. Absolute weight

Variable	Thigh weight	Femur length	Drum weight	Tibia length	Fat
	(kg)	(cm)	(kg)	(cm)	(kg)
Strain[1]					
BUT	.511	11.46	.426	18.10	.106
NIC	.518	11.23	.416	17.64	.147
Lighting program					
Step-down	.525	11.35	.429	17.88	.120
Step-up	.504	11.33	.413	17.85	.133
SEM	.078	.06	.029	.06	.004
Source of variation	Probability				
Strain	.527	.007	.118	.0001	.0001
Lighting program	.057	.824	.019	.714	.075

[1]BUT = British United Turkeys; NIC = Nicholas.

TABLE 9. Effects of lighting program and strain on thigh and drum characteristics and abdominal fat (Fat) in turkey hens at 16 wk of age. 2. Relative weight (grams per gram BW × 100)

Variable	Thigh weight	Drum weight	Fat
	(% BW)		
Strain[1]			
BUT	6.29	5.26	1.31
NIC	6.21	4.98	1.75
Lighting program			
Step-down	6.27	5.13	1.42
Step-up	6.23	5.10	1.64
SEM	.06	.04	.06
Source of variation	Probability		
Strain	.377	.0001	.0001
Lighting program	.706	.569	.008

[1]BUT = British United Turkeys; NIC = Nicholas.

ments for growth will also reach a plateau. The younger age at the POI observed for the NIC might allow for increased nutrient availability for lipid synthesis and subsequent increases in abdominal fat and total carcass lipid as was observed for NIC hens at 16 wk.

The step-down lighting program also resulted in a greater magnitude of early growth but a significant decrease in the age and weight at the POI relative to the step-up lighting program. Contributing to this was the significant decrease in feed intake from 4 to 8 wk observed for hens in the step-up light program when lights were decreased to 10 h at the start of the light study. The opposite was observed from 12 to 16 wk, as the step-down light program probably did not allow for adequate feeding time compared with the step-up light program. The increased feed intake for the latter growing period (12 to 16 wk) may have also contributed to the increased 16 wk BW and associated increase in abdominal fat and total carcass lipid for those hens in the step-up program.

McCartney (1956) reported that a minimum photoperiod of 13 h/day was needed to maximize feed intake and BW gain in growing turkeys and 15 h/day was optimal. Aukland (1978a) reported that different photoperiods (2 to 16 wk) had no effect on BW at 16 wk, but 23 h of light per day increased BW at 6 wk compared with other constant light programs (14 or 8 h/day) or a step-down (22 to 14 h) treatment. Hester *et al.* (1983) reported, however, that an HISU (20 lx) treatment decreased BW gain in hens compared with an LISD (2.51 lx) treatment. It is difficult to compare the results of Hester *et al.* (1983) with the results of the present experiment, however. The LISD treatment only decreased light from 4 to 15 days, after which the hens were

TABLE 10. The effect of lighting program and strain on carcass protein and lipid in commercial hens at 16 wk of age

Variable	Carcass protein	Carcass lipid
	(% DM)	
Strain[1]		
BUT	51.0	35.2
NIC	48.3	40.0
Lighting program		
Step-down	50.9	35.8
Step-up	48.4	39.4
SEM	.8	1.0
Sources of variation	Probability	
Strain	.082	.008
Lighting program	.105	.043

[1]BUT = British United Turkeys; NIC = Nicholas.

exposed to a 12L:12D photoperiod (diurnal), whereas, in the present experiment, the photoperiod was actually decreased for the majority of the growing period.

The NIC hens randomly selected for processing were significantly heavier than the BUT hens. With respect to whole carcass and breast development, however, the only strain difference was the relative weight of the *P. minor* which was larger in BUT hens. The reason for this is not readily apparent. The increased absolute weight of the hot and chilled carcasses and two breast muscles in hens from the step-down light program was probably a reflection of the increased BW associated with those hens randomly selected for processing. The relative weight of the *P. major* was also significantly greater in those hens from the step-down program, however, similar to what was reported by Peng *et al.* (1985), albeit the results from the latter study were more evident at later ages than those studied in the present experiment.

The decreased length of the tibia and femur in NIC hens compared with BUT hens is similar to what has been reported for NIC hens and toms compared with another fast-growing strain (F line; Lilburn and Nestor, 1991). Hester *et al.* (1983) reported that in hens, a LISD lighting program significantly increased drum length compared with a HISU treatment, contrary to the lack of treatment effects observed in the present experiment. In the Hester *et al.*, (1983) study, however, the step-down treatment increased BW significantly and this may have influenced skeletal growth. That study also incorporated major differences in light intensity that were not addressed in the current study. The increased weight of the thigh and drum associated with the step-down program in the present study was probably a reflection of the increased BW observed in hens chosen for processing, because there were no program effects on the relative weight of the thigh or drum.

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