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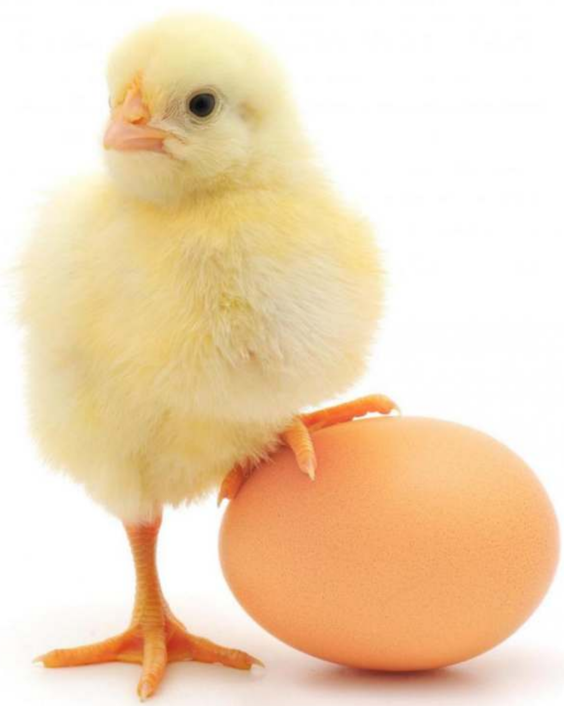

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Effect of Rearing Program, Body Conformation and Protein Level of Breeder Feed on Broiler Breeder Hen Reproductive Performance

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Abstract: The effect of pullet growth curve on body conformation and subsequent reproductive performance and effect of breeder feed protein level on reproductive performance was determined. The cost effectiveness of the different programs was evaluated. Cobb 700e pullets were reared from day of age in floor pens. Each pen was assigned to one of two growth curves from 16 weeks of age to housing at 21 weeks of age. One growth curve followed a standard (SD) body weight curve and a second followed a lighter (LI) body weight curve. At 23 weeks of age, half of the hens from each of the growth curves were assigned to one of two breeder diets. Half of the hens were fed a low (LO)-protein (14%) breeder diet and half were fed a higher (HI)-protein breeder diet (16%) during the production phase. Pullet growth curve significantly affected body weight through 30 weeks of age. The protein level of the breeder feed significantly affected body weight at 35 and 40 weeks of age. Pullet growth curve affected body conformation, but did not affect age of first egg. Pullet growth curve did not affect egg weight. Protein level of the breeder feed significantly affected egg weight; hens fed the HI-protein diet laid heavier eggs. Egg production was not affected by pullet rearing growth curve ($p = 0.0845$) or protein level ($p = 0.7348$) of the breeder feed. Feeding a LO-protein diet resulted in feed cost savings. The feed cost of SD reared hens fed LO-protein diet was $0.03227 per hen less than for those fed HI-protein diets. The feed cost of LI reared hens fed LO-protein diet was $0.3616 per hen less than for those fed HI-protein diet.

Key words: Broiler breeder, growth curve, protein, egg production, body conformation

INTRODUCTION

Renema *et al*. (2007a) noted the genetic potential for broiler growth has increased dramatically over the past 40 years, but breeder stock target body weights (BW) have only seen small changes. Breeder stock body weights are restricted to improve the welfare of the birds and improve reproductive performance. Many approaches have been taken to rearing pullets and feeding broiler breeders in order to improve breeder production. Sun and Coon (2005) separated group raised pullets based on BW. Wilson *et al*. (1995), Robinson *et al*. (2005), Robinson *et al*. (2007), Renema *et al*. (2007b), Zuidhof *et al*. (2007), Harper (2008) and De Beer and Coon (2009) varied the target BW growth curve, shape of the growth curve, or age of most growth restriction to find out what BW or type of growth curve resulted in the best performance in the production house. These growth curves were within 20-25% of primary breeder target weights at housing or curves converged at 21 weeks of age. Research by Robinson *et al*. (2005), Robinson *et al*. (2007), Renema *et al*. (2007b) and Zuidhof *et al*. (2007) indicate there may be strain differences in the production house in response to different pullet growth curves. Currently, many believe there is a critical age period for proper physiological development for reproductive success. In general, most research with pullet rearing BW programs have found influences on hen BW, body conformation, age at first egg, settable eggs and weight of eggs obtained during the production period.

The protein intake of broiler breeders has also been suggested to influence the reproductive performance of breeder hens. Primary breeders recommend formulating diets based on digestible or an ideal amino acid profile. They also give a target or range of kcal intake and nutrient intake recommendations for hens at peak production. For the purpose of assessing the range of crude protein intake being fed to breeder hens in the Industry, crude protein was extrapolated from nutrient intake recommendations provided by primary breeder companies (Cobb-Vantress, 2013; Aviagen, 2013a-d; Aviagen, 2014; Hubbard, 2014a-d). The crude protein

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(CP) intakes range from 23.6 to 27.5 g CP/b/d at peak feed allotment. Joseph *et al*. (2000) reported hens fed 21.3 g CP laid fewer and lighter eggs compared to hens fed 23.6 or 26.6 g CP/b/d. Joseph *et al*. (2002) fed diets with 16 or 18% CP with peak protein intakes of 26.4 or 28.8 g CP/b/d and reported one strain of hens performed better at lower CP intakes. Spratt and Leeson (1987) reported hens fed 25 g CP/b/d at peak consumption laid heavier eggs but egg production was reduced by 1.6% compared to hens fed 19 g CP/b/d. Lopez and Leeson (1994) showed hens fed lower intakes of protein may lay more eggs compared to hens fed higher intakes of protein. Pearson and Herron (1982) reported that breeders consuming 27 g protein intake per day produced an increased number of dead and deformed embryos and a decreased hatchability of fertile eggs compared to breeders consuming 23.1 g of protein intake per bird per day. Lower levels of protein consumption maybe associated with lower egg weights and lower hen weights. Recently, Ekmay *et al*. (2013a) showed broiler breeders fed adequate digestible amino acids using an ideal profile only need 20 g of digestible crude protein per day (digestible essential amino acids and digestible non-essential amino acids) to maximize egg mass and breeder body weight gain. The researchers utilized dietary glutamic acid to provide additional amino acid nitrogen above the essential amino acid requirements.

MATERIALS AND METHODS

Bird housing and management: Four thousand two hundred and forty day old Cobb 700 (high yielding) pullets were weighed and randomly assigned to sixteen 10.67m x 5.18m floor pens (265 pullets per pen). The house was solid sided and tunnel ventilated. Six hundred day old Cobb cockerels were weighed and placed in two 15.24 x 6.10 M floor pens. Each pen was equipped with hanging feed cans to provide a minimum of 15.24 cm of feeder space per bird. Each pen was equipped with a nipple drinker system. The pullets had an overall mortality of 3.7% from 0 to 21 weeks of age and miss sexed birds were removed prior to housing at 21 weeks of age.

At 21 weeks of age 4.080 pullets and 480 roosters were transferred to a solid-sided, tunnel ventilated production house. Birds were housed 85 hens and 10 roosters per pen in 48 pens. The roosters were later reduced to 9 males per pen. Each pen measured 4.27 M x 4.27 M. Each pen was equipped with nipple type drinkers and hanging can type feeders.

Daily bird management was based on the Cobb Breeder Management Guide (Cobb Vantress, 2013) and personal communication with Cobb-Vantress staff.

Day length in pullet house was 24 h of light from 0 to 3 days of age, from 4 to7 days of age day length was 16 h, from 8 to 21 days of age day length was 12 h and from 22 days of age until housing, day length was 8 h. At 22 days of age, the light intensity was reduced to between 0.75 and 1 foot candle at bird level. When birds were moved to the production house at 21 week of age, day length was increased to 13 h of light; at 22 weeks of age day length was increased to 14 h of light. The day length was increased to 15 h of light when hens reached 5% production and at 60% production, day length was increased to 16 h of light.

Birds were vaccinated according to the schedule used by a local integrator. Bird health was monitored and blood samples submitted as required to the State Lab for NPIP certification. This study complied with the provisions of the Institute Animal Care and Use Committee as specified by the Animal and Plant Health Inspection Service, USDA in 9 CFR Part 1(1-91).

Table 1: Calculated nutrient content of pullet diets.

Nutrient	Chick starter	Pullet grower
ME kcal/kg	2.860	2.816
CP (%)	19.00	15.00
Lysine (%)	1.09	0.84
Methionine+cystine (%)	0.76	0.71
Calcium (%)	0.90	0.90
Phosphorus-non-phytate (%)	0.45	0.45

Table 2: Low protein (LO) and high protein (HI) breeder diets

Ingredient	LO-Protein (%)	HI-Protein (%)
Corn 8.5% CP	62.01	59.85
SBM 47.7% CP	18.02	23.77
Limestone	7.00	6.97
Wheat midds	6.82	3.23
Fat	3.20	3.20
Dicalcium phosphate	1.85	1.85
Salt	0.33	0.34
Sodium bicarbonate	0.20	0.20
Methionine	0.18	0.21
Choline chloride	0.11	0.09
Vitamin breeder premix	0.10	0.10
Trace mineral	0.06	0.06
Copper sulfate	0.05	0.05
Propionic acid	0.05	0.05
Selenium Premix-.06%	0.02	0.02
Ethoxyquin	0.02	0.02
Nutrient		
ME kcal/kg	2.865	2.865
CP (%) (calculated)	14.00	16.00
CP (%) (analyzed)	15.20	17.10
Fat (%)	5.86	5.73
Calcium (%)	3.10	3.10
Phosphorus-Non-phytate (%)	0.45	0.45
Total Phosphorus (%)	0.68	0.69
Calculated digestible		
Lysine (%)	0.66	0.79
Methionine (%)	0.40	0.46
TSAA (%)	0.62	0.71
Isoleucine (%)	0.62	0.74
Phenylalanine (%)	0.69	0.81
Phenyl and Tyro (%)	1.19	1.39
Threonine (%)	0.49	0.57
Valine (%)	0.69	0.81

Experimental design, measurements and feeding: From 0 to 21 weeks of age, pullets and cockerels were fed the same diets regardless of treatment (Table 1). Chick starter, 2860 kcal ME/kg and 19% CP, was fed from 0 to 4 weeks of age. Pullet grower, 2816 kcal ME/kg and 15% CP, was fed from 4 to 23 weeks of age. Birds were fed everyday to 21 days of age. Beginning at 22 days of age, the feeding program was changed to a four-three feeding schedule. At sixteen weeks of age, birds were placed on a five-two feeding schedule and at 21 weeks of age birds were placed on everyday feeding. At 23 weeks of age, half of the pullets from each growth curve were assigned to one of two different breeder hen feeds giving a 2 x 2 factorial arrangement (two pullet growth curves x two hen feeds). There were 12 replications per treatment. The two breeder diets (Table 2) were formulated to contain 14% (LO-protein) or 16% (HI-protein) CP. Both breeder diets were formulated to contain 2865 kcal ME/kg, 3.1% calcium and 0.45% available P. Both breeder diets were formulated to provide the digestible amino acid requirements for breeders as reported by Coon *et al.* (2006). Proximate analysis showed the feeds were similar to what was formulated (Table 2). Roosters were fed the 14% CP breeder diet beginning at 23 weeks of age.

Cockerels were reared following body weight recommendations for the Cobb male. From 0 to 15 weeks of age pullets were reared following target body weights for a modified Avian 24K growth curve. At 15 weeks of age, each pen of pullets was weighed and assigned by average body weight to one of two growth curves (8 pens per growth curve). The standard (SD) growth curve continued to follow target body weights for a modified Avian 24K growth curve and a light (LI) growth curve followed target body weights for a 2.57% lighter body weight hen at housing. At 21 weeks of age, the target body weights were 2213 and 2156 g for the SD and LI growth curves, respectively. The target body weights for LI growth curve hens (2717 g) were 5% lighter than SD growth curve hens (2860 g), at 25 weeks of age. From 0 to 21 weeks of age, a random sample of at least 25 birds per pen was weighed weekly. Daily feed allotment (kg per 100 birds) was adjusted based on target body weight and the growth rate and feed conversion from the previous week (Table 3).

From 21 weeks of age until the end of the trial, 8 hens per pen were weighed weekly to monitor weight gain. At 25 weeks of age, when production reached 5%, the daily feed allocation was increased for every 8-10% increase in production until 440 kcal ME per bird per day was being consumed at 65% production (Table 4) for all treatments. If the hens were gaining weight too rapidly relative to the increase in egg production the amounts of each feed increase was reduced to maintain a lighter hen through the end of production. At 29 weeks of age, feed intake was reduced by 0.14 to 0.23 kg/100 birds to control body weight. At peak production, hens were consuming 430 to 433 kcal ME per bird per day. After peak production, daily feed intake was reduced weekly by amounts varying from 0.11 to 0.18 kg/100 birds depending on body weights and rate of gain. Daily feed intake was reduced each week after peak until hens were consuming 390 kcal ME per bird per day (Table 4). At 65% production, hens were consuming 21.5 or 24.6 grams CP/b/d for hens being fed LO-protein and HI-protein diets, respectively (Table 4). All feeding amounts are reported as an amount per 100 birds per day as this is the common practice in industry. Cumulative feed amounts are also reported as per 100 birds per period. The amounts actually fed each pen per day were adjusted to the number of birds per pen and adjusted daily for any mortality. All pens on a given treatment were fed at the same rate (kg/100 birds/day), or same amount per bird per day.

Feed costs were calculated based on local feed mill ingredient prices (May 2014) with no milling or delivery charges included. Starter feed cost $0.3813 per kg, grower feed cost $0.2775 per kg; breeder LO-protein feed cost $0.3499 per kg and breeder HI-protein feed cost $0.3697 per kg.

Table 3: Daily and cumulative feed amounts from one day of age to 5% production

Age weeks	Trt 1 [1]SD-HI Pro kg/100 b/d	Trt 2 [2]SD-LO Pro kg/100 b/d	Trt 3 [3]LI-HI Pro kg/100 b/d	Trt 4 [4]LI-LO Pro kg/100 b/d
0-1	2.04	2.04	2.04	2.04
1-2	2.95	2.95	2.95	2.95
2-3	3.09	3.09	3.09	3.09
3-4	3.23	3.23	3.23	3.23
4-5	3.32	3.32	3.32	3.32
5-6	3.36	3.36	3.36	3.36
6-7	3.48	3.48	3.48	3.48
7-8	3.82	3.82	3.82	3.82
8-9	4.09	4.09	4.09	4.09
9-10	4.27	4.27	4.27	4.27
10-11	4.39	4.39	4.39	4.39
11-12	4.55	4.55	4.55	4.55
12-13	4.75	4.75	4.75	4.75
13-14	5.00	5.00	5.00	5.00
14-15	5.23	5.23	5.23	5.23
15-16	5.52	5.52	5.52	5.52
16-17	6.14	6.14	5.98	5.98
17-18	6.82	6.82	6.55	6.55
18-19	7.61	7.61	7.23	7.23
19-20	8.75	8.75	8.18	8.18
20-21	9.89	9.89	9.32	9.32
21-22	10.02	10.02	9.45	9.45
22-23	10.45	10.45	10.00	10.00
23-24	10.91	10.91	10.45	10.45
24-25	11.02	11.02	10.57	10.57
Cumulative Feed from 0 weeks of age to 5% production				
kg/100 birds	1012.87	1012.87	985.66	985.66
$/100 birds	$313.72		$305.08	

[1]SD-HI Pro:Standard BW curve pullets-breeders in production fed high protein.
[2]SD-LO Pro:Standard BW curve pullets-breeders in production fed low protein.
[3]LI-HI Pro: Light BW curve pullets-breeders in production fed high protein.
[4]LI-LO Pro: Light BW curve pullets-breeders in production fed low protein.

Table 4: Daily and cumulative feed amounts from 5% production to 41 weeks of age

Prod (%)	Trt 1 [1]SD-HIPro kg/b/d	Trt 2 [2]SD-LO Pro kg/b/d	Trt 3 [3]LI-HI Pro kg/b/d	Trt 4 [4]LI-LO Pro kg/b/d
5	11.02	11.02	10.57	10.57
15	11.48	11.48	11.02	11.02
25	12.05	12.05	11.59	11.59
35	12.73	12.73	12.27	12.27
45	13.52	13.52	13.18	13.18
55	14.43	14.43	14.20	14.20
65	15.36	15.36	15.36	15.36
@ 29 weeks	15.23	15.14	15.23	15.23
@ peak prod	15.11	15.02	15.09	15.11
Week post peak				
1	15.00	14.89	14.95	14.98
2	14.86	14.70	14.82	14.84
3	14.68	14.61	14.64	14.66
4	14.59	14.48	14.55	14.57
5	14.45	14.39	14.41	14.43
6	14.36	13.93	14.32	14.34
7	13.91	13.93	13.86	13.89
@ 390 kcal	13.60	13.60	13.60	13.60
kcal ME/b/day				
@ 65% prod	440	440	440	440
@ 29 weeks	436	436	436	436
@ peak prod	433	430	432	433
g CP/b/d				
@ 65% prod	24.6	21.5	24.6	21.5
@ 29 weeks	24.4	21.2	24.4	21.3
@ peak prod	24.2	21.0	24.1	21.2
Cumulative feed intake kg/100 birds 5% prod to 41 week of age				
kg/100 birds	1630	1630	1614	1602
$/100 birds	$602.61	$570.34	$596.70	$560.54

[1]SD-HI Pro: Standard BW curve pullets-breeders in production fed high protein.
[2]SD-LO Pro: Standard BW curve pullets-breeders in production fed low protein.
[3]LI-HI Pro: Light BW curve pullets-breeders in production fed high protein.
[4]LI-LO Pro: Light BW curve pullets-breeders in production fed low protein

From start of lay until the end of the study, 30 eggs were weighed weekly from every pen of breeders. Shank and keel length were measured at 4, 8, 12, 16, 20 and 24 weeks of age. As an indicator of level of maturation, pullets were evaluated for fleshing and fat deposition. The Cobb Breeder Management Guide (Cobb Vantress, 2013) recommended method for evaluation of fleshing and fat deposition was used. Pullets were evaluated for comb and wattle development and pelvic spread as indicators of sexual maturity.

At 40 weeks of age, 1043 eggs from hens being fed HI-protein and 1039 eggs from hens fed LO-protein feed were collected and sent to a local company for a progeny rearing field trial. The progeny from these eggs were sexed and reared to 28 days of age. They were fed a common starter and grower diet formulated to Cobb recommendations. The treatments for rearing study were sex of chick and the level of protein in the feed fed the breeder hens. Chicks were weighed weekly. Average body weight and uniformity were determined for each treatment. Uniformity was defined as the percent of chicks whose body weight fell within 10% (plus or minus) of the average.

Statistics were run using JMP® program (2008). Completely randomized design with 2x2 factorial arrangement was used to analyze the data.There were no significant interaction between pullet growth curve and hen feeding program so only main effects are reported and significant differences separated using the Student's t-test.

RESULTS AND DISCUSSION

Total feed amounts: Pullets and cockerels in rearing period were not fed *ad libitum*. The birds were fed a controlled daily amount of feed. Statistical analysis of differences for total feed consumed and cost of feed between treatments could not be determined because all birds were fed the same amount of feed per bird per day. However, pullets reared on the SD growth curve consumed 1012.9 kg per 100 birds (cumulatively) compared to 985.7 kg per 100 birds reared on the LI growth curve from day of age to 5% production (Table 3). From day of age to 5% production, LI growth curve reared pullets consumed 27.2 kg less feed per 100 pullets than SD growth curve reared pullets (Table 3). From day of age to 5% production, the feed cost per 100 pullets reared with the SD growth curve was $313.72 and the cost per 100 pullets reared with the LI growth curve was $305.08 (Table 3). This is a difference of $8.64 per 100 pullets in ingredient feed costs.

The SD growth curve reared hens, across protein intake, cumulatively consumed 1630 kg feed per 100 hens from 5% production to 41 weeks of age (Table 4). The HI-and LO-protein fed hens within the LI growth curve reared hens consumed 1614 and 1602 kg per 100 hens from 5% production to 41 weeks of age, respectively (Table 4). The difference in cumulative feed consumed per 100 hens during this time period is due to differences between treatments in the number of days between each feed increase (defined as a 10% increase in egg production). The LI hens were 1 to 2 days behind SD hens in percent production and, thus were 1 to 2 days behind in feed increases (Fig. 1). However, the LI hens reached peak production at the same time as SD growth curve reared hens (Fig. 1). From 5% production to 41 weeks of age, LI growth curve reared hens consumed 16 and 28 kg less feed per 100 birds than SD growth curve reared hens being fed HI-and LO-protein diets, respectively. Based on May 2014 ingredient costs, the feed cost per 100 hens from 5% production to 41 weeks of age for the SD reared hens averaged $586.47 compared to $578.62 for the LI reared hens, thus making a difference of $7.85 per 100 hens.

The larger savings in feed costs per 100 hens from 5% production to 41 weeks of age is realized between the hens fed the LO-protein and HI-protein diets (Table 4). The feed cost per 100 hens from 5% production to 41 weeks of age for SD reared hens fed HI-and LO-protein diets was $602.61 and $570.34, respectively. The feed

Table 5: Body weights of hens fed from 15 weeks of age to housing for two different growth curves and fed two different levels of protein during production

	--------- Treatment ----------						
Age (wk)	Pullet	Hen	Target BW (g)	BW (g)	SEM	p-value	CV
0	SD[1]			45	0.15	0.4946	1.09
	LI[2]			44	0.15		0.79
16	SD			1418	16.81	0.9876	3.75
	LI			1418	16.81		2.90
20	SD			1854	23.73	0.1839	4.39
	LI			1807	23.73		2.70
21	SD		2213	2072[a]	29.26	0.0160	4.32
	LI		2156	1959[b]	29.26		3.91
25	SD		2860	2839[a]	22.43	<.0001	4.38
	LI		2717	2701[b]	22.43		3.73
25		HI pro[3]		2799	22.43	0.0689	5.29
		LO pro[4]		2740	22.43		3.96
Pullet * Hen trt interaction						0.2637	
30	SD		3305	3307[a]	21.90	0.0036	3.27
	LI		3140	3212[b]	21.90		3.29
30		HI pro		3279	21.90	0.2123	3.84
		LO pro		3240	21.90		3.22
Pullet * Hen trt interaction						0.8926	
35	SD		3440	3547	24.76	0.0888	4.41
	LI		3259	3486	24.76		3.39
35		HI pro		3584[a]	24.76	0.0004	3.83
		LO pro		3449[b]	24.76		3.17
Pullet*Hen trt interaction						0.3050	
40	SD		3523	3622	29.79	0.8905	4.94
	LI		3347	3616	29.79		3.76
40		HI pro		3679[a]	29.79	0.0073	4.70
		LO pro		3560[b]	29.79		3.24
Pullet * Hen trt interaction						0.1138	

[ab]Numbers within a column with different superscripts differ significantly. [1]SD: Standard BW curve pullets, [2]LI: Light BW curve pullets, [3]HI pro: Breeders in production fed high protein and [4]LO pro: Breeders in production fed low protein

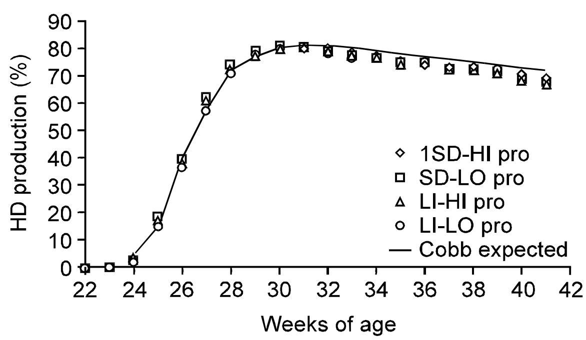

Fig. 1: Weekly (%) egg production of hens reared to 2 growth curves from 15 weeks of age to housing and fed 2 protein levels during the laying cycle.

[1]SD-HI Pro: Standard BW curve pullets-breeders in production fed high protein.

[2]SD-LO Pro: Standard BW curve pullets-breeders in production fed low protein,

[3]LI-HI Pro: Light BW curve pullets-breeders in production fed high protein.

[4]LI-LO Pro: Light BW curve pullets-breeders in production fed low protein.

cost of SD reared hens fed LO-protein feed was $32.27 less per 100 hens compared to hens fed HI-protein feed. The feed cost per 100 hens from 5% production to 41 weeks of age for LI reared hens fed HI-and LO-protein diets was $596.70 and $560.54, respectively. The feed cost of LI reared hens fed LO-protein feed was $36.16 less per 100 hens compared to hens fed HI-protein feed.

Body weights: Because there was no significant interaction between pullet growth curve and protein level of the breeder feed only main effects will be discussed. At 16 weeks of age, pullets weighed 1.418 g for the SD and LI reared pullets (Table 5, Fig. 2). At 20 weeks of age there were no significant differences in BW for SD (1.854 g) and LI (1.807 g) reared pullets. At 21, 25 and 30 weeks of age, the BW of LI growth curve reared hens was significantly less than BW of SD growth curve reared hens (Table 5, Fig. 2). The LI growth curve reared hens weighed 113, 138 and 95 g less than SD growth curve reared hens at 21, 25 and 30 weeks of age, respectively. The BW of SD and LI growth curve reared hens were not significantly different at 35 and 40 weeks of age.

Protein level of the breeder diet did not significantly affect BW at 25 and 30 weeks of age (Table 5). However, by 35 and 40 weeks of age, the BW of hens fed the HI-protein feed was statistically heavier than hens fed the LO-protein feed (Table 5). At 40 weeks of age, the hens

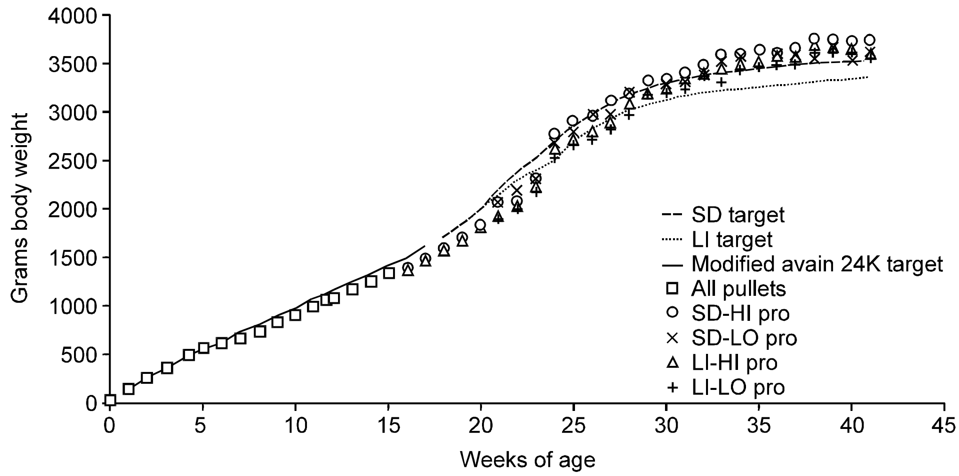

Fig. 2: Body weight of birds reared on 2 growth curves from 15 weeks of age to housing and fed 2 protein levels during the laying cycle.

[1]SD-HI Pro: Standard BW curve pullets-breeders in production fed high protein.
[2]SD-LO Pro: Standard BW curve pullets-breeders in production fed low protein.
[3]LI-HI Pro: Light BW curve pullets-breeders in production fed high protein.
[4]LI-LO Pro: Light BW curve pullets-breeders in production fed low protein.

fed HI and LO protein feeds weighed 3.679 and 3.560 g per hen, respectively. The lower protein breeder feed helped control weight gain of hens during the production period.

Both uniformity and BW are of critical importance to performance during the breeder production phase. Petitte *et al.* (1982) reported breeder performance was improved during the first 10 weeks of production in more uniform flocks. Furthermore, Hudson *et al.* (2001) showed an overall improvement in number of cumulative eggs produced by a more uniform flock. It is therefore imperative to maintain uniformity to ensure optimal breeder production. At 40 weeks of age, uniformity as indicated by the coefficient of variation was 10.9 and 10.5% for the HI-protein and LO-protein fed hens, respectively, which indicated both groups were uniform in BW.

Skeletal conformation: To evaluate readiness of a pullet flock to lay and to be light stimulated, field technicians handled the pullets and evaluated pelvic spread, fat deposition and fleshing scores of the birds. At 20 weeks of age, SD growth curve reared pullets had a significantly wider pelvic spread (20 mm) compared to LI growth curve reared pullets (18 mm) (Table 6). However, pelvic spread was not a reliable indicator of readiness to lay as there was no significant difference in age at first egg due to pullet rearing growth curve (Table 10). Average age at first egg was 24.1 weeks of age for the flock as a whole with a SEM of 0.041. Growth curve did not significantly affect onset of lay in this study.

At 15 weeks of age, (105 d) pullets were assigned to one of two growth curves (SD or LI) based on average pen weight. At 16 weeks of age, the significant difference in fleshing score due to growth curve (Table 7) was only an indicator that at this age the birds were in fact separated into two different growth weight groups.

At no other age were differences found in shank, keel and pelvic measurements or in fat and fleshing score due to pullet rearing growth curve or protein level of the breeder feed (Table 6, 7 and 8). Lilburn *et al.* (1989) also found no effect of a low protein diet or body weight gain on the skeletal growth characteristics of broiler breeder pullets. In a series of experiments, De Beer and Coon (2006, 2007) found no differences in shank and keel length of 21and 28 wk-old hens fed different protein levels or reared on different feeding regimens. De Beer and Coon (2006, 2007) did find a body weight effect on shank and keel length. The researchers reported pullets at 6 and 16 wk of age reared to a heavier BW than standard BW had longer shanks and keels than pullets reared to less BW than standard. De Beer and Coon reported that keel length remained significantly longer in the heavier BW pullets at 21 wk. The shank and keel lengths for 21 wk old pullets for the SD and LI groups in the present study were not significantly different. Since the formation of frame size is known to occur within the first 12-15 wk of the rearing period, it is unlikely that assorting the pullets into two body weight groups at 15 wk would lead to differences in shank and keel length at 21 wk. At 24 weeks of age there were no significant differences in shank or keel length due to rearing growth curve or protein level of the breeder feed (Table 8).

Egg production, age at first egg and egg weights: Robinson and Robinson (1991) found hens with low body weight at 21 wks (1.539 g) produced fewer eggs than hens at medium and heavier body weights, 2.025

Table 6: Body conformation of pullets reared on two growth curves

	[1]SD growth curve				[2]LI growth curve			
Age days	Wgt (g)	Shank (mm)	Keel (mm)	Pelvic (mm)	Wgt (g)	Shank (mm)	Keel (mm)	Pelvic(mm)
30	513	70	94					
56	761	82	117					
81	1075	93	140					
116	1480	101	160	15	1473	100	159	16
140	1867	103	171	20^x	1814	102	170	18^y

^{xy}Letters with different superscripts within a row are significantly different p<0.05. [1]SD: Standard BW curve pullets and [2]LI: Light BW curve pullets

Table 7: Fat and fleshing scores*of hens reared on 2 growth curves and fed 2 protein levels

	[1]SD growth curve				[2]LI growth curve			
	[3]HI Pro		[4]LO Pro		[3]HI Pro		[4]LO Pro	
Age days	Flesh	Fat	Flesh	Fat	Flesh	Fat	Flesh	Fat
38	3.91							
56	3.90							
81	3.76							
112	3.97^y	3.31			4.35^x	3.36		
140	4.49	2.54			4.51	2.43		
168	5.19	3.08	5.19	3.17	5.09	3.04	4.84	2.98
196	5.42	2.83	5.70	2.94	5.21	2.96	5.18	2.77

^{xy}Letters with different superscripts within a row are significantly different p<0.05. *Fat score was 1-5 with 3 being ideal for that age. Fleshing score was 1-7 with 3 being ideal for that age. Growth curve targets were different from 16 weeks to 21 weeks of age. [1]SD: Standard BW curve pullets, [2]LI: Light BW curve pullets, [3]HI: breeders in production fed high protein, [4]LO: breeders in production fed low protein

Table 8: 24 week body conformation of hens reared on 2 growth curves and fed 2 protein levels

	Standard growth curve							
	[1]HI pro				[2]LO pro			
Age days	Wgt (g)	Shank (mm)	Keel (mm)	Pelvic (mm)	Wgt (g)	Shank (mm)	Keel (mm)	Pelvic (mm)
168	2723	105	187	27	2617	105	188	28
Light growth curve								
168	2523	104	189	26	2544	105	190	27

[1]HI: breeders during production fed high protein and [2]LO: breeders during production fed low protein

Table 9: Eggs per hen housed of hens reared on 2 growth curves and fed 2 protein levels

	Growth curve		Protein level	
Age wks	[1]SD EHH	[2]LI EHH	[3]HI Pro EHH	[4]LO Pro EHH
41	80.5	79.4	79.9	80.1
Prob>F	0.0845		0.7348	

[1]SD: Standard BW curve pullets, [2]LI: Light BW curve pullets,
[3]HI: breeders in production fed high protein and
[4]LO: breeders in production fed low protein

Table 10: Age at first egg for hens reared on 2 growth curves and fed 2 levels of protein

	Growth curve		Protein level	
	[1]SD week	[2]LI week	[3]HI Pro week	[4]LO Pro week
	24.1	24.2	24.1	24.2
Prob >F	0.1295		0.3590	

[1]SD: Standard BW curve pullets, [2]LI: Light BW curve pullets,
[3]HI: breeders in production fed high protein and
[4]LO: breeders in production fed low protein

and 2.446 g, respectively. In the present study, the SD and LI target body weight curves at 21 wk were 2.156 and 2.213 g, respectively. The body weights of both of these groups should support good production when compared to the medium body weights in Robinson and Robinson's (1991) study.

At 41 weeks of age in present study, there were no significant differences in eggs per hen housed due to pullet rearing growth curve or breeder feed protein level (Table 9). At 41 weeks of age, LI growth curve reared hens had laid 79.4 eggs per hen housed compared to 80.5 eggs per hen housed for SD growth curve reared hens (Table 9, p = 0.0845). Based on ingredient feed cost (Table 3 and 4), the feed cost per dozen eggs was $1.3178 and $1.3594 for LI and SD reared hens, respectively. Ekmay *et al*. (2012) recently reported a decrease in eggs per hen housed for hens reared to a 20% lighter body weight than Cobb standard growth curve as compared with the Cobb standard. It has been hypothesized that young broiler breeders rely on protein turnover and endogenous lysine sources during early egg production (Ekmay *et al*., 2013a, 2014) compared to older breeders that are producing less hatching eggs. The strong impact of the pullet growth curve on egg production in the present study is in line with what would be expected under this hypothesis. A larger hen with more body reserves may support a higher level of egg production during the early part of production.

At 41 weeks of age, hens fed HI-protein breeder feed had laid 79.9 eggs per hen housed compared to 80.1 eggs per hen housed for hens fed LO-protein feed (Table 9, p = 0.7348). Hens reared on the LI growth curve and fed LO-protein breeder feed were slightly behind the other treatments coming into production, but all groups peaked at the same time and at essentially the same level of production (Fig. 1). Based on the

Table 11: Egg weights for hens reared on 2 growth curves and fed 2 protein levels

	Growth curve			Protein level		
Age wks	[1]SD (g)	[2]LI (g)	Prob>F	[3]HI pro (g)	[4]LO pro (g)	Prob>F
27	51.2	50.8	0.1325	51.5[a]	50.5[b]	0.0002
28	53.3	52.8	0.1288	53.4[a]	52.7[b]	0.0223
29	54.4	54.4	0.9712	54.7[a]	54.1[b]	0.0019
33	57.8	58.1	0.2403	58.2[a]	57.7[b]	0.0390
34	60.0	60.2	0.6368	60.5[a]	59.7[b]	0.0348
35	61.0	61.4	0.0541	61.3	61.1	0.1842
36	61.9	61.9	0.6902	62.4[a]	61.4[b]	<.0001
37	62.7	62.4	0.3820	63.0[a]	62.1[b]	0.0023
38	63.0	63.4	0.1995	63.6[a]	62.8[b]	0.0018

[1]SD:Standard BW curve pullets, [2]LI:Light BW curve pullets,
[3]HI:breeders in production fed high protein and [4]LO:breeders in production fed low protein

Table 12: 28-day body weights of broilers from hens fed LO or HI protein breeder feed

	Female broilers		Male broilers	
Hen feed: Chick age (d) body weights	[1]HI pro (g)	[2]LO pro (g)	[1]HI pro (g)	[2]LO pro (g)
0	38	39	39	39
7	153	159	158	159
14	387	409	419	411
21	802	847	893	880
28	1334	1413	1500	1516
Uniformity	%	%	%	%
0	68.7	78.3	77.9	80.2
7	58.2	67.3	58.9	65.6
14	66.3	74.5	60.0	66.3
21	55.4	68.7	56.7	61.4
28	67.5	71.8	59.1	65.1

[1]HI: breeders in production fed high protein and
[2]LO: breeders in production fed low protein

ingredient feed cost (Table 3 and 4), the feed cost per dozen eggs was $1.3696 and $1.3063 for hens fed HI-and LO-protein breeder feed (this cost includes the rearing period feed).

There were no significant differences in age at first egg due to growth curve or breeder feed protein level (Table 10). The SD growth curve reared hens reached age at first egg at 24.1 weeks of age compared to 24.2 weeks of age for LI growth curve reared hens. Hens fed HI-protein in the production house produced the first egg at 24.1 weeks of age compared to 24.2 weeks of age for hens fed LO-protein feed.

There was no significant interaction between pullet growth curve and breeder feed protein level on egg weights. There was no significant difference in egg weight due to pullet growth curve (Table 11).

The protein level of the breeder feed significantly affected egg weight. Eggs from hens fed HI-protein feed were heavier than those from hens fed LO-protein feed (Table 11). At all ages, except 35 weeks of age, hens fed HI-protein feed laid significantly heavier eggs: a difference of 0.50 to1.0 g per egg. Protein historically has been found to increase egg weight (Summers and Leeson, 1993; Coon *et al*., 2006); therefore the results presented here are in line with previous reports. Ekmay *et al*. (2012) reported that breeders reared with a 20% heavier body weight compared to the Cobb standard pullet growth curve resulted in increased egg weight and egg mass during the production period. In that same study, it was also shown that 26 g of CP intake at peak production resulted in larger eggs and larger chicks compared to 22 g of CP intake. Ekmay *et al*. (2013b) reported a non-significant decrease of 3 eggs per hen housed for breeders consuming 26 g CP compared to breeders consuming 22 g CP. Furthermore, the higher CP intake resulted in a significant reduction in fertility ($p = 0.007$) and a numerical reduction in hatchability ($p = 0.10$). These results suggest that a lower protein intake would result in more saleable chicks. Ekmay *et al*. (2013a) proposed breeders need 20 g of digestible protein for optimal egg mass and body weight gain at peak production.

Hatch and progeny grow-out feeding study: Eggs for hatchability and a progeny grow-out study were sent to a commercial hatchery. The eggs were kept separated by treatment but not by pen, therefore, statistical replications needed for showing significant differences due to treatment in hatchability and progeny performance were not available. For the progeny grow-out study conducted by the company, only final BW and uniformity were reported. One thousand and thirty eight eggs from hens fed LO-protein diets and 1.043 eggs from hens fed HI-protein diets were transferred to the breeder's hatchery. The hatchability of these eggs was 80.67 and 75.18% from hens fed LO-protein and HI-protein diets, respectively. Lower fertility was reported by Ekmay *et al*. (2013a) for breeder hens consuming above 20 g intake of protein and amino acids. Lopez and Leeson (1994) reported decreased fertility in eggs from hens fed 16% CP rather than 10-14%. Similarly, Pearson and Herron (1982) reported increased embryonic mortality in eggs from hens fed 27 g CP at peak rather than 23 g CP.

Eggs from hens fed LO-protein diets produced 5.49% more hatched chicks than eggs from hens fed HI-protein diets. At 28 days of age, the female broilers from hens fed LO-protein diets were 6% heavier than female broilers from hens fed HI-protein diets (Table 12). Male broilers from hens fed LO-protein diets were 1% heavier than from hens fed HI-protein diets. There was a 4.3 and 6% improvement in the uniformity at 28 days of age of the female and male broilers, respectively, for progeny of the LO-protein fed breeder hens compared to uniformity of progeny at 28 days from HI-protein fed hens (Table 12). The lack of an added progeny benefit from breeders fed higher levels of protein was also shown by Wilson and Harms (1984). The researchers did not see a difference in 49d progeny weight when breeder protein intake was varied between 20 and 23 g CP per day. Although the field hatchability and progeny data reported herein could not be compared statistically, the data may indicate there were no negative effects on hatchability or progeny performance for breeders fed LO-protein diets.

Conclusion: At 20 weeks of age, LI growth curve pullets were 52 g lighter in BW than SD growth curve pullets and cumulatively consumed 27.2 kg/100 birds less feed from hatched chick to 5% production. LI growth curve hens continued to consume less feed during production. From 5% production to 41 weeks of age, the cumulative feed consumed for the LI growth curve hens was 16 to 28 kg/100 birds less than SD reared hens. The LI growth curve reared hens laid 1.1 fewer eggs per hen than SD growth curve reared hens ($p = 0.0845$). Hens fed LO-protein (14% CP) feed laid 0.2 more eggs per hen than hens fed HI-protein feed (16% CP) ($p = 0.7348$). Based on ingredient prices (May 2014), feed cost per dozen eggs was $1.3696 and $1.3063 for hens fed HI-and LO-protein breeder feed, respectively. Breeders fed the LO-protein diets consumed daily requirements of digestible amino acids as suggested by Ekmay *et al.* (2013a). Research reported by Ekmay *et al.* (2014) indicates lean mass increases in breeders fed 24 and 26 g per day compared to breeders fed 22 g. Increasing lean mass and increasing egg size by increasing dietary protein and amino acids (as occurred in present study) would increase the daily requirement for energy. A breeder hen would either need to be fed more calories or become deficient in caloric intake to maintain her current egg mass production.

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