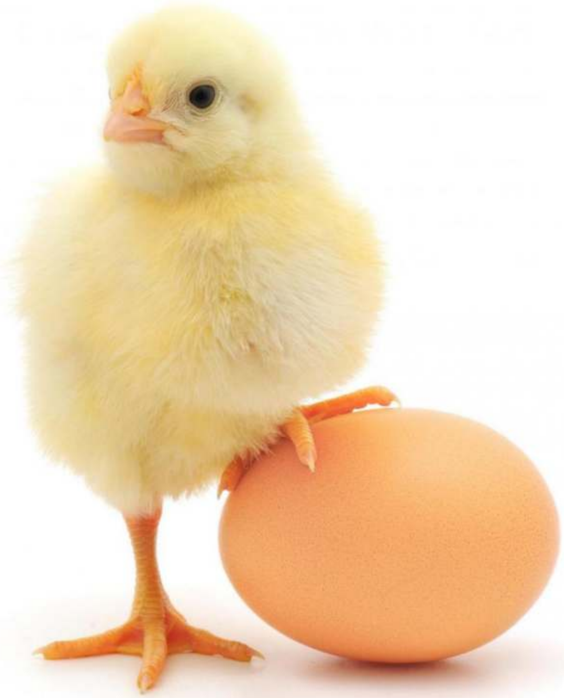
ISSN 1682-8356
ansinet.org/ijps



INTERNATIONAL JOURNAL OF POULTRY SCIENCE

ANSInet
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorijps@gmail.com

International Journal of Poultry Science 5 (9): 812-821, 2006
ISSN 1682-8356

The Effect of Increased Protein Intake During the Starter and Prebreeder Periods on Reproductive Performance of Ultra High Yield Broiler Breeder Hens

Marc de Beer and Craig N. Coon[1]
University of Arkansas, Center of Excellence for Poultry Science, Fayetteville, AR 72701, USA

Abstract: This study evaluated the provision of additional protein to broiler breeder pullets during the starter and prebreeder phases and its effect on production. The effect of lower body weight during rearing was also evaluated. Pullets were fed to reach breeder recommended target weights (H) or to be approximately 90 g smaller (L) than targets. Groups of H pullets were fed starter rations (19% CP) for one (H5) or two (H6) extra weeks and then according to breeder guidelines. Separate groups of H pullets were fed a 17% CP (HHP) or 14% CP (HLP) prebreeder diet from 16 to 21 weeks. Groups of L pullets were fed a 17% CP (LHP) or 14% CP (LLP) prebreeder from 16 to 21 weeks. Frame size and carcass protein was increased and carcass fat reduced in H5 and H6 during early rearing but differences dissipated. By the onset of lay no differences existed in carcass fat, protein or ash percentages. Egg production at 65 weeks of H5 and H6 groups was marginally improved as was HHP and LHP, although none differed significantly from H. Egg production of LLP was lowest ($P<0.05$). H and HHP groups had the highest egg weights with L and LLP the lowest. Early stimulation of growth and frame size by providing additional protein gave moderate improvements in performance as did higher protein prebreeder diets. Lower than normal protein intake during the prebreeder phase resulted in reduced performance. L hens performed equivalently to H hens in all areas but egg size.

Key words: Broiler breeder, rearing, crude protein, nutrition

Introduction

The ultra-high yield breeder may have different nutritional requirements compared to lower yielding breeders. Broiler breeder management related to feeding programs in the rearing period has been shown to be critical to reproductive fitness prior to peak egg production (Robinson *et al.*, 1995). Body weight and composition affect the onset of sexual maturity (Soller *et al.*, 1984; Yuan *et al.*, 1994). The amounts of body fat (Bornstein *et al.*, 1984) and lean body mass (Soller *et al.*, 1984) have also been shown to be critical in the initiation of reproductive development. In order to maximize the reproductive performance of the modern ultra-high yield strains it is essential that the optimum feeding strategy to obtain ideal frame size, fleshing and body composition is determined.

Although Luther *et al.* (1976) concluded that body weight at sexual maturity was the most important determinant of broiler breeder performance, irrespective of diet; there have been reports of improved performance as a result of increased protein intake at various stages of rearing. Authors have paid specific attention to the prebreeder period but some data does exist for the early part of the rearing period also. The early rearing period is critical for establishing frame size. Higher protein intake during the starter period stimulates early body weight gain and skeletal growth but these effects tend to dissipate with age (Leeson and Summers, 1984; Lilburn *et al.,* 1987). Hudson *et al.* (2000) speculated that a larger frame would provide a greater calcium reservoir for the laying period. They reported an increase in cumulative and settable egg production after feeding more protein to broiler breeder hens in the first six weeks of rearing.

Cave (1984) reported that increased protein intake during the prebreeder period increased egg production during the subsequent laying period, even though body weights were similar among treatments. Brake *et al.* (1985) and Lilburn and Myers-Miller (1990a) also found that increased protein intake during the prebreeder period increased egg production. More recently Joseph *et al.* (2000) found that increased protein intake during the prebreeder and early breeder periods increased egg production and egg size. Development of the reproductive organs (Yu and Marquardt, 1974) and activation of the estrogen dependant hepatic biosynthetic pathways (Scheide *et al.*, 1963) occurs during the relatively short prebreeder period. These processes may benefit from increased protein intake.

Feeding more protein during key phases of rearing to ultra-high yield type broiler breeder pullets may result in similar positive findings. The objective of this experiment was to study the effect of a variety of nutritional treatments during rearing on the subsequent reproductive performance of ultra high yield broiler breeder females. In particular, it was intended to determine whether increased crude protein intake during the starter and prebreeder periods affected subsequent egg production. A further objective was to determine the effects of maintaining a lower body weight throughout rearing on reproductive performance.

Table 1: The composition and calculated nutrient contents of experimental diets used during the experiment

Ingredient	Starter	Grower	Prebreeder (Std)	Prebreeder (HP)[1]	Prebreeder (LP)[2]	Breeder I	Breeder II
Corn, Yellow	61.36	61.41	67.78	66.19	66.84	66.78	67.95
Soybean Meal	26.83	15.44	20.37	180	9.63	22.16	20.12
Wheat Midds	7.71	19.04	7.09	10.31	17.45		
Calcium Di-P	1.83	1.74	1.73	1.50	1.48	1.80	1.70
Limestone	0.69	0.72	1.62	2.26	2.30	6.36	7.24
Termin-8	0.30	0.30	0.30			0.30	0.30
Salt 96+%	0.29	0.31	0.31	0.51	0.49	0.08	0.06
Fat, Poultry	0.25	0.50	0.25	0.50	1.00	1.67	1.77
Microsystem Soy	0.25	0.25	0.25			0.25	0.25
L-Lysine HCl	0.10			0.01	0.10		
Threonine				0.01	0.03		
DL-Methionine	0.10	0.07	0.08	0.08	0.04	0.19	0.15
Choline Cl-70%	0.09	0.07	0.08	0.20	0.20	0.09	0.10
Trace Mineral	0.06	0.06	0.06	0.10	0.10	0.06	0.06
Copper sulphate	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Vit. Premix	0.04	0.04	0.04	0.20	0.20	0.05	0.05
Stafac 20	0.04						
Ethoxyquin	0.01			0.02	0.02		
Selenium (0.06%)				0.02	0.02		
S-Carb						0.10	0.15
HyD						0.05	0.05
Propionic acid				0.05	0.05		
Nutrients							
ME, Kcal/lb	1300	1280	1325	1325	1325	1325	1325
CP calculated (%)	18.99	15.16	16.23	17.26	14.25	15.95	15.08
CP analyzed (%)[3]	18.80	15.27	16.40	17.44	14.47	16.11	15.17
Lysine (%)	1.09	0.75	0.83	0.88	0.73	0.84	0.78
Methionine (%)	0.40	0.33	0.35	0.37	0.31	0.44	0.39
Crude Fat (%)	2.82	3.27	2.96	2.95	2.95	4.15	4.27
Calcium (%)	0.95	0.90	1.25	1.25	1.25	3.10	3.4
Total P (%)	0.74	0.75	0.69	0.69	0.69	0.64	0.62
Avail. P (%)	0.45	0.45	0.42	0.42	0.42	0.41	0.39

[1]High protein. [2]Low protein. [3]Corrected to 90% DM

Materials and Methods

Stock and Management: Sixteen hundred and eighty day old Cobb 700 breeder pullets were randomly assigned to 48, 7.8´ x 6´ floor pens. The 48 pen experimental units were divided into eight treatments with six replicate pens of 35 pullets each per treatment. Initial stocking density was 1.34 square feet per pullet but was reduced to two square feet per pullet because pullets were sacrificed during the experiment for body composition. The Cobb Breeder Management Guide (Cobb-Vantress, 2005) was used as a reference for all management conditions, including light schedules for dark-out rearing houses. The compositions of the diets utilized throughout the experiment are shown in Table 1. The nutritional treatments are shown in Table 2. The control group (H) was fed according to breeder recommended guidelines (Cobb-Vantress, 2005). Cobb breeder recommendations for body weights at specific ages were used as target body weights. A second group (L) was fed the same diets as H but in smaller amounts to weigh approximately 90 grams (0.2 lbs) less than breeder recommendation at housing.

Two further groups, H5 and H6 were fed to reach the same weights as H, except they received starter (18.80% CP) for five and six weeks, respectively, as opposed to four weeks for all other treatments. Waiting to switch to the grower diet meant these pullets had higher protein intakes up to six weeks of age. Treatments LHP and LLP were fed to reach the same weights as L but received high (17.44%) and low (14.47%) protein prebreeder from 16 weeks of age, respectively. Treatments HHP and HLP were fed to reach the same weights as H but received high (17.44%) and low (14.47%) protein prebreeder from 16 weeks of age, respectively. All prebreeder diets had the same energy content (1325 kcal/lb). Treatments H, H5, H6, HHP and HLP were fed to reach the same breeder recommended target weights at housing, even though their protein intakes were not the same. Treatments L, LHP and LLP were fed to weigh approximately 90 grams (0.2 lbs) less than breeder recommendations at housing. Pullets were weighed weekly in groups until week 21 in order to track weight changes.

Cumulative protein intakes are shown in Table 3. Increased protein intake for H5 and H6 was achieved by extending the period of feeding starter diet from four, to five and six weeks, respectively. H5 and H6 received 10g and 20g more protein/pullet than control (H) pullets by week six, respectively. LHP and HHP pullets received high protein prebreeder from week 16 and received 53

Table 2: Nutritional treatments during rearing and production

Treatment	Weeks of age							
	4	5	6	16	18	21	22	45
H	ST[1]	GR[2]	GR	GR	PBStd[5]	PBStd	BR I[6]	BR II[7]
L	ST	GR	GR	GR	PBStd	PBStd	BR I	BR II
H5	ST	ST	GR	GR	PBStd	PBStd	BR I	BR II
H6	ST	ST	ST	GR	PBStd	PBStd	BR I	BR II
LHP	ST	GR	GR	PBHP[3]	PBHP	PBHP	BR I	BR II
LLP	ST	GR	GR	PBLP[4]	PBLP	PBLP	BR I	BR II
HHP	ST	GR	GR	PBHP	PBHP	PBHP	BR I	BR II
HLP	ST	GR	GR	PBLP	PBLP	PBLP	BR I	BR II

[1]ST = Starter diet (18.80% CP). [2]Gr = Grower diet (15.27% CP). [3]PBHP = Prebreeder high protein (17.44% CP). [4]PBLP = Prebreeder low protein (14.47% CP). [5]PBStd = Prebreeder standard (16.40% CP). [6]BR I = Breeder I (16.11% CP). [7]BR II = Breeder II (15.17% CP)

Table 3: Calculated cumulative CP intake at 4, 6, 18 and 21 weeks of age and total CP intake from 16 to 21 weeks of age (g/bird) for the various nutritional treatments

Treatment	Weeks of age					
	4	6	16	18	21	16-21
	g CP intake per bird					
H	195.3	286.7	941.9	1136.7	1515.4	573.5
L	180.2	269.7	893.7	1086	1464.8	571.1
H5	195.3	297.2	948.6	1143.3	1522.1	573.5
H6	195.3	307.5	957.4	1152.1	1530.9	573.5
LHP	180.2	269.7	893.7	1112.8	1521	627.4
LLP	180.2	269.7	893.7	1076.8	1413.9	520.3
HHP	195.3	286.7	941.9	1163.8	1572.1	630.2
HLP	195.3	286.7	941.9	1127.4	1464.4	522.5

Table 4: Feed allocation schedule for all hens after housing

Age (weeks)	Feed (g/bird/day)
22	110
23	115
24	120
25	125
26*	129
27	134
28	139
29	144
30	144
31**	144
32	142
33	141
34	140
35	139
36	138
37	137
38	136
39	135
40	134
41	133
42	132
43	132
44	131
45	131
46	130
47	129
48	128
49	127
50	126
65	126

* Onset of lay. ** Peak production

and 56 grams more protein during the prebreeder period than controls, respectively. LLP and HLP pullets received low protein prebreeder from week 16 and received 53 and 51 grams less protein than controls, respectively.

Pullets were photostimulated with 13 hours of light at 21 weeks and 40 representative birds from each treatment were housed individually in breeder cages. Photoperiod was extended by one hour per week each week until 16 hours of light was reached. All groups were fed Breeder I from week 22 to week 45 and Breeder II from week 45 till the end of the experiment. During the production period all hens were fed approximately 90 % of the breeder's recommended allocation. Maximum feed allocation was 144 grams per bird which was 420 kcal ME/hen/day (Reyes & Coon, unpublished data). This was done to account for the reduced energy expenditure as a result of being housed in individual cages. The post-housing feed allocation schedule is shown in Table 4. Feed withdrawal began at week 33 and continued until week 50. At week 50 hens received 126 g/hen/day which is equivalent to 367 kcal ME. This represents approximately 87% of maximum feed allocation.

Reproductive performance: Egg production was recorded daily and egg weights were measured twice weekly, throughout the production period. All soft shelled double yolk and cracked eggs were recorded. Age at first

Table 5: The effect of nutritional treatments on average body weight (g) of broiler breeders at various stages of rearing and production and percentage gain from week 16 to week 21 (%)

Treatment	Weeks of age									Gain (W16-21)
	4	5	6	16	18	21	26	31	65	%
	BW (g)									
H	588^{a}	670^{b}	723^{b}	1550^{a}	1820^{abc}	2378^{ab}	3319^{ab}	3742	4304	34.9
L	535^{b}	619^{c}	685^{c}	1454^{b}	1763^{c}	2250de	3235^{bc}	3667	4094	35.3
H5		714^{a}	778^{a}	1545^{a}	1835^{abc}	2351^{abc}	3254^{abc}	3649	4143	33.4
H6		717^{a}	794^{a}	1568^{a}	1858^{ab}	2386^{a}	3321^{ab}	3761	4213	35.2
LHP					1806^{bc}	2222^{ef}	3259^{abc}	3654	3991	33.1
LLP					1799^{bc}	2174^{f}	3171^{c}	3643	4014	34.6
HHP					1890^{a}	2332^{bc}	3370^{a}	3763	4174	32.6
HLP					1889^{a}	2298^{cd}	3290^{abc}	3699	4158	33.5
SEM	4	10	11	13	27	14	26	41	65	

a,b Within a column, means not having the same superscript are significantly different (P<0.05)

egg (sexual maturity) and peak were recorded. Peak was determined as a five day rolling average. Shank and keel lengths were measured on 20 birds per treatment at various ages and used as a measure of frame size. From 21 weeks of age all hens were weighed individually every week until week 33 and then monthly until the end of the experiment. Mortality was recorded on a daily basis.

All hens were artificially inseminated at week 33 and every four weeks after that. One week's worth of eggs was collected from each hen to determine hatchability at each interval. Semen was collected from broiler breeder males using the abdominal massage method as described by Burrows and Quinn (1937). Semen was pooled and sperm cell concentration determined using an IMV Micro-Reader I[2], using an optical density of 381 nm (King and Donoghue, 2000). Semen was diluted to 5 x 10^{7} sperm/50 µl using Beltsville Poultry Semen Extender to ensure all hens were inseminated with the same number and volume of sperm cells. Each hen was inseminated with 50 µl of diluted semen. Semen was diluted to 5 x 10^{7} sperm/50 µl prior to insemination to allow detection of variation in fertility levels. While this low number of sperm cells does not produce exceptionally high fertility levels, by not filling the sperm host glands in the hen it allows for differences among treatments to be determined. All eggs were collected for one week after each insemination and set in Jamesway[3] machines for incubation and hatching.

Carcass composition: In order to determine the effect of the various nutritional programs on carcass composition, pullets were sacrificed by CO_2 asphyxiation at intervals during rearing. Eight birds from each treatment were sacrificed at each interval for analysis of body composition. At the end of the 65 week trial period eight hens from each treatment were sacrificed for final body composition analysis. Each breeder carcass was frozen at -20°C until autoclaving. The carcasses were placed in trays covered with foil and autoclaved at 120°C for 15h in an AMSCO 3053 sterilizer[4]. The carcasses were homogenized after autoclaving using a Waring 4L blender[5]. Sub-samples were collected after grinding and freeze-dried in a Genesis SQ 12 EL Freeze drier[6]. Carcass protein, ash and fat were analyzed according to AOAC (1990).

All procedures were carried out in accordance with Animal Use Protocol No. 03008 for the experiment, which was approved by the University of Arkansas Institutional Animal Care and Use Committee (IACUC).

Statistical analysis: Data analysis was performed using JMP IN 5.1[7] statistical analysis software. Chicks were assigned to treatments on day one in a completely random manner. All data were analyzed based on a completely randomized design. Data are presented as mean ± SEM. When significant differences were observed means were separated using Tukey's Studentized range test. All statements of significance are based on testing at P = 0.05.

Results

Body weight, frame size and carcass characteristics: Average body weights are shown in Table 5. H represents the control group which was fed to reach the body weights recommended by the breeder company. Pullets H5 and H6 were heavier at six weeks of age than H birds due to increased protein intake. By 16 weeks of age these pullets fed extra protein during the starter period were no longer significantly heavier than control pullets. L, LLP and LHP pullets weighed less than H pullets throughout rearing due to lower feed allocations. Groups fed high protein prebreeder diets (LHP and HHP) made similar gains in body weight to other groups fed lower protein prebreeder diets, from 16 to 21 weeks. Industry reports indicate that it is important to obtain an increase of around 30 % of body weight in the period from week 16 to 21. Table 5 shows that all groups met or exceeded this criterion. L, LLP and LHP pullets weighed less than H pullets at housing as intended, due to lower feed allocations. By week 26 (first egg) only LLP hens were still significantly lighter than H. L and LHP hens, which were maintained at a lighter body weight

Table 6: The effect of nutritional treatments on shank and keel lengths (cm) of broiler breeders at 6, 16, 21 and 28 weeks of age

Treatment	Weeks of age							
	Week 6		Week 16		Week 21		Week 28	
	Shank	Keel	Shank	Keel	Shank	Keel	Shank	Keel
H	7.08^b	11.23^b	8.86^b	15.19^a	9.11^{ab}	16.95^{bc}	9.98^{ab}	17.45^a
L	6.74^c	10.60^c	8.52^c	14.61^b	8.94^{bc}	16.58^d	9.91^{ab}	17.07^b
H5	7.18^{ab}	11.64^a	8.90^{ab}	15.29^a	9.16^a	17.12^{ab}	10.07^a	17.76^a
H6	7.25^a	11.77^a	9.08^a	15.45^a	9.18^a	17.15^{ab}	10.08^a	17.79^a
LHP					8.93^{bc}	16.65^{cd}	9.90^{ab}	17.15^{ab}
LLP					8.90^c	16.58^d	9.78^b	16.95^b
HHP					9.13^{ab}	17.28^a	10.07^a	17.48^a
HLP					9.12^{ab}	17.19^{ab}	10.06^a	17.39^a
SEM	0.04	0.08	0.06	0.11	0.05	0.13	0.05	0.15

a,b Within a column, means not having the same superscript are significantly different ($P<0.05$)

during rearing, were no longer significantly lighter than H by the time they started producing eggs. Despite the differences that existed in body weight at housing there were no differences in body weight of any treatments by the time the hens had reached peak (31 weeks of age). No differences in body weight were observed at any time after hens reached 31 weeks of age.

During the production period all groups gained more weight than breeder guidelines recommend despite more severe feed restriction. This can be attributed to the lack of activity associated with being in individual cages.

Table 6 shows the shank and keel lengths of birds measured at various ages. At week 6 pullets fed the starter diet for two extra weeks (H6) had longer keels and shanks than H pullets. Keel length for H5 was greater than H but shank length did not differ. L pullets had shorter shanks and keels than H due to lower allocations of feed. By week 16, H5 and H6 did not differ in keel length compared to H pullets, while L pullets continued to display shorter keel lengths. The shank length of H6 pullets was still longer than control pullets at 16 weeks while the lower feed allocations to L continued to ensure that their shank length was less than control birds. At week 21 the H5 and H6 still had the longest shanks but they did not differ ($P<0.05$) from H pullets. The only pullets that had shanks significantly shorter than the control group were LLP. LLP pullets were maintained at a lighter body weight and fed a low protein prebreeder from 16 weeks of age. A similar trend was noted for the keel lengths, although it appears that pullets fed the high protein prebreeder from 16 weeks of age (LHP and HHP) tended to have longer keels than pullets fed the low protein prebreeder (LLP and HLP).

The breast muscle weight at various ages is presented in Table 7. Pullets given smaller feed allocations to ensure lower body weights have consistently lower breast muscle weights. This difference is attenuated somewhat by feeding the high protein prebreeder diet to the smaller pullets (LHP). LLP had the lowest breast muscle weight. H5 and H6 groups had higher breast muscle weight in the first six weeks but by 12 weeks these groups did not have significantly more breast meat than H pullets. HHP had the highest breast weight at 21 weeks of age but this was only significantly ($P<0.05$) higher than L, LLP and HLP pullets.

Body composition of breeder pullets was affected by nutritional treatments (Table 8). Differences in total protein and ash content of the carcass were evident between the L and H pullets at four weeks of age. By six weeks of age H had more total protein, fat and ash than L, although the percentage of each component did not differ. H5 and H6 had more total protein and ash, but less fat than H pullets. The percentage of carcass protein and ash was numerically higher for H5 and H6 than either H or L pullets. Carcass fat percentage was significantly lower than control pullets. H5 and H6 groups had similar total fat but lower percentage fat than L pullets. This reflects their increased protein intake during the first six weeks which resulted in larger frame sizes and increased breast muscle mass while fat percentage was reduced.

By 21 weeks of age none of the treatments differed in the percentage of each carcass component but H, H5, H6 and HHP had significantly more total protein than LLP. Total carcass ash was consistently higher in the groups fed to reach target body weights compared to those fed to reach lower body weights. Feeding a high protein prebreeder to lighter birds tended to attenuate these differences somewhat (LHP).

At the end of the production period (65 weeks of age) no differences existed in percentage or total carcass fat, protein or ash.

Reproductive performance: LLP hens took longer to reach sexual maturity than hens from other treatments (Table 9). There were no differences in age at first egg of any of the other treatments. LLP hens also had smaller frames (Table 6), lower breast weights (Table 7), less total carcass protein and ash (Table 8) at housing than other groups and received the least dietary protein during the rearing period (Table 3).

Table 9 shows a summary of the performance data from the entire production period. Peak (calculated as a 5 day

Table 7: The effect of nutritional treatments on breast weights of broiler breeder pullets at 4, 5, 6, 12, 16 and 21 weeks of age

Treatment	Weeks of age					
	4	5	6	12	16	21
	(g)					
H	67.9^{a}	77.6^{b}	89.0^{b}	198.5^{ab}	256.8^{a}	372.8^{abc}
L	62.5^{b}	66.8^{c}	75.4^{c}	179.0^{b}	227.4^{b}	347.4^{c}
H5		89.4^{a}	100.1^{ab}	208.6^{a}	253.9^{a}	384.4^{ab}
H6		89.4^{a}	107.2^{a}	212.8^{a}	258.8^{a}	384.6^{ab}
LHP						362.4^{abc}
LLP						338.5^{c}
HHP						392.4^{a}
HLP						352.8^{bc}
SEM	2.7	3.6	4.3	7.9	11.7	12.6

a,b Within a column, means not having the same superscript are significantly different ($P<0.05$)

rolling average) was similar in all treatments except LLP. Peak was lowest in LLP hens and their peak was also delayed compared to other groups. By week 65 H6 hens laid approximately 4.5 more total eggs per hen than H. H5 hens had laid about 2.2 more eggs than H hens. LLP hens were the only hens to lay significantly fewer total eggs than control hens. Settable egg production (Table 9) was calculated as the number of eggs weighing more than 50 g minus the number of soft shell, double yolk and cracked eggs. Hens fed the low protein prebreeder (LLP and HLP), laid the least settable eggs, regardless of body weight. Similar trends were evident in settable egg production as in total egg production. Hens from H5 and H6 treatments produced 3.2 and 3.9 more settable eggs per hen than H hens, respectively. LLP and HLP hens produced the lowest number of settable eggs, in keeping with the trends witnessed for total egg production. This was due to a combination of fewer total eggs and fewer eggs exceeding 50 g. Hens receiving high protein prebreeder (LHP and HLP) produced 3.2 and 3.1 more settable eggs per hen than H hens, respectively. Hens from the LLP treatment also laid the smallest eggs. HHP hens laid the largest eggs but they were not significantly larger than eggs for H hens. Pullets that weighed less at housing (L, LLP and LHP) tended to lay smaller eggs than other groups but this was not as obvious when a high protein prebreeder diet was fed (LHP).

None of the treatments differed significantly from controls in terms of abnormal eggs per hen but there was a tendency for larger birds to lay more abnormal eggs. Groups that received more protein tended to produce more soft shelled eggs than groups receiving less total protein to 21 weeks of age.

Neither fertility nor hatchability (not shown) differed between treatments. There were no differences in hatchability of fertile eggs among treatments.

Feed conversion was expressed in terms of grams of feed per settable egg and total eggs, grams of protein per settable egg and total eggs and kcal per settable egg and total eggs (Table 10). Feed conversion was best for hens in treatments that received high protein at either the starter or prebreeder phase but none differed significantly from control hens for any of the calculated parameters. Numerically, hens fed higher protein during the starter period showed the best efficiency in protein and energy utilization. The worst feed conversion was observed in LLP and HLP hens, which were fed low protein prebreeder diets. There were no differences in mortality among treatments throughout the rearing and production periods

Discussion

Increasing crude protein intake during the period from four to six weeks of age resulted in increased body weight at six weeks. Feeding was controlled thereafter so that those groups fed extra protein during the starter period would not be heavier than controls at housing. While feeding more protein during the starter period had a significant effect on body weight, pullets fed high protein prebreeder diets were not significantly heavier than those fed low protein prebreeder. Energy content of all prebreeder diets was equal. Other authors (Joseph *et al.,* 2000; Lilburn *et al.,* 1987; Spratt and Leeson, 1987) found similar trends in their work, indicating that extra energy intake is more likely to cause increases in body weight of older birds than extra protein intake. Higher protein intake early in rearing increased skeletal size but differences generally tended to dissipate as hens got older and entered production. This is similar to the findings of Hudson *et al.* (2000) and Leeson and Summers (1984). Birds of lower body weight however, continued to have shorter shanks and keels even at 28 weeks of age and also had less total carcass ash, indicating a smaller frame size. The development of a large frame is seen as important in order to act as a calcium reservoir.

Protein intake did not affect age at first egg. This is in agreement with the work of Hudson *et al.* (2000). Hens fed low protein prebreeder that were already smaller than other birds (LLP) came into lay later than other groups. The combined effects of lower body weight, smaller frame size, less breast muscle tissue and less total carcass protein resulted in the slower onset of

Table 8: The effect of nutritional treatments on carcass dry matter, fat, protein and ash of broiler breeders at 4, 6, 21 and 65 weeks of age

Treatment	Dry matter*		Fat**		Protein		Ash	
	%	g	% DM	g	% DM	g	% DM	g
4 Weeks								
H	30.6^{a}	180.0^{a}	19.6	35.4	61.5	110.7^{a}	9.7	17.4^{a}
L	29.3^{b}	156.7^{b}	20.7	32.4	62.1	97.4^{b}	9.6	15.0^{b}
SEM	0.4	2.2	0.8	1.4	0.7	1.6 0.2	0.3	
6 Weeks								
H	29.2	232.1^{b}	22.1^{a}	51.3^{a}	63.6^{ab}	147.6^{b}	10.1	23.4^{b}
L	28.7	213.7^{c}	21.2^{a}	45.3^{b}	63.1^{b}	134.9^{c}	10	21.4^{c}
H5	30	251.3^{a}	18.6^{b}	46.7^{b}	65.8^{a}	165.4^{a}	10.2	25.6^{a}
H6	30.2	257.3^{a}	18.3^{b}	47.1^{b}	66.0^{a}	169.8^{a}	10.3	26.5^{a}
SEM	0.7	4.6	0.5	1.5	0.6	3	0.2	0.5
21 Weeks								
H	33.2	789.5^{a}	30.12	237.8	55.2	435.8^{a}	9.9	78.0^{a}
L	32.7	735.8^{ab}	30.72	226	54.8	403.2^{ab}	9.5	69.9^{bc}
H5	33.1	778.2^{a}	29.45	229.2	55.8	434.2^{a}	10	77.4^{a}
H6	33.2	785.5^{a}	29.21	229.4	56	439.9^{a}	10	78.5^{a}
LHP	32.8	728.8^{ab}	30.25	220.5	55.2	402.3^{ab}	9.7	70.7^{bc}
LLP	32.6	708.7^{b}	32.35	229.3	53.2	377.0^{b}	9.5	66.3^{c}
HHP	32.8	764.9^{a}	29.51	225.7	56.8	434.5^{a}	9.9	75.6^{a}
HLP	32.7	751.4^{ab}	30.94	232.5	54.4	408.8^{ab}	9.9	74.1^{ab}
SEM	1.1	25.7	2	16.1	1.8	14.4	0.2	2.7
65 Weeks								
H	36.9	1492.8	40.5	624.3	46	711.5	8.7	129.1
L	38.5	1577.7	41.9	663.8	46.9	736.5	6.6	104.3
H5	39.5	1635.1	41.1	676.2	47	766.1	7	114.6
H6	38.7	1630.6	43.3	715.5	46.1	745.1	6.5	104.4
LHP	38.8	1549.7	39.4	616.7	47.8	737.7	8	123.9
LLP	40.5	1624.7	43.7	709.2	45.2	734.4	6.9	112.6
HHP	35.9	1498.8	39.2	591.5	48.6	723.2	6.6	98.6
HLP	37.9	1575.8	41.6	675.4	46.5	741.2	7.2	114.1
SEM	1.3	55.6	2.2	48	1.5	26.6	0.5	8.7

* Dry matter determined as a percentage of total wet carcass weight

** Fat, protein and ash determined as a percentage of dry carcass weight

a,b Within a column, means not having the same superscript are significantly different ($P<0.05$)

sexual maturity in these hens. It is of interest to note that the total carcass fat content of LLP hens was similar to other groups while the total carcass protein was lower. This suggests that under these circumstances, carcass protein is more important than carcass fat in determining the development of sexual maturity.

Differences in body weight at housing disappeared during the laying period. All hens were fed identical amounts of feed from 21 weeks onwards. This is a common observation as smaller hens may take longer to reach sexual maturity and thus can partition more of their nutrient intake to growth before egg production begins. Egg weight has been shown to have a highly significant positive correlation with body weight (McDaniel, 1981). Studies have also shown that diet can affect egg size (Pearson and Herron, 1980, 1981; Wilson and Harms, 1986). Table 9 shows that smaller hens (L, LLP and LHP) laid smaller eggs than H hens, which would allow them to partition more of their dietary nutrients to growth. These factors combined would account for the general equalization in body weights during the production period.

Carcass protein and ash was increased and fat was decreased when early protein intake was increased. These differences tended to dissipate with age as body weight equalized with the control pullets which mirrors the findings of several other investigators (Hudson *et al.*, 2000; Lillburn and Myers-Miller, 1990b; Leeson and Summers, 1984. The only differences in carcass composition that existed by 21 weeks of age were not related to the percentage of each component in the carcass but rather to the total content of each component. The observed differences were due only to differences in body weight. Lilburn and Myers-Miller (1990b) found a similar trend in carcass composition when they fed pullets on a starter ration during rearing compared to a conventional grower diet. In their work they fed the starter through 18 weeks, while in this trial the starter was only fed to six weeks of age. They found increases in early breast muscle weight independent of body weight, much like our findings. They also found that the differences had all but disappeared by 25 weeks of age.

In the same experiment, Lilburn and Myers-Miller (1990b) found that the hens fed the starter diet through 18 weeks of age had higher egg production from 28 to

Table 9: The effect of nutritional treatments on age at sexual maturity, peak production, age at peak, eggs per hen, abnormal eggs, settable eggs, hatch of fertile eggs and average egg weights from week 25 to week 65

Treat-ment	Age at SM[1] (d)	Peak (%)	Age at peak (d)	Total eggs	Abnormal eggs[2]	Eggs > 50g (%)	Settable eggs[3]	Hatch of fertile(%)	Average egg wt
H	185.3±1.1[b]	83.6	221	171.0±4.6[a]	1.48±0.38[ab]	94.5	160.2±4.3[ab]	89.7±2.2	62.59±0.16[a]
L	185.9±1.2[b]	84.5	219	170.0±5.3[a]	1.36±0.22[ab]	94.1	158.5±5.3[ab]	91.9±2.4	61.21±0.14[c]
H5	183.9±1.5[b]	82.2	220	173.2±4.6[a]	1.21±0.26[ab]	95.1	163.4±4.7[ab]	90.7±2.3	61.78±0.15[b]
H6	183.4±1.3[b]	84.3	219	175.5±5.0[a]	1.88±0.27[a]	94.5	164.1±4.4[a]	90.1±2.2	61.92±0.16[b]
LHP	185.0±1.3[b]	83.8	218	172.9±4.8[a]	1.18±0.20[ab]	95.1	163.4±4.6[ab]	90.7±2.3	61.68±0.14[b]
LLP	190.2±1.3[a]	78.3	224	165.8±3.8[b]	0.79±0.19[b]	93.5	154.9±3.6[b]	89.7±2.0	60.79±0.14[d]
HHP	183.6±1.1[b]	81.1	219	170.9±4.6[a]	1.94±0.41[a]	96.5	163.3±4.6[ab]	93.0±2.2	62.83±0.14[a]
HLP	185.2±1.2[b]	80	220	169.2±5.5[ab]	1.60±0.32[ab]	94.2	157.4±5.4[b]	90.2±2.5	61.95±0.15[b]

a,b Within a column, means not having the same superscript are significantly different ($P<0.05$). [1]SM = Sexual maturity; defined as first oviposition. [2]Includes soft-shelled, double yolked and cracked eggs. [3]Number of eggs weighing > 50g, not including soft shells, double yolks or cracks

32 and 32 to 36 weeks of age. In their work and ours, differences in egg production occurred despite the fact that any differences in frame size and carcass composition tended to disappear before the onset of lay. This supports other data in which differences in carcass composition alone could not explain differences in production (Bornstein *et al*., 1984; Soller *et al*., 1984).

Hudson *et al*. (2000) reported benefits of feeding more protein during the starter period. In their work, feeding 20% crude protein starter rather than 16% or 14% resulted in 1.3 and 3.5 more eggs, respectively from 25 to 33 weeks. They did not follow egg production further than 33 weeks. Our work showed similar beneficial effects. Hens fed starter for five and six weeks produced marginally more eggs by 65 weeks of age than control hens. Establishing adequate frame size during early rearing is important but alone cannot explain the improvements in egg production of hens fed more protein to six weeks of age because the differences in frame size tended to dissipate before the onset of production. Body weights for these groups were not larger than control pullets at housing and all frame and carcass parameters were similar to those of the control pullets by 21 weeks of age. Hudson *et al*. (2000) did not offer a specific explanation for their findings but pointed out that the starter period is a critical period during which pullets are sensitive to protein intake.

Hens from treatments with higher early protein intakes also displayed the best feed conversions, though none of the differences were significant. Through the rearing period these treatments were allocated less total feed to ensure that their body weights were not greater than control birds at housing. Their improved egg production and lower total feed intakes translated to better efficiency. The added cost of feeding the starter diet for two extra weeks is easily negated by the lower feed allocations required to maintain target body weights thereafter, and also by the improved egg production.

Lilburn and Myers-Miller (1990a) reported that an 18% protein prebreeder from 18 to 24 weeks increased egg production compared to a 14% prebreeder during the same period. They found these results despite all body weights being equal. Cave (1984) reported an increase of almost 10 eggs per hen after feeding 189 g of extra protein during the period from 19 to 26 weeks of age. Brake *et al*. (1985) reported that an additional 140 g of protein during this period resulted in an increase of nearly six eggs. Our work shows an increase of only 3.2 and 3.1 settable eggs for LHP and HHP hens over control hens, respectively. There was little difference in peak between these groups and little difference in age at first egg but the hens fed high protein prebreeder still produced slightly more eggs. This agrees with the work of Cave (1984), who found that the differences in egg production due to high protein prebreeder diets were seen mostly after 35 weeks of age. A possible explanation for the smaller observed increase in egg production in our trial is that LHP and HHP treatments received only 53 and 56 grams more protein than controls during the prebreeder period, respectively. Smaller differences observed in our work may also be due to the fact that feeding of high protein prebreeder diets ended at 21 weeks and was not continued through to egg production. In the studies of Cave (1984) and Brake *et al*. (1985) the high protein prebreeder rations were fed through 26 and 23 weeks respectively. The major increase in ovarian development and liver growth occurs after lighting and did not coincide with the period of greater protein intake in our study. Increased levels of protein in the prebreeder ration may be most beneficial when fed through the period of maximal ovarian and liver growth.

Cave (1984) suggested that high protein intake during the prebreeder period stimulated ovarian growth and development and thus reduced the amount of ovulated yolks not being caught by the infindibulum. The work showed normal follicular hierarchies in hens fed less protein. It is possible that capture of ovulated yolks was less efficient in these hens resulting in more “internal laying”. Yu and Marquardt (1974) reported hypertrophy of the liver during the pre-lay and early laying period. Extra protein prior to sexual maturity may further maximize protein storage. The total carcass protein content of hens fed high protein prebreeder was higher than those

Table 10: The effect of nutritional treatments on feed conversion ratio for all nutritional treatments expressed in terms of total feed intake, protein intake and energy intake per egg and per settable egg*

Treatment	g feed/ settable egg	g feed/ egg (total)	g protein/ settable egg	g protein/ egg (total)	kcal/ settable egg	kcal/ egg (total)
H	311	292.5	50.9	49.4	920.1	864.5
L	318.3	296.9	50.1	50.6	942.1	878.9
H5	307.5	290.3	49.1	49	909.6	858.7
H6	303.8	283.8	47.9	48.4	899.2	840
LHP	309.8	291.4	49.9	49.1	917.7	860.1
LLP	324.6	301.8	52.6	51.5	959.3	893.3
HHP	308.8	294.7	50.6	49.4	914.4	872.7
HLP	322.5	299.8	51.2	50.9	955.1	887.8

* No significant ($P<0.05$) differences were observed in any parameters

on the low protein prebreeder. It may be important for both the liver and other body protein reserves to provide a relatively large supply of labile protein for the hen to draw on for egg protein formation. The liver protein turnover rate may increase as production commences in order to adequately supply the protein requirements for albumin formation. Having a larger labile protein reserve in the body may be beneficial to hens once laying begins.

Feeding high protein prebreeder diets led to larger eggs compared to low protein prebreeder diets. This finding is similar to that of Joseph *et al*. (2000), who reported that hens fed 16 or 18% protein rations from 20 to 29 weeks produced larger eggs that those given a 14% protein prebreeder. They also found that those fed a 14% prebreeder produced fewer eggs up to 29 weeks of age even though there was no difference in age at sexual maturity. They attributed the increases in egg production to the direct supply of amino acids for egg formation rather than an increase in protein stores, as they continued to feed the high protein diets during the laying phase. The larger egg weights were attributed to increases in albumen weight. They also found that there were no differences in egg size or production when a 16% protein ration was compared to an 18% protein ration from 20 to 29 weeks. This is similar to our findings that show the egg production and egg size of hens fed a 17.44% protein prebreeder was better than hens fed a 14.47% protein prebreeder but not much better than hens of the same weight fed the standard prebreeder (16.40 % protein).

Low protein intakes from week 16 to week 21 had a negative effect on egg production, and feed conversion parameters. While excess protein during this period may or may not be of great benefit to the bird, it does seem that lower than recommended protein intake has a detrimental effect on performance.

Hens fed to be slightly smaller than breeder recommended weights during rearing had smaller frame sizes but performed equally as well as control hens in terms of all parameters but egg size. Egg size for the smaller set of hens was increased when a high protein prebreeder was fed. As long as sufficient protein was fed during the prebreeder period, following a slightly lower body weight curve seems to be a viable alternative. Our results once again demonstrate that body weight is not the only important predictor of reproductive fitness.

Walsh and Brake (1997) found that at least 1180 g of cumulative crude protein intake by 20 weeks is required to maximize fertility in broiler breeder females regardless of energy intake or 20 week body weight. Protein intake at 20 weeks in our trial exceeded those limits in all groups and no differences were observed in fertility, hatchability and hatch of fertile eggs.

Moderate increases in egg production and improved protein and energy utilization resulting from higher protein intakes suggest that there are key periods during rearing when sufficient protein intake is essential to achieving maximum performance. Current research would suggest that nutritional treatment during the starter and prebreeder period are of particular interest. Promoting growth in the first few weeks appears to have had a beneficial effect on performance despite body weights returning to normal. This may be comparable to the nutritional programming described by Knight and Dibner (1998) for broilers during the first days of life. The challenge remains to identify the specific mechanisms responsible for increased production, particularly for pullets fed more protein early in rearing. Though their body weight is not different from other hens at lighting they tend to be more efficient and lay more eggs. It is also clear that nutritional status, independent of body weight, during the prebreeder period is important in determining how productive a broiler breeder hen will be.

Acknowledgments

The authors would like to thank Cobb-Vantress Inc, for donating chicks and for financial support for these experiments. The authors would also like to thank the staff at the University of Arkansas, Poultry Research Farm for assistance during the trials.

References

Association of Official Analytical Chemists, 1990. Official Methods of Analysis. 15th ed. Association of Official Analytical Chemists, Washington, DC.

Bornstein, S., I. Plavnik and Y. Lev, 1984. Body weight and/or fatness as potential determinants of the onset of egg production in broiler breeder hens. Br. Poult. Sci., 25: 323-341.

Brake, J., J.D. Garlich and E.D. Peebles, 1985. Effect of protein and energy intake by broiler breeders during the prebreeder transition period on subsequent reproductive performance. Poult. Sci., 64: 2335-2340.

Burrows, W.H. and J.P. Quinn, 1937. The collection of spermatozoa from the domestic fowl and turkey. Poult. Sci., 16: 19-24.

Cave, N.A.G., 1984. Effect of a high protein diet fed prior to the onset of lay on performance of broiler breeder pullets. Poult. Sci., 63: 1823-1827.

Cobb-Vantress. 2005. Breeder Management Supplement, Cobb 700. Cobb-Vantress, Siloam Springs, AR.

Hudson, B.P., R.J. Lien and J.B. Hess, 2000. Effects of early protein intake on development and subsequent egg production of broiler breeder hens. J. Appl. Poult. Res., 9: 324-333.

Joseph, N.S., F.E. Robinson, D.R. Korver and R.A. Renema, 2000. Effect of dietary protein intake during the pullet-to-breeder transition period on early egg weight and production in broiler breeders. Poult. Sci., 79: 1790-1796.

King, L.M. and A.M. Donoghue, 2000. Adaptation of the sperm mobility test for identification of turkey toms with low fertilizing potential. J. Appl. Poult. Res., 9: 66-73.

Knight, C.D. and J.J. Dibner, 1998. Nutritional programming in hatchling poultry: Why a good start is important. Poult. Digest, 57: 20-26.

Leeson, S. and J.D. Summers, 1984. Influence of nutritional modification on skeletal size of leghorn and broiler breeder pullets. Poult. Sci., 63: 1222-1228.

Lilburn, M.S. and D.J. Myers-Miller, 1990a. Effect of body weight, feed allowance and dietary protein intake during the prebreeder period on early reproductive performance of broiler breeder hens. Poult. Sci., 69: 1118-1125.

Lilburn, M.S. and D.J. Myers-Miller, 1990b. Dietary effects on body composition and subsequent production characteristics in broiler breeder hens. Poult. Sci., 69: 1126-1132.

Lilburn, M.S., K. Ngiam-Rilling, and J.H. Smith, 1987. Relationships between dietary protein, dietary energy, rearing environment, and nutrient utilization by broiler breeder pullets. Poult. Sci., 66: 1111-1118.

Luther, L.W., W.W. Abbot and J.R. Crouch, 1976. Low lysine, low protein, and skip-a-day restriction of summer and winter reared broiler breeder pullets. Poult. Sci., 55: 2240-2247.

McDaniel, G.R., J. Brake and M.K. Eckman, 1981. Factors affecting broiler breeder performance. 4. The interrelationship of some reproductive traits. Poult. Sci., 60: 1792-1797.

Pearson, R.A. and K.M. Herron, 1980. Feeding standards during lay and reproductive performance of broiler breeders. Br. Poult. Sci., 21: 171-181.

Pearson, R.A. and K.M. Herron, 1981. Effects of energy and protein allowances during lay on the reproductive performance of broiler breeder hens. Br. Poult. Sci., 22: 227-239.

Robinson, F.E., N.A. Robinson, R.T. Hardin and J.L. Wilson, 1995. Effects of 20 week body weight and feed allocation during early lay on growth, carcass composition and reproductive performance of female broiler breeders. J. Appl. Poult. Res., 4: 203-210.

Scheide, D.A., M. Wilkens, R.G. Candless, R.J. Munn, M. Peterson and E. Carlsen, 1963. Liver synthesis, plasma transport and structural alterations accompanying passage of yolk proteins. Am. Zool., 3: 167-184.

Soller, M., Y. Eitan and T. Brody, 1984. Effect of diet and early quantitative feed restriction on the minimum weight requirement for onset of sexual maturity in White Rock broiler breeders. Poult. Sci., 63: 1255-1261.

Spratt, R.S. and S. Leeson, 1987. Broiler breeder performance in response to diet protein and energy. Poult. Sci., 66: 683-693.

Walsh, T.J. and J. Brake, 1997. The effect of nutrient intake during rearing of broiler breeder females on subsequent fertility. Poult. Sci., 76: 297-305.

Wilson, H.R. and R.H. Harms, 1986. Performance of broiler breeders as affected by body weight during the breeding season. Poult. Sci., 65: 1052-1057.

Yu, J.Y.L. and R.R. Marquardt, 1974. Hyperplasia and hypertrophy of the chicken (*Gallus domesticus*) oviduct during a reproductive cycle. Poult. Sci., 53: 1096-1105.

Yuan, T., R.J. Lien and G.R. McDaniel, 1994. Effects of increasing rearing period body weights and early photostimulation on broiler breeder egg production. Poult. Sci., 73: 792-800.

[1]To whom correspondence should be addressed (ccoon@uark.edu).

[2]IMV Technologies, Minneapolis, Minnesota

[3]Jamesway Incubator Company, Ltd., P.O. Box 3067, Cambridge, Ontario, Canada.

[4]Steris Corporation, Ohio

[5]Waring products division, Dynamics Corporation of America, New Hartford, Connecticut.

[6]The Virtis Company, Gardiner, New York. [7]SAS Inst., Inc., Cary, North Carolina