Journal of the Andaman Science Association Vol. 25(2):165-173 (2020)
ISSN 0970-4183, Printed in India

Significance of Pubertal Booster Feed of Pullets in Layer House

T. Sujatha* and P.A.Bala

Division of Animal Science, ICAR-Central Island Agricultural Research Institute, Port Blair, A&N Islands- 744105

**Corresponding author: drsujathaars@rediffmail.com*

Abstract

Present investigation was undertaken to study the efficacy of pre-lay feeding strategy during transition period on laying performance. At 15 weeks of age, pre-lay pullets were randomly assigned to one of seven pre-lay dietary treatments in a completely randomized design. Each diet was given to 12 replicates consisting of six birds per replicate. Dietary treatments comprised of BIS control (T1); Dietary treatment with crude protein of 16 per cent, metabolizable energy of 2500 kcal/kg and calcium of 1.5 per cent (T2); Dietary treatment with crude protein of 16 per cent, metabolizable energy of 2500 kcal/kg and calcium of 2 per cent(T3); Dietary treatment with crude protein of 16 per cent, metabolizable energy of 2700 kcal/kg and calcium of 1.5 per cent (T4); Dietary treatment with crude protein of 16 per cent, metabolizable energy of 2700 kcal/kg and calcium of 2 per cent (T5); Dietary treatment with crude protein of 18 per cent, metabolizable energy of 2700 kcal/kg and calcium of 1.5 per cent (T6); Dietary treatment with crude protein of 18 per cent, metabolizable energy of 2700 kcal/kg and calcium of 2 per cent (T7); The pre-lay pullets were randomly allotted to dietary treatments till 5 per cent egg production. Immediately after 5% of egg production the layers were shifted to BIS recommendation of layer feed up to 42 weeks of age. Pullets provided with higher calcium levels wither 1.5 or 2 per cent irrespective of protein and energy levels had significantly ($P<0.05$) higher hen day and hen housed egg production with heavier eggs (55.39 g), higher shell weight and thickness when compared to pullets fed 1 per cent calcium during the pre-lay period of 15 weeks to 5 per cent egg production. Egg feed price ratio for HHEP was best in 2700/18/2 group followed by 2700/18/1.5 group..

Keywords: prelay period, calcium increment, shell quality characteristics

Introduction

The Dynamics of the Global Poultry Industry over the past decades has been phenomenal. There has been a major regional shift from developed to developing countries and India is ranked third among the top ten egg producing countries. The productive capacity of commercial layers has increased considerably during the recent past in our country. This could be attributed to an improved age at first egg which two decades back was about 20/21 weeks and presently stands at 18 weeks of age. Uniform mature targeted pullet bodyweight at sexual maturity is much more important consideration than the specific calendar age for a profitable layer. Most of strains of layers have a unique multi-phasic growth pattern during pullet stage that comprised of three distinguishable growth spurts. When she begins to show first and visual signs of sexual maturity (e.g. comb development), the pullet has usually reached a mature pullet weight. As the pullet (pre-layer) matures, the rate of body weight gain declines, the growth slows and her nutrient requirement at this time are minimal. The third pronounced phase 'pubertal growth spurt' at 14 to 20 weeks in layer pullets predicts point of lay (Kwakkal *et al.* 1991). During this spurt, body weight increases considerably by about 200-300 g that involves development of the ovary and oviduct, an increase in liver size and other major physiological changes. Further, nutrient requirement of pre-layer which has plateaued as she approaches a mature pullet weight will now begin to increase and change as well. Energy and protein are now required in greater quantities for tissue synthesis to augment rapid physiological development.

The medullary bone formation takes place in the bone of pullets during transitional phase of 2-3 weeks before the onset of lay to lay down calcium reserves needed for production cycle. This establishment of calcium reservoir necessitates the increase in calcium requirement during transition period. Based on this metabolic changes taking place before on set of egg mass production, traditionally low density diets (Bureau of Indian Standards, 2007) during pre-lay stage may not support a high yielding layer to establish essential reservoirs. Hence, the present investigation was undertaken to study the efficacy of pre-lay feeding strategy during transition period on laying performance.

Materials and methods

General management

Day old, Bovans' white commercial strain of white leghorn pullets were raised in conventional floor pens up to 13 weeks. Pullets were vaccinated against Newcastle and infectious bursal disease at 7 and 14 days respectively. At 13 weeks of age, pullets were transferred from the floor pens to cages with four birds per cage (309.6 cm^2). The size of the welded mesh for the sides and the roof of the cage were made of 0.5 x 1.0 inch. At the age of five per cent egg production to 43 weeks of age, each pullet was provided with 412cm^2 of cage space. During the chick stage (0-2 weeks) 23 hours light with 20 lux intensity and one hour darkness was provided. After the brooding period, the birds were reared under natural day light that extended to 11 hours with 10 lux intensity. Thereafter at 18 weeks (5% egg production) of age the lighting period was increased ½ hour each week to 16 hours with 3 lux of intensity per sqft.

Design of Experiment

All birds were fed *ad libitum* feed as per Bureau of Indian Standards (BIS, 2007) recommendation from 0 to 14 weeks of age. The birds were provided with 20 per cent CP and 2800 kcal ME/kg chick ration for the first 8 weeks and fed a 16 per cent CP and 2500 kcal ME/kg grower ration from 9 to 14 weeks of age. At 15 weeks of age, pre-lay pullets were randomly assigned to one of seven pre-lay dietary treatments in a completely randomized design. Each diet was given to 12 replicates consisting of six birds per replicate. Dietary treatments comprised of T1 (BIS control); T2(Control + 1.5% Ca): Dietary treatment with crude protein of 16 per cent, metabolizable energy of 2500 kcal/kg and calcium of 1.5 per cent; T3 (Control + 2% Ca): Dietary treatment with crude protein of 16 per cent, metabolizable energy of 2500 kcal/kg and calcium of 2 per cent; T4 (High energy + 1.5% Ca): Dietary treatment with crude protein of 16 per cent, metabolizable energy of 2700 kcal/kg and calcium of 1.5 per cent; T5 (High energy + 2% Ca): Dietary treatment with crude protein of 16 per cent, metabolizable energy of 2700 kcal/kg and calcium of 2 per cent; T6 (High dense diet + 1.5% Ca): Dietary treatment with crude protein of 18 per cent, metabolizable energy of 2700 kcal/kg and calcium of 1.5 per cent; T7 (High dense diet + 2% Ca): Dietary treatment with crude protein of 18 per cent, metabolizable energy of 2700 kcal/kg and calcium of 2 per cent; The pre-lay pullets were randomly allotted to dietary treatments till 5 per cent egg production. Immediately after 5% of egg production the layers were shifted to BIS recommendation of layer feed up to 42 weeks of age. The ingredient and nutrient composition of the pre-lay dietary treatments and layer feed is presented in Table 1.

Egg production and egg quality characteristics

At five per cent egg production and thereafter individual daily record of egg production and egg weight were taken for the determination of weekly and total egg production. Based on the data, hen-day egg production was calculated and expressed in eggs per hen per day for each 28 day period. Egg mass was calculated based on hen day egg production and egg weight. The feed consumption was arrived at and feed efficiency for a dozen eggs and kilogram egg mass was calculated for each 28 day period. Egg characteristics such as haugh unit, shell thickness and per cent shell were determined at fortnightly.

Economics

Cost of production was calculated for pullets produced for various pre-lay feeding treatments taking into consideration the prevailing market rates of feed ingredient, chick cost and other miscellaneous cost. Egg-feed price ratio was calculated from the receipts from egg and expenditure on feed.

Statistical Analysis

Statistical analysis of data was carried as per Snedecor and Cochran (1994) by using the SPSS 10.0 program package (SPSS, 2001). The significance of the difference among the groups was determined by Duncan's multiple range tests (Petrie and Watson, 1991).

Results and discussion

Per cent Hen day and hen housed egg production

Pullets provided with higher calcium levels wither 1.5 or 2 per cent irrespective of protein and energy levels had significantly ($P<0.05$) higher hen day and hen housed egg production when compared to pullets fed 1 per cent calcium during the pre-lay period of 15 weeks to 5 per cent egg production (table 2 & 3). Pullets fed with the high dense feed with 2700 kcal energy and 18 per cent dietary pre-lay protein either 1.5 or 2 per cent calcium had significantly ($P<0.05$) the best hen housed and hen day egg production followed by the high energy group of 2700 kcal and 16 per cent protein with either 1.5 or 2 per cent calcium levels. As seen in the first experiment, higher pre-lay protein and energy level had improved hen day and hen housed egg production and this agreed with findings of Razvani *et al. (*2000) and Oke *et al.* (2003) had observed that higher pre-lay calcium improved hen day egg production.

Pre-lay pullets with a good body composition due to higher dietary energy and protein were also benefited with higher dietary calcium levels of 1.5 and 2 per cent which had provided them enough calcium reserves, on the other hand pullets fed pre-lay diet with 2500 kcal of energy and 16 per cent protein with just 1 per cent calcium had a significantly ($P<0.05$) lower hen day and hen housed egg production which was more pronounced during early period of lay. Between calcium levels of 1.5 and 2 per cent calcium, the hen housed and hen day egg production were comparable. It is important to get pullets off to a good start. It has been hypothesized that when pullets have been fed with high dense diet, these move easily from juvenile to adult stage and nutrients have been preferentially portioned to the reproductive organs and for their system to develop, major input of nutrients (protein, energy and calcium) will be required. Calcium plays an important role in pre-lay nutrition as both the rearing phase and lay cycle are two periods of extreme calcium mobilization with calcium being primarily deposited into the bone (positive calcium balance) during rearing, while during the lay cycle, calcium is essentially withdrawn (negative calcium balance) (Fosnaught, 2009). A certain threshold of body, skeletal, and reproductive tract maturation must occur in pullets during rearing before the onset of lay will commence. This is why, pullets on higher level of nutrition used in our study, would have been positioned with improved development of oviduct and thus ovulation. Most probably, the calcium, protein and energy interaction could have resulted in higher hen day and hen housed egg production with higher calcium level. Hence, if a feeding program is not designed to take high quality pullets in to laying phase, they may fail to develop properly which later impedes the maximum production capacity which could have been attained if good nutrition had been provided during pre-lay period. Still, calcium by itself may have had a minimal effect on egg production and more work needs to be done with regards to this.

Egg weight and Egg mass

Throughout the period of study from 20 weeks to 55 weeks, pullets provided with high dense feed with 2 per cent calcium level gave heavier eggs (55.39 g). On the other hand, pullets fed with BIS feed with low energy and protein levels of 16 per cent and 1 per cent calcium laid eggs which were small, weighing just 50.08 g (Table 4). The overall mean egg weight proved that the high dense diet gave the best egg weight compared to that of low dense diet having 2500 kcal of energy with 16 per cent protein. The same trend was observed with egg mass also. This agreed with findings of Oke *et al.* (2003) who observed that high dense diet having high rearing energy and protein had higher egg weight. Between calcium levels, pullets provided with 1.5 or 2 per cent calcium levels laid heavier eggs with higher egg mass when compared to pullets fed with 1 per cent calcium level. This agreed with findings of Koutoulis *et al.* (2009). It was also observed by Zhou *et al.* (2000) that improved body weight at sexual maturity increased egg weight by 1.3 g and also increased in egg mass, the same was observed in this experiment (Table 5). As pullets of the present study were reared in hot climate, higher levels of pre-lay calcium provided towards sexual maturity which in combination with high pre-lay energy and protein had lead to a bigger sized eggs and higher egg mass.

Feed consumption and Feed efficiency

Varying pre-lay diets did not significantly influence the feed consumption among calcium levels. This agreed with Razvani *et al.* (2000) observed no significant difference in feed intake with regards to pullets fed varying rearing protein and energy levels. Higher calcium levels had not influenced feed intake (Koutoulis *et al.*, 2009). Feed efficiency per dozen eggs and per kg egg mass was consistently the best in the high dense feed groups with 2 per cent calcium level although, it was comparable with the two other groups with 2700 kcal of energy and 18 per cent pre-lay protein with 1.5 per cent calcium and 16 per cent protein with 2 per cent calcium (Table 6). Again, pullets fed with BIS feed of 2500 kcal energy and 16 per cent protein with 1 per cent calcium had a poor feed efficiency for both per dozen and kg egg mass and this was comparable with that of the other low energy groups with 1.5 and 2 per cent calcium levels (Table 7). Anderson and Jenkins (2011) agreed with the above findings No literature could be traced with regards to pre-lay calcium on feed efficiency. Obviously the number of eggs laid and egg mass had plaid a more significant role in these results rather than feed intake.

Shell characters as influenced by pre-lay calcium

Shell weight and shell thickness

Shell weight of eggs laid under different pre-lay calcium with energy and protein regimens from age at sexual maturity up to 55 weeks of age was highest in the high nutrient dense group with 2 per cent calcium although it was comparable with 1.5 per cent calcium and 2700 kcal energy and 16 per cent protein with 2 per cent calcium group (Table 8). The lowest shell weight was found in the pullets fed with control (BIS) feed with 1 per cent calcium although it was comparable with the other two same energy and protein levels with 1.5 and 2 per cent calcium. The same trend was observed with regards to higher shell thickness but, only pullets fed with control (BIS) feed with 1 per cent calcium level had significantly lower shell thickness and this stood apart. Very minimal literature was available with regard to energy, protein and calcium of pre-lay pullets and its influence on shell weight and thickness. Bar *et al.* (1997) agreed with the present findings of increased pre-lay calcium significantly influencing higher shell weight and thickness, the same was observed by Koutoulis *et al.* (2009). Slow, constant and uniform release of extra calcium withdrawn from well developed medullary calcium reservoir might have benefited shell quality (Koutoulis *et al.*, 2009) of pullets fed with high nutrient dense feed supplemented with 2 per cent pre-lay calcium.

Shell breaking strength

Shell breaking strength was comparable between all the treatment groups other than the group fed with a pre-lay diet of control (BIS) feed with 1 per cent calcium. Even between calcium levels, a significant ($P<0.05$) difference was seen between 1 per cent calcium during pre-lay period to those fed 1.5 and 2 per cent calcium. Minimal literature could be traced with regards to shell breaking strength as influenced by pre-lay diets. Keshavarz (1987) recorded no significant difference in shell breaking strength among pullets fed a higher calcium level for varying durations when compared with that of control diet of 0.8 per cent calcium. Shell breaking strength could be well correlated to shell weight and shell thickness.

Egg Feed Price Ratio

Egg feed price ratio for HHEP was best in 2700/18/2 group followed by 2700/18/1.5 group. The same trend persisted in HDEP. Once again pre-lay low energy group birds had poor egg feed price ratio. This could be attributed to higher feed consumption and lower egg production. The production cost per pullet was best in both pre-lay high calcium levels.

Table 1: Per cent ingredient and nutrient composition of experimental rations

Ingredients	Inclusion Level (kg)							
	T1 (2500/16/1)	T2 (2500/16/1.5)	T3 (2500/16/2)	T4 (2700/16/1.5)	T5 (2700/16/2)	T6 (2700/18/1.5)	T7 (2700/18/2)	Layer feed (5% to 55 weeks)
Yellow Maize	30	24	25	40	40	37.36	37.6	49
Broken rice								4
Cumbu/Bajra	26	15	15	17	17	10.83	12	5
Ragi	0	20	19.27	10.34	11	16	17	-
Deoiled rice bran	14	11.97	8.6	10	9.25	7.5	4	4.5
Wheat bran	9	9	10	0	0	0	0	2
Sunflower oil cake								3.5
Soybean oil cake	9.5	11	11	11	11.5	19	18.3	19.5
Dry fish	4	6	7	5.5	7	6.5	7	5.2
Mineral mixture	2	2	2	2	2	2	2	2
Dicalcium phosphate	0.34	0.18	0.14	0.26	0.2	0.19	0.15	0.29
Shell grit	0	0.7	1.94	0.85	2	0.6	1.93	5.2
DL-Methionine	0.05	0.05	0.05	0.05	0.05	0.02	0.02	-
Salt	0.08	0.1	0	0	0	0	0	-
Total	100	100	100	100	100	100	100	
Moisture%	9.7	9.7	9.2	9.9	9.8	9.5	9.6	9.8
CP%	15.94	15.95	16.06	16.23	15.93	18.33	18.4	17.85
Metabolizable Energy (kcal / kg)	2500	2500	2500	2700	2700	2700	2700	2602
Calcium %	1.04	1.52	2.05	1.49	2.11	1.53	2. 06	3.12
Total Phosphorus %	0.57	0.58	0.59	0.57	0.58 0	0.59	0.57	0.58

Table 2: Effect of various pre-lay feeding strategies on per cent hen day egg production

Pre-lay treatments	T1* (2500/16/1)	T2* (2500/16/1.5)	T3* (2500/16/2)	T4* (2700/16/1.5)	T5* (2700/16/2)	T6* (2700/18/1.5)	T7* (2700/18/2)
Age in Weeks	----------Standard layer feed----------						
20-25^{NS}	$64.52^{B} \pm 2.80$	$65.39^{C} \pm 2.79$	$64.60^{C} \pm 2.18$	$67.14^{C} \pm 2.47$	$68.80^{C} \pm 3.06$	$70.79^{C} \pm 2.67$	$71.74^{C} \pm 2.20$
26-31*	$61.90^{Bc} \pm 3.27$	$75.56^{Bb} \pm 2.14$	$76.03^{Bb} \pm 1.65$	$77.77^{Bb} \pm 1.82$	$78.57^{Bb} \pm 1.66$	$86.34^{Aa} \pm 1.60$	$86.82^{Ba} \pm 1.06$
32-37*	$80.15^{Ac} \pm 1.46$	$82.86^{Ac} \pm 1.20$	$82.69^{Ac} \pm 0.96$	$87.53^{Ab} \pm 0.88$	$88.05^{Ab} \pm 1.15$	$91.11^{Aa} \pm 0.83$	$91.58^{Aa} \pm 0.65$
38-43*	$81.34^{Ad} \pm 1.00$	$81.43^{Ad} \pm 1.64$	$82.11^{Ad} \pm 1.28$	$86.26^{Ac} \pm 1.87$	$86.82^{Abc} \pm 1.69$	$90.87^{Aab} \pm 1.41$	$91.54^{Aa} \pm 1.09$
44-49*	$83.25^{Ab} \pm 1.69$	$83.97^{Ab} \pm 1.26$	$83.86^{Ab} \pm 1.07$	$87.21^{Aab} \pm 1.56$	$87.19^{Aab} \pm 1.57$	$90.07^{Aa} \pm 0.61$	$91.05^{Aa} \pm 0.72$
50-55*	$65.53^{Bc} \pm 0.77$	$68.56^{Cc} \pm 1.78$	$68.81^{Cc} \pm 1.44$	$76.56^{Bb} \pm 1.30$	$76.81^{Bb} \pm 1.26$	$80.75^{Bab} \pm 2.23$	$83.47^{Ba} \pm 1.25$
Over all mean	$72.78^{d} \pm 1.00$	$76.29^{c} \pm 0.88$	$76.35^{c} \pm 0.76$	$80.41^{b} \pm 0.84$	$81.04^{b} \pm 0.86$	$84.99^{a} \pm 0.83$	$86.03^{a} \pm 0.68$
	Calcium level %*						
Overall mean	1		1.5			2	
	$72.78^{b} \pm 1.00$		$80.57^{a} \pm 0.75$			$81.15^{a} \pm 0.68$	

*- Significant (P<0.05) , NS-Not Significant; Mean values bearing different lower case superscripts in a same row/ column differ significantly; The values are mean (±SE)

Table 3: Effect of various pre-lay feeding strategies on per cent hen housed egg production

Pre-lay treatments	T1* (2500/16/1)	T2* (2500/16/1.5)	T3* (2500/16/2)	T4* (2700/16/1.5)	T5* (2700/16/2)	T6* (2700/18/1.5)	T7* (2700/18/2)
Age in Weeks			---Standard layer feed---				
20-25^{NS}	64.52^{B} ± 2.80	65.39^{C} ± 2.79	64.60^{C} ± 2.18	67.14^{C} ± 2.47	68.80^{C} ± 3.06	70.79^{C} ± 2.67	71.74^{C} ± 2.20
26-31*	61.90^{Bc} ± 3.27	75.56^{Bb} ± 2.14	76.03^{Bb} ± 1.65	77.77^{Bb} ± 1.82	78.57^{Bb} ± 1.66	86.34^{Aa} ± 1.60	86.82^{Ba} ±1.06
32-37*	80.15^{Ac} ± 1.46	82.86^{Ac} ± 1.20	82.69^{Ac} ± 0.96	87.53^{Ab} ± 0.88	88.05^{Ab} ± 1.15	91.11^{Aa} ± 0.83	91.58^{Aa} ±0.65
38-43*	81.34^{Ad} ± 1.00	81.43^{Ad} ± 1.64	82.11^{Ad} ± 1.28	86.26^{Ac} ± 1.87	86.82^{Abc} ±1.69	90.87^{Aab} ± 1.41	91.54^{Aa} ±1.09
44-49*	83.25^{Ab} ± 1.69	83.97^{Ab} ± 1.26	83.86^{Ab} ± 1.07	87.21^{Aab} ± .56	87.19^{Aab} ±1.57	90.07^{Aa} ± 0.61	91.05^{Aa} ±0.72
50-55*	56.89^{Bf} ± 0.14	59.42^{Be} ± 0.12	61.69^{Bd} ± 0.08	66.17^{Bc} ± 0.34	69.54^{Bb} ± 0.13	69.91^{Bb} ± 0.26	75.77^{Ba} ±0.40
Overall mean	71.34^{d} ± 1.72	74.77^{c} ± 1.52	75.16^{c} ± 1.20	78.68^{b} ± 1.49	79.82^{b} ± 1.54	83.18^{a} ± 1.23	84.75^{a} ± 1.02
				Calcium level %*			
Overall mean	1		1.5		2		
	71.18^{b} ± 1.09			78.94^{a} ± 0.80		79.96^{a} ± 0.72	

*- Significant (P<0.05) , NS-Not Significant Mean values bearing different lower case superscripts in a same row/ column differ significantly; The values are mean (±SE)

Table 4: Egg weight (g) of layers as influenced by various prelay feeding strategies

Pre – lay treatments	T1* (2500/16/1)	T2* (2500/16/1.5)	T3* (2500/16/2)	T4* (2700/16/1.5)	T5* (2700/16/2)	T6* (2700/18/1.5)	T7* (2700/18/2)
Age in weeks			---Standard layer feed---				
20-25*	41.53^{Fd} ± 0.39	43.55^{Ec} ± 0.32	43.69^{Fc} ± 0.28	45.03^{Eb} ± 0.36	44.89^{Eb} ± 0.32	46.16^{Ea} ± 0.47	46.45^{Da} ± 0.57
26-31*	46.56^{Ee} ± 0.15	47.61^{Dd} ± 0.16	48.26^{Ed} ± 0.17	49.08^{Dc} ± 0.30	50.03^{Db} ± 0.28	50.34^{Db} ± 0.24	51.18^{Ca} ± 0.46
32-37*	50.67^{De} ± 0.13	53.38^{Cd} ± 0.15	53.53^{Dd} ± 0.20	55.06^{Cc} ± 0.18	55.47^{Cbc} ± 0.21	55.97^{Cb} ± 0.23	56.53^{Ba} ± 0.31
38-43*	52.49^{Cc} ± 0.28	55.93^{Bb} ± 0.29	55.64^{Cb} ± 0.28	56.10^{Bb} ± 0.39	57.08^{Ba} ± 0.36	57.05^{Ba} ± 0.35	57.52^{Ba} ± 0.24
44-49*	53.64^{Be} ± 0.43	57.60^{Ad} ± 0.31	58.44^{Abc} ± 0.19	58.08^{Ac} ± 0.18	59.16^{Ab} ± 0.19	59.01^{Ab} ± 0.13	60.08^{Aa} ± 0.25
50-55*	55.56^{Ag} ± 0.27	56.54^{Bf} ± 0.12	57.07^{Be} ± 0.18	58.11^{Ad} ± 0.15	58.70^{Ac} ± 0.17	59.25^{Ab} ± 0.13	60.58^{Aa} ± 0.21
Overall mean*	50.08^{f} ± 0.32	52.44^{e} ± 0.33	52.77^{de} ± 0.34	53.58^{cd} ± 0.32	54.22^{bc} ± 0.34	54.63^{ab} ± 0.32	55.39^{a} ± 0.35
				Calcium level %*			
Overall mean	1			1.5			2
	50.08^{b} ± 0.32			53.55^{a} ± 0.32			54.13^{a} ± 0.34

*- Significant (P<0.05) , NS-Not Significant ;Mean values bearing different lower case superscripts in a same row/ column differ significantly; The values are mean (±SE)

Table 5: Egg mass (g) per bird per day of layers as influenced by various prelay feeding strategies

Pre-lay treatments	T1* (2500/16/1)	T2* (2500/16/1.5)	T3* (2500/16/2)	T4* (2700/16/1.5)	T5* (2700/16/2)	T6* (2700/18/1.5)	T7* (2700/18/2)
	Age in weeks ----------	----------	----------	Standard layer feed	----------	----------	----------
20-25*	$27.11^{Dc}\pm1.28$	$28.74^{Ebc}\pm1.32$	$28.39^{Ebc}\pm1.05$	$30.38^{Dabc}\pm1.20$	$31.16^{Dab}\pm1.46$	$33.03^{Da}\pm1.41$	$33.69^{Da}\pm1.30$
26-31*	$28.86^{Dd}\pm1.54$	$35.96^{Dc}\pm1.01$	$36.75^{Dbc}\pm.86$	$38.32^{Cbc}\pm1.04$	$39.40^{Cb}\pm.95$	$43.59^{Ca}\pm.97$	$44.57^{Ca}\pm.87$
32-37*	$40.62^{Bd}\pm.76$	$44.22^{Bc}\pm.63$	$44.25^{Bc}\pm.52$	$48.19^{Ab}\pm.50$	$48.79^{Ab}\pm.58$	$51.03^{Aa}\pm.58$	$51.78^{Ba}\pm.50$
38-43*	$42.69^{ABd}\pm.57$	$45.53^{Bc}\pm.93$	$45.67^{Bc}\pm.72$	$48.40^{Ab}\pm1.12$	$49.41^{Ab}\pm.84$	$51.70^{Aa}\pm.63$	$52.63^{ABa}\pm.63$
44-49*	$44.80^{Ae}\pm1.10$	$48.36^{Ad}\pm.77$	$49.04^{Ad}\pm.69$	$50.69^{Acd}\pm.97$	$51.61^{Abc}\pm.97$	$53.15^{Aab}\pm.35$	$54.71^{Aa}\pm.51$
50-55*	$36.43^{Ce}\pm.51$	$38.79^{Cde}\pm1.03$	$39.29^{Cd}\pm.86$	$44.48^{Bc}\pm.75$	$45.07^{Bc}\pm.72$	$47.86^{Bb}\pm1.33$	$50.57^{Ba}\pm.78$
Overall mean	$36.75^{d}\pm.59$	$40.27^{c}\pm.57$	$40.57^{c}\pm.53$	$43.41^{b}\pm.59$	$44.24^{b}\pm.59$	$46.73^{a}\pm.58$	$47.99^{a}\pm.55$
				Calcium level %*			
Overall mean	1		1.5		2		
	$36.75^{b}\pm0.59$		$43.47^{a}\pm0.54$		$44.27^{a}\pm0.52$		

*- Significant ($P<0.05$), NS-Not Significant: Mean values bearing different lower case superscripts in a same row/ column differ significantly; The values are mean (±SE)

Table 6: Feed consumption (g) per bird per day in layers as influenced by various prelay feeding strategies

Pre-lay treatments	T1* (2500/16/1)	T2* (2500/16/1.5)	T3* (2500/16/2)	T4* (2700/16/1.5)	T5* (2700/16/2)	T6* (2700/18/1.5)	T7* (2700/18/2)
	Age in weeks ----------	----------	----------	**Standard layer feed**	----------	----------	----------
20-31NS	$94.38^{B}\pm5.28$	$97.98^{B}\pm4.89$	$92.13^{B}\pm4.67$	$93.14^{B}\pm4.40$	$92.40^{B}\pm4.56$	$92.76^{B}\pm4.48$	$92.57^{B}\pm4.56$
32-43NS	$130.3^{A}\pm2.31$	$125.5^{A}\pm3.41$	$123.7^{A}\pm2.87$	$122.7^{A}\pm2.78$	$124.3^{A}\pm2.83$	$124.2^{A}\pm3.08$	$122.1^{A}\pm2.67$
44-55*	$126.2^{Ab}\pm0.75$	$128.1^{Ab}\pm1.04$	$124.2^{Aab}\pm1.06$	$116.3^{Aa}\pm3.93$	$120.5^{Aab}\pm2.68$	$119.8^{Aab}\pm1.66$	$115.6^{Aa}\pm3.39$
OverallNS mean	116.9 ±11.3	117.2 ±8.98	113.3 ±11.3	110.7 ±8.97	112.4±10.0	112.2 ±9.81	110.1 ±8.95
				Calcium level %NS			
Over all mean	1			1.5		2	
	115.9±3.62			112.4±3.85		113.3±3.86	

*- Significant ($P<0.05$) , NS-Not Significant; Mean values bearing different lower case superscripts in a same row/ column differ significantly; The values are mean (±SE)

Table 7: Feed efficiency per dozen eggs and kilogram of egg mass in layers as influenced by various prelay feeding strategies

Pre-lay treatments	T1* (2500/16/1)	T2* (2500/16/1.5)	T3* (2500/16/2)	T4* (2700/16/1.5)	T5* (2700/16/2)	T6* (2700/18/1.5)	T7* (2700/18/2)
				Per dozen of table eggs			
Age in weeks			-------------Standard layer feed-------------				
20-31*	$1.87^{b}\pm0.24$	$1.69^{ab}\pm0.07$	$1.58^{ab}\pm0.07$	$1.58^{ab}\pm0.09$	$1.53^{ab}\pm0.10$	$1.43^{a}\pm0.08$	$1.41^{a}\pm0.07$
32-43*	$1.82^{b}\pm0.03$	$1.83^{b}\pm0.04$	$1.80^{b}\pm0.05$	$1.80^{b}\pm0.04$	$1.71^{ab}\pm0.06$	$1.64^{a}\pm0.05$	$1.60^{a}\pm0.03$
44-55*	$1.90^{bcd}\pm0.09$	$1.98^{cd}\pm0.09$	$2.04^{d}\pm0.11$	$1.86^{bcd}\pm0.06$	$1.76^{abc}\pm0.04$	$1.69^{ab}\pm0.05$	$1.59^{a}\pm0.04$
Overall mean*	$1.86^{d}\pm0.08$	$1.83^{cd}\pm0.05$	$1.81^{cd}\pm0.06$	$1.74^{bcd}\pm0.04$	$1.67^{abc}\pm0.04$	$1.59^{ab}\pm0.04$	$1.53^{a}\pm0.03$
				Calcium level %*			
Overall mean	1		1.5			2	
	$1.86^{b}\pm0.08$		$1.72^{a}\pm0.04$			$1.67^{a}\pm0.04$	
				Per kilogram egg mass			
20-31*	$3.55^{b}\pm1.15$	$3.09^{ab}\pm0.42$	$2.87^{ab}\pm0.42$	$2.80^{ab}\pm0.48$	$2.69^{a}\pm0.53$	$2.50^{a}\pm0.52$	$2.44^{a}\pm0.49$
32-43*	$2.94^{d}\pm0.14$	$2.79^{cd}\pm0.17$	$2.75^{cd}\pm0.18$	$2.70^{bc}\pm0.19$	$2.53^{ab}\pm0.19$	$2.42^{a}\pm0.17$	$2.33^{a}\pm0.11$
44-55*	$2.91^{c}\pm0.42$	$2.89^{c}\pm0.38$	$2.95^{c}\pm0.46$	$2.66^{bc}\pm0.23$	$2.50^{ab}\pm0.14$	$2.38^{ab}\pm0.19$	$2.19^{a}\pm0.14$
Overall mean*	$3.14^{e}\pm0.57$	$2.93^{de}\pm0.32$	$2.86^{cde}\pm0.35$	$2.72^{bcd}\pm0.30$	$2.57^{abc}\pm0.29$	$2.43^{ab}\pm0.29$	$2.32^{a}\pm0.25$
				Calcium level %*			
Overall mean	**1**		**1.5**			**2**	
	$3.14^{b}\pm0.17$		$2.69^{a}\pm0.07$			$2.58^{a}\pm0.06$	

*- Significant ($P<0.05$) ; Mean values sharing any one common superscript in a row or column do not differ significantly; The values are mean (±SE)

Table 8: Effect of various prelay feeding strategies on shell parameters

Pre-lay treatments	T1* (2500/16/1)	T2* (2500/16/1.5)	T3* (2500/16/2)	T4* (2700/16/1.5)	T5* (2700/16/2)	T6* (2700/18/1.5)	T7* (2700/18/2)
Age in weeks			-------------Standard layer feed-------------				
				Shell weight (per cent)			
5% egg production*	$8.77^{b}\pm0.23$	$9.40^{a}\pm0.24$	$9.48^{a}\pm0.23$	$9.94^{a}\pm0.06$	$10.04^{a}\pm0.06$	$10.08^{a}\pm0.23$	$10.54^{a}\pm0.22$
50% egg production*	$8.77^{b}\pm0.16$	$9.30^{ab}\pm0.61$	$9.39^{ab}\pm0.07$	$9.59^{ab}\pm0.14$	$9.85^{a}\pm0.25$	$9.93^{a}\pm0.21$	$10.16^{a}\pm0.26$
35 weeks^{NS}	9.70 ± 0.12	9.74 ± 0.14	9.74 ± 0.32	10.27 ± 0.12	10.27 ± 0.12	10.36 ± 0.25	10.37 ± 0.24
45 weeks*	$8.77^{b}\pm0.46$	$8.82^{ab}\pm0.42$	$9.26^{ab}\pm0.46$	$9.42^{ab}\pm0.47$	$9.60^{ab}\pm0.22$	$10.01^{a}\pm0.37$	$10.54^{a}\pm0.29$
55 weeks*	$8.82^{b}\pm0.29$	$8.89^{ab}\pm0.22$	$9.17^{ab}\pm0.53$	$9.43^{ab}\pm0.29$	$9.57^{ab}\pm0.44$	$9.94^{ab}\pm0.06$	$10.28^{a}\pm0.15$
Overall mean*	$\mathbf{9.07^{b}\pm0.12}$	$\mathbf{9.31^{b}\pm0.14}$	$\mathbf{9.48^{b}\pm0.13}$	$\mathbf{9.75^{ab}\pm0.10}$	$\mathbf{9.87^{ab}\pm0.10}$	$\mathbf{10.04^{ab}\pm0.09}$	$\mathbf{10.30^{a}\pm0.09}$
				Shell thickness (mm)			
5% egg production*	$0.35^{b}\pm0.01$	$0.37^{ab}\pm0.01$	$0.38^{a}\pm0.01$	$0.38^{a}\pm0.01$	$0.38^{a}\pm0.01$	$0.38^{a}\pm0.01$	$0.39^{a}\pm0.00$
50% egg production*	$0.33^{d}\pm0.01$	$0.34^{cd}\pm0.00$	$0.34^{cd}\pm0.00$	$0.35^{c}\pm0.01$	$0.36^{bc}\pm0.01$	$0.39^{ab}\pm0.01$	$0.39^{a}\pm0.00$
35 weeks^{NS}	$0.32^{d}\pm0.00$	$0.34^{cd}\pm0.01$	$0.34^{cd}\pm0.01$	$0.35^{c}\pm0.01$	$0.36^{bc}\pm0.00$	$0.37^{ab}\pm0.00$	$0.37^{a}\pm0.00$
45 weeks*	$0.33^{d}\pm0.00$	$0.34^{cd}\pm0.00$	$0.34^{bc}\pm0.00$	$0.36^{ab}\pm0.00$	$0.36^{ab}\pm0.00$	$0.36^{ab}\pm0.00$	$0.37^{a}\pm0.00$
55 weeks*	$0.32^{c}\pm0.00$	$0.35^{b}\pm0.00$	$0.35^{b}\pm0.00$	$0.36^{ab}\pm0.00$	$0.37^{a}\pm0.00$	$0.37^{a}\pm0.00$	$0.37^{a}\pm0.00$
Overall mean*	$\mathbf{0.33^{d}\pm0.00}$	$\mathbf{0.35^{c}\pm0.00}$	$\mathbf{0.35^{c}\pm0.00}$	$\mathbf{0.36^{b}\pm0.00}$	$\mathbf{0.37^{ab}\pm0.00}$	$\mathbf{0.37^{ab}\pm0.00}$	$\mathbf{0.38^{a}\pm0.00}$
				Shell breaking strength (N)			
5% egg production*	$23.36^{b}\pm1.69$	$25.84^{ab}\pm2.89$	$29.61^{ab}\pm0.86$	$24.10^{ab}\pm1.70$	$25.09^{ab}\pm2.49$	$28.79^{ab}\pm1.15$	$30.52^{a}\pm2.58$
50% egg production*	$20.49^{b}\pm1.61$	$28.01^{ab}\pm2.40$	$28.28^{ab}\pm3.28$	$26.68^{ab}\pm4.32$	$29.01^{ab}\pm1.99$	$29.97^{a}\pm1.33$	$30.14^{a}\pm3.11$
35 weeks^{NS}	29.87 ± 1.45	31.08 ± 3.21	33.92 ± 2.54	31.28 ± 1.37	32.77 ± 1.91	31.88 ± 0.42	32.54 ± 0.48
45 weeks*	$25.18^{b}\pm0.94$	$29.80^{ab}\pm0.99$	$30.49^{a}\pm1.26$	$28.98^{ab}\pm2.47$	$31.37^{a}\pm0.45$	$30.21^{a}\pm2.10$	$30.41^{a}\pm1.60$
55 weeks*	$23.05^{c}\pm0.91$	$27.51^{b}\pm1.44$	$29.67^{ab}\pm0.32$	$28.32^{ab}\pm0.95$	$28.26^{ab}\pm0.17$	$30.84^{a}\pm0.97$	$30.79^{a}\pm0.90$
Overall mean*	$\mathbf{25.36^{b}\pm0.83}$	$\mathbf{28.37^{ab}\pm0.99}$	$\mathbf{29.39^{ab}\pm0.99}$	$\mathbf{29.97^{ab}\pm0.93}$	$\mathbf{30.43^{ab}\pm0.53}$	$\mathbf{30.86^{a}\pm0.76}$	$\mathbf{30.99^{a}\pm0.80}$

Between calcium levels	Shell weight (%)*	Shell thickness (mm)*	Shell breaking strength (N)*
1	$9.07^{b}\pm0.12$	$0.33^{b}\pm0.00$	$25.36^{b}\pm0.83$
1.5	$9.71^{a}\pm0.08$	$0.36^{a}\pm0.00$	$29.73^{a}\pm0.61$
2	$9.89^{a}\pm0.06$	$0.37^{a}\pm0.00$	$30.27^{a}\pm0.50$

* Significant ($P<0.05$), NS-Not Significant Mean values sharing any one common superscript in a row or column do not differ significantly; The values are mean (±SE)

References

Anderson, K.E., & Jekins, P.K. (2011). Effect of rearing dietary regimen, feeder space and density on egg production quality and size distribution in two strains of brown egg layer. *International Journal of Poultry Science*. 10:169-175

Bar, A., E. Vax & Striem, S. (1997). Effects of age at onset of production, light regime and dietary calcium on performance, egg shell traits, duodenal calbindin and cholicalciferol metabolism. *British Poultry Science.* 39: 282-290.

Bureau of Indian Standards (BIS), 2007. Indian standard poultry feeds- Specification. 5th edn. New Delhi.

Fosnaught, Mary. H. (2009). Mediating Bone Mineral Status in Laying Hens by Feeding increased calcium during Rearing and the Lay Cycle. Dissertation submitted to the Graduate Faculty of North Carolina State University.

Keshavarz, K. (1987). Influence of feeding a high calcium diet for various durations in prelay period on growth and subsequent performance of White Leghorn Pullets. *Poultry Science*. 66: 1576-1582.

Koutoulis, K.C., Kyriazakis, I.., Perry G.C. & Lewis, P.D. (2009). Effect of different calcium sources and calcium intake on shell quality and bone characteristics of laying hens at sexual maturity and end of lay. *International Journal of Poultry Science*. 8: 342-348.

Kwakkel, R.P., De Koning, F.L.S. Verstegen M.W.A. & Hof, G. (1991). Effect of method and phase of nutrient restriction during rearing on productive performance of light hybrid pullets and hens. *British Poultry Science*.32:747-761

Oke , U.K., Herbert, U. & Akimutimi, A.H. (2003). Early lay characteristics and Haematology of Pearl Guinea Fowls a sInfluenced by Dietary Protein and Energy levels. International Journal of Poultry Science. 2:128-132.

Petrie, A. & Watson, P. (1991). Statistics for Veterinary and Animal Sciences. Blackwell Sci., Malden, MA.

Razvani, M.R., Golian, A. Sharoudi, F.E. & Maghaddam, H.N. (2000). Effects of pullet nutrition and dietary energy and fat of layer rations on the performance of Hy- line layers. *Journal of Science & Technology Of Agriculture & Natural Resources*. 4:81-91

Snedecor, G.W. & Cochran, W.G. (1994). Statistical Methods, 8th edn; Oxford and IBH Publishing Company, New Delhi, India.

Zhou, W., Horii, S. Kosmatsu, M. Osada, H.& Hosoya, M. (2000). Immature body weight of layers and their laying performance. *Japanese Poultry Science*. 37: 43-49

Received : 15th June 2020 Accepted : 25th August 2020