Advances in Bioresearch
Adv. Biores., Vol 8 (6) November 2017: 107-117

Print ISSN 0976-4585; Online ISSN 2277-1573
Journal's URL:http://www.soeagra.com/abr.html
CODEN: ABRDC3
DOI: 10.15515/abr.0976-4585.8.6.107117

Advances in Bioresearch

ORIGINAL ARTICLE

Effects of Cumulative Protein intake on Egg production, egg Quality traits, Fertility and Hatchability in Broiler Breeder Hens

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ABSTRACT

A study was conducted to evaluate the effects of crude protein (CP) intake on egg production and egg quality traits of broiler breeder hens. Three hundred sixty (360) day-old female chicks were randomly distributed into 3 groups. Each group was allotted to one of the three treatments i.e. starter diets containing 18, 19 or 20% CP up to 5th week of age. From each group, out of 120 birds, 96 grower pullets with higher body weight (BW) were selected for the second experiment. The birds of each group (96) were further divided into two groups i.e. high body weight (HB) group and low body weight (LB) group. The pullets of each BW group were randomly distributed in 6 replicate groups. Three of the replicate groups were allotted to grower diets with 10 or 14% CP from 6th to 20th week of age. From 21st to 23rd week, a pre-breeder diet and from 24th week onwards, a breeder diet was offered. The 5th week BW had positive and highly significant correlation ($P\leq0.01$) with overall period (24-50 week) hen-day egg production (%) and significant ($P\leq0.05$) correlation with hen-day egg production (%) for the post peak (41-50 week) period. The ratio of ME and CP intakes from 0-20 week period had negative and highly significant ($P\leq0.01$) correlation with hen-day egg production (%) for the pre-peak (24-30 week) and overall period (24-50 week). It was concluded that the broiler breeder pullets with cumulative CP intake of more than 1350g during growing period had better egg production and fertility than pullets with cumulative CP intake of 1075-1108g. Further, pullets having ME:CP intake ratio of 18-19 had better egg production.

Keywords; *Crude protein intake, Egg production, Egg quality traits, Broiler breeder hens*

Received 14.06.2017 Revised 25.06.2017 Accepted 21.08.2017

How to cite this article:
S K Naik, N C Behura, L Samal, P K Mishra, R Swain and G Naik. Effects of Cumulative Protein intake on Egg production, egg Quality traits, Fertility and Hatchability in Broiler Breeder Hens. Adv. Biores., Vol 8 [6] November 2017.107-117.

INTRODUCTION

The modern commercial broiler is the product of intensive genetic selection for rapid and efficient growth. An unintended consequence of this selective breeding has been the loss of the ability for self-regulation of feed intake to closely match the requirements for maintenance, growth, production and reproduction. Thus, the broiler tends to over consume feed, resulting in a range of metabolic and health problems related to the development of obesity. To manage this situation, broiler breeder birds must be subjected to severe feed restriction, beginning early in life, to ensure that appropriate body weight (BW) and composition are achieved at critical phases of the production cycle. The female broiler breeder requires the most intensive management with respect to feed allocation throughout production to attain BW targets that ensure good liveability and efficient egg and chick production.

The most economical variable of interest in a broiler breeding enterprise is number of hatching eggs produced. The potential of a hen to perform satisfactorily can largely be guaranteed by providing appropriate nutrients during the rearing and laying periods. It has been demonstrated that the levels of dietary metabolizable energy (ME), crude protein (CP), amino acids, calcium and available phosphorus

play important roles in both maintenance and egg production of broiler breeder hens. Feed restriction is a standard method followed worldwide to achieve target BW at sexual maturity, high flock uniformity and higher egg production. During restricted feeding, energy models are employed to predict the ME and feed intake taking the targeted BW gain in to consideration. Broiler breeders are fed on a controlled diet from 3 to 5 weeks onwards to attain a target BW at 20 weeks of age to maximize egg production.
Feed cost represents 65-75% of the total cost of intensive poultry production, depending mainly on the relative costs of feed constituents, labour, housing and miscellaneous items in particular situations [1]. The optimal use of protein is essential in any feeding system, because protein supplements are usually much more expensive than energy feeds and wasteful usage increases the cost of production. Excess protein if fed may increase elimination of nitrogenous compounds in faeces and urine, which has environmental implications. In the present era, when potential pollutants are receiving considerable attention, reducing nitrogen in waste material has to be an important consideration. Comparing the nitrogen excretion of the bird fed the 20% protein with the 14% diet, approximately 40% less nitrogen was excreted with lower protein diet [2]. Therefore, economically as well as nutritionally it is imperative that balanced diets should be provided during the brooding, rearing and laying stages [1]. Although the National Research Council (NRC) recommended a feeding standard for chicken, this has not been totally practical in the tropics, for obvious reasons of environmental differences and type and quality of available feed ingredients. Furlan et al [3] reported that, in tropical areas, the feeding of high-protein diets to broilers was not recommended, because among dietary nutrients, protein has the highest heat increment. Consequently, for many years low-protein diets were recommended, to decrease the amount of heat produced and its harmful effects on bird's performance. On the other hand, when low feed intake of heat-stressed birds is associated with low-protein content of diets, there is a reduction in amino-acid intake. With this backdrop, the present study was undertaken to evaluate the effects of different levels of cumulative CP intake during rearing period on egg production, egg quality traits, fertility and hatchability of coloured synthetic male line (CSML) broiler breeder hens.

MATERIAL AND METHODS

Experimental birds, feeding and management

Three hundred sixty (360) day-old female broiler breeder CSML chicks were randomly distributed into 9 replicate groups having 40 chicks each and housed in floor pens. Three of the replicate groups were randomly allotted to each of the three dietary treatment groups having 120 birds per treatment group. Each treatment group was assigned to starter diets containing 18, 19 or 20 % CP. All the experimental starter diets were iso-caloric containing 2850 kcal ME/kg diet. The starter diets were fed *ad libitum* up to 5th week of age. On completion of 5th week, BW of chicks was recorded. From each treatment group, out of 120 birds, 96 grower pullets with higher BW were selected for the second experiment. The birds of each treatment group (96) were divided further into two groups i.e. high body weight (HB) group and low body weight (LB) group on the basis of 5th week BW with 48 birds per group. The pullets of each BW group were randomly distributed into 6 replicate groups with similar mean BW. Three of the replicate groups were randomly allotted to iso-caloric (2750 kcal ME/kg) grower diets with 10 or 14% CP from 6th to 20th week of age. The details of the dietary treatments during the rearing period are presented in Table 1. There are 12 dietary treatments (18-HB-14 i.e. 18% starter diet-high BW-14% grower diet, 18-HB-10, 18-LB-14, 18-LB-10, 19-HB-14, 19-HB-10, 19-LB-14, 19-LB-10, 20-HB-14, 20-HB-10, 20-LB-14, 20-LB-10). Restricted feeding was practiced from 6th to 20th week of age. From 21st week of age, a pre-breeder diet with 16% CP and 2850 kcal ME/kg diet was fed @ 120g/pullet/day up to 23rd week. From 24th week of age, a breeder diet with 16% CP and 2750 kcal ME/kg diet were fed. The experimental diets were analyzed for proximate composition as per AOAC [4]. Calcium and available phosphorus were determined according to the methods of Talapatra et al [5]. The gross and proximate compositions of the experimental diets have been presented in Table 2. All the birds had access to clean and fresh drinking water round the clock. The chicks were exposed to 23 h of lighting and a dark period of 1 h per day from 0-5 weeks. From 6th week onwards, the birds were maintained under natural day light till 20th week of age. Then lighting hours was gradually increased to 17 h at 24th week. Routine vaccination and medication program was carried out regularly for the experimental stock. Starting from 8th week, deworming of the stock was carried out at every two months interval. The birds were beak trimmed during 10th week of age. After 20 week onwards, birds were shifted to cage house. Eggs were collected thrice daily, during morning, noon and evening hours.

Protocol design

For all the treatment groups, the target 20th week BW was 2200 g. The weekly target body weights were set by plotting a linear graph targeting a BW of 2200 g at 20th week. By subtracting the target BW at 20th week from the recorded 5th week BW and dividing it by the number of weeks, the weekly gain required was calculated. Weekly ME requirement/bird/day was calculated by energy model of Sakomura et al [6]. Similarly during breeder period, ME requirement was calculated based on the BW, BW gain and egg production data using the energy model of Sakomura [7]. The ME models used in the experiment have been presented in Table 3.

Daily maximum and minimum temperature forecast data were collected. The daily effective temperature was calculated by using the following formula [2] and this effective temperature was used in energy model.

$$\text{Effective temperature} = [(\text{daytime high temperature} \times 2) + (\text{night low temperature})] / 3$$

The mean weekly minimum and maximum temperature of poultry sheds have been presented in Table 4. Data related to egg production, egg quality traits, fertility and hatchability were collected following standard procedures as described below.

Egg production: It was recorded daily from 1st day of lay till end of experimental period and calculated on hen day basis.

$$\text{Hen day egg production } \% = \frac{\text{Total No. of egg produced}}{\text{No. of hen days}} \times 100$$

Egg quality traits: Three eggs were collected randomly at 25th, 30th, 35th, 40th, 45th and 50th weeks of age from each replicate group to study the external egg quality traits such as egg weight and shape index. Eggs were collected randomly at 35th and 50th of age from each replicate group to study the internal egg quality traits such as yolk index, albumen index, Haugh unit and shell thickness.

Egg weight: Each egg was weighed by electronic top pan balance with 0.1 g accuracy.

Shape index: The length and breadth of eggs were measured in millimetre with a digital calliper and the shape index was calculated.

$$\text{Shape index} = \frac{\text{Width of the egg}}{\text{Length of the egg}} \times 100$$

Albumen height: It was measured by a spherometer at 3 different sites and their mean was taken.

Albumen width: It was measured by a digital calliper at 2 different sites and their mean was taken.

Albumen index: It was calculated by using the following formula.

$$\text{Albumen index} = \frac{\text{Mean height of albumen}}{\text{Mean width of albumen}} \times 100$$

Yolk index: After the egg was broken on a leveled glass plate, the yolk was separated from the albumen and the height of the yolk was measured with the help of a spherometer at 3 different sites and the mean was taken. Similarly, the width of the yolk was taken at 3 different sites with the help of a digital caliper. Then the mean width of the yolk was calculated. The yolk index was estimated by using the following formula.

$$\text{Yolk index} = \frac{\text{Mean height of yolk}}{\text{Mean width of yolk}} \times 100$$

Shell thickness: Three pieces of dried eggshell from different locations (air cell, equator, and sharp end) were taken and measured by an Ames thickness measure accurately.

Haugh unit: Each egg was weighed and then broken on a leveled glass slab with care so as that the yolk and the thick albumen remained intact. The height of the thick albumen was measured by a spherometer. The Haugh unit was calculated according to the following formula.

$$\text{Haugh unit} = 100 \log (H + 7.57 - 1.7\, W^{0.37})$$

H= Average height of albumen in mm

W= Average weight of the egg in g

Fertility and hatchability: Fertility and hatchability of both the treatment groups were studied during 35th, 40th and 50th week of age. The fertility percentage was calculated on the basis of total egg set by the following formula.

$$\text{Fertility \%} = \frac{\text{Number of fertile eggs}}{\text{Total number of eggs set}} \times 100$$

Hatchability was calculated on the basis of total number of eggs set (TES) as well as on fertile eggs set (FES). Percent hatchability is the percentage of eggs, which actually hatched out as live young.

$$\text{Hatchability \% (on TES)} = \frac{\text{Number of chicks hatched out}}{\text{Total number of eggs set}} \times 100$$

$$\text{Hatchability \% (on FES)} = \frac{\text{Number of chicks hatched out}}{\text{Total number of fertile eggs set}} \times 100$$

Statistical analysis

A completely randomized design was used to evaluate the dietary treatments. All data were analyzed using the General Linear Model (GLM) procedure of SPSS 16.0. Significant differences among treatment means were determined by Duncan's multiple range tests. All statements of significance are based on the 5% level of probability, unless and otherwise specified. Pearson procedure was used to correlate cumulative feed intake, cumulative CP intake, cumulative ME intake, ratio of cumulative ME:CP intake and body weight on hen day egg production (%) during different periods.

RESULTS AND DISCUSSION

Egg production

The hen-day egg production (%) of different treatment groups during pre-peak (24-30 week), peak (31-40 week), post-peak (41-50 week) and overall period (24-50 week) have been presented in Table 5. The overall hen-day egg production (%) of treatment groups ranged between 40.89% (20-LB-10) and 55.18% (19-HB-14) group. The hen-day egg production (%) of 18-LB-10, 19-LB-10 and 20-LB-10 groups were 42.34%, 45.24% and 40.89% respectively, which were significantly ($P \leq 0.05$) lower than all other treatment groups without having any significant ($P \leq 0.05$) difference between them. The hen-day egg production (%) of the other 9 treatment groups did not differ significantly ($P \leq 0.05$). The overall hen-day egg production (%) of the treatment groups were significantly ($P \leq 0.001$) affected by 5th week BW and grower crude protein (GCP) level.

Pre-peak egg production: During the pre-peak (24-30 week) laying phase, more than 30% hen-day egg production (%) was recorded in 18-HB-14, 18-LB-14, 20-HB-14 and 20-LB-14 groups. In all other treatment groups, the hen-day egg production (%) ranged between 17.29% (18-LB-10) to 24.38% (18-LB-14). The hen-day egg production (%) during pre-peak phase was significantly ($P \leq 0.05$) influenced by GCP and SCP*GCP interaction.

Peak egg production: During the peak (31-40 week) laying phase, highest hen-day egg production i.e. 70.10% was recorded in 18-LB-14 group and lowest hen-day egg production (%) was recorded in 19-LB-10 group. The hen-day egg production (%) of 18-LB-10, 19-LB-10 and 20-LB-10 groups were 57.40%, 54.18% and 55.62% respectively without having any significant difference ($P \leq 0.05$) between them but were significantly ($P \leq 0.05$) lower than18-LB-14 and 20-HB-10 groups. The peak laying phase hen-day egg production (%) was influenced by BW and GCP.

Post-peak egg production: During the post-peak (41-50 week) laying phase, highest hen-day egg production i.e. 70.38% was recorded in 19-HB-14 group which was similar to 18-HB-14, 18-HB-10, 18-LB-14, 20-HB-14 and 20-HB-10 groups. The hen-day egg production (%) of other six groups was lower than the above stated groups without having any significant difference ($P \leq 0.05$) between them. The hen-day egg production (%) during this phase was significantly ($P \leq 0.05$) influenced by BW. GCP level do not exhibit any significant influence on hen-day egg production (%) during this phase.

Correlation of nutrient intake and BW on egg production

The correlation of cumulative CP intake, ME intake, ratio of ME and CP intake and BW with hen-day egg production (%) has been presented in Table 6.

Effect of cumulative CP intake on egg production: The correlation between cumulative CP Intake from 0-5 week and hen-day egg production (%) during different periods were not significant (r =-0.117 to 0.241) (Table 6). The correlation between cumulative CP Intake from 6-20 week and 0-20 week periods were significant (P≤0.05) for pre-peak, peak and post-peak hen-day egg production (%). However, the correlation between overall period (24-50week) hen-day egg production (%) and cumulative CP Intake from 6-20 week (r = 0.478) and 0-20 week (r = 0.489) periods were highly significant (P≤0.01). In the present experiment, all treatment groups fed 14% GCP (6-20 weeks) had higher egg production than 10% GCP groups. The effect of dietary CP level on egg production has been well documented. Keshavarz [8], Hocking et al [9] and Emous et al [10] using different CP levels during starter and grower phase reported no significant effect of dietary CP level on egg production. However, Lilburn et al [11] and Babiker et al [12] reported that feeding high level of CP during rearing period resulted in higher egg production. Such contradictory reports could be due to the level of CP used at different stages of growth, strain of birds and environmental factors.

As the egg production could not be directly correlated to CP levels at different stages of rearing, it was thought to analyse the data in the perspective of cumulative CP and ME intake and their ratio. It was evident that treatment groups with cumulative CP intake (0-20 week) of greater than 1350g had higher egg production than other treatment groups where the cumulative CP intake was less. Moreover, the correlation between cumulative CP intake for 0-20 week and 6-20 week with egg production was positive and highly significant (P≤0.01). However, the cumulative protein intake for 0-5 week did not have any significant correlation with egg production and this could be due to the fact that very close CP levels were used during the starter period. The minimum cumulative protein intake for optimum egg production, as recorded at 20^{th} week by different workers are: Walsh and Brake [13, 14], 1180g; Peak and Brake 15], 1200g. In the present experiment, 3 levels of SCP (18, 19 and 20%) and two levels of GCP i.e. 10% and 14% were tried. The cumulative CP intake in 14% GCP groups ranged between 1351g to1384g which is more than the reported values and in 10% GCP groups ranged between 1083g to 1108g which was less than the reported values. Therefore, the high egg production in the high cumulative CP intake groups as recorded in the present experiment agree with the findings of the previous workers.

Effect of cumulative ME intake on egg production: The correlation between cumulative ME Intake from 0-5 week and hen-day egg production (%) during different periods was found to be very low and not significant. The correlation between cumulative ME Intake from 6-20 week was negative and highly significant (P≤0.01) for all the period except for post-peak when it was significant at (P≤0.05) level. However, the correlation between cumulative ME Intake from 0-20 week was negative and significant (P≤0.05) for the pre-peak period. For all other period the correlation coefficient value was low and non-significant. The ME intake during the growing period had a significant negative correlation with egg production. The ME intake in the treatment groups ranged between 24730 kcal to 26080 kcal. A minimum cumulative ME intake of 22000 kcal has been recorded by Peak and Brake [15] for optimum egg production. Walsh and Brake [13, 14] also reported that ME intake of 21610 kcal to 24789 kcal during rearing period was sufficient to ensure optimum egg production. However, in the present experiment a significant negative correlation of ME intake with egg production indicates that increase in cumulative ME decreases egg production. The cumulative ME in the present experiment was more than the normal recommendation of 21000 kcal to 22000 kcal. As more cumulative ME intake than the recommended values were obtained in this experiment, it could have adversely affected the egg production thereby altering the ME:CP ratio.

Effects of ratio of cumulative ME to CP intake on egg production: The ratio of Cumulative ME and CP from 6-20 week and 0-20 week periods had negative and highly significant correlation (P≤0.01) with hen-day egg production (%) for the period pre-peak and overall period as well as negative and significant (P≤0.05) correlation with hen-day egg production (%) for the period peak and post-peak. The correlation between ratios of cumulative ME and CP from 0-5 week had low and non-significant correlation with hen-day egg production (%). The ratio of ME to CP intake was also significant (P≤0.01) and negatively correlated with egg production. Treatment groups with ratio of ME to CP intake around 18 had higher egg production than those having ratio of ME to CP intake around 23. This also indicates the adverse effect of higher ME intake on egg production. This could also have been due to the fact that in all treatment groups whose ratio of ME to CP intake were high had lower than recommended cumulative CP intake. The ME intake remaining almost similar in all the treatment groups, the negative effect of high ratio of ME to CP intake may be attributed to low cumulative CP intake in the groups.

Effect of body weight on egg production: The 5^{th} week BW had positive and highly significant correlation (P≤0.01) with overall period hen-day egg production (%) and significant (P≤0.05) correlation with hen-day egg production (%) for the post-peak (41-50 week) period. Correlation between 20th week BW and hen-day egg production (%) were low and non-significant. From the findings of the experiment, it was observed that 5th week BW had highly significant effect on egg production. De Beer and Coon [16] reported that early significance of growth and frame size by providing additional protein gave moderate improvement in performance. Hens fed starter for 5 and 6 weeks produced marginally more eggs by 65 week 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 6 week 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 carcass parameters were similar to those of the control pullets by 21 week of age. Hudson et al [17] 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. The findings of the present experiment are in agreement with the findings of the previous workers. The 20th week body weight did not have any effect on egg production as the 20th week body weights of all treatment groups were similar without any significant difference between them.

Fertility and hatchability

The fertility and hatchability of treatment groups during different period has been presented in Table 7. The 30th week fertility was influenced ($P \leq 0.05$) by BW where as hatchability was significantly affected ($P \leq 0.05$) by SCP, BW and GCP. But considering 40th week, 50th week and overall period, only fertility had shown to be effected by dietary treatment. The fertility, hatchability and chick production data revealed that there was no significant difference ($P \geq 0.05$) between the treatment groups as overall chick production is concerned. However, there was significant difference between the treatment groups for fertility. 5th week BW×GCP interaction had significant effect on the fertility. Robinson et al [18] reported that difference in BW at 20th week of age lead to difference in fertility and hatchability. In the present experiment, the 20-HB-14 group which exhibited highest fertility (94.77%) had also the highest 20th week BW among treatment groups, although a linear effect of BW on fertility could not be established.

A minimum cumulative CP intake of 1180g has been recommended by Walsh and Brake [14] for optimum fertility. Walsh and Brake [13] reported that hens with cumulative CP intake of 1336g from 0-20 weeks had higher fertility vs. 1212g cumulative CP group. Similarly, minimum cumulative ME intake of 22000 kcal for optimum fertility has been recorded by Peak and Brake [15] and Zaghari et al [19]. In all the treatment groups the cumulative ME intake was more than 23000 kcal. However, in some treatment groups the cumulative CP intake was less than 1180g. Considering the findings of the present experiment it may be said that the difference in fertility as obtained in the present experiment was influenced by 5th week BW and cumulative CP intake as evidenced from previous findings.

Egg quality traits

External egg quality traits

At 25th, 30th, 35th, 40th, 45th and 50th week egg weight and egg shape index of different treatment groups are presented in Table 8. The egg weight of treatment groups differed during all the periods for which data were recorded. In general 19-HB-14 and 20-HB-14 groups exhibited highest egg weights during different periods. However, these values did not differ significantly from many other treatment groups for particular periods. The egg weight values during different periods were influenced by SCP, GCP, BW and their interactions. Keshavarz et al [8], Babikar et al [20] and Emous et al [10] reported that egg weight during laying period was not influenced by CP levels fed during growing period. Contrary to this, Hocking et al [9] and Hudson et al [17] reported that egg weight was increased by increasing the grower CP. Keshavarz [8] and De Beer and Coon [16] reported that egg weight was positively correlated with BW. In the present investigation, although there was significant difference in egg weight between different treatment groups during different periods, neither any definite pattern was observed in egg weight of different treatment groups nor it could be correlated with CP intake. This might be due to the fact that throughout the whole laying period, there was no significant difference in BW between the treatment groups. Further, the feed and CP intake during pre-breeder period and laying period were similar in all the treatment groups though CP intake up to 20 weeks differed among treatment groups. This could be the reason for obtaining inconsistent result for egg weight during different periods.

The egg shape index (ESI) values of treatment groups did not differ significantly ($P \leq 0.05$) between treatment groups at 30th, 35th, 40th and 50th week. However, significant difference in ESI was recorded during 25th and 45th week. At 25th week, the 18-HB-10 group had significantly ($P \leq 0.05$) lower ESI value than all other treatment groups which has similar values. Similarly, at 45th week 20-Hb-10 group had the highest ($P \leq 0.05$) ESI value than all other treatment groups without any significant difference among them. The ESI was not influenced by BW and CP intake. Keshavarz [8], Babikar et al [20] and Lacin et al [21] reported that BW and CP level during growing period has no significant effect on ESI of different treatment groups. The finding of the present experiment as regards ESI, are in agreement with the previous findings.

Table 1; Dietary groups during the experimental period (0-20 wks)

Dietary Groups	Starter CP (SCP %) 0-5 wks*		5th wk BW	Grower CP (GCP %) 6-20 wks**	
	CP (%)	ME (kcal/kg)		CP (%)	ME (kcal/kg)
18-HB-14	18	2850	HB	14	2750
18-HB-10				10	
18-LB-14			LB	14	
18-LB-10				10	
19-HB-14	19	2850	HB	14	2750
19-HB-10				10	
19-LB-14			LB	14	
19-LB-10				10	
20-HB-14	20	2850	HB	14	2750
20-HB-10				10	
20-LB-14			LB	14	
20-LB-10				10	

**Ad libitum* feeding ** *Restricted feeding*

Table 2; Gross and proximate composition of experimental diets

Ingredient	Starter			Grower		Pre- breeder	Breeder
	18% CP	19% CP	20% CP	10% CP	14% CP	16% CP	16% CP
Maize	62.5	61	60	63	58.5	64.5	60
Soya bean meal	24.5	27	30	5.25	17.5	19.5	19.5
DORB	10	9	7	28.75	21	10	12
Broken rice	--	--	--	--	--	3	3
Mineral mixture[1]	3	3	3	3	3	2.5	5
Common salt	0.3	0.3	0.3	0.3	0.3	0.3	0.3
L-Lysine (98.5%)	0.1	0.1	0.1	0.25	0.1	0.03	0.03
DL-Methionine (99%)	0.13	0.11	0.1	0.1	0.1	0.05	0.05
Trace mineral[2]	0.1	0.1	0.1	0.1	0.1	0.12	0.12
Choline chloride	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Toxin binder	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Anti Coccidial[3]	0.5	0.5	0.5	--	--	0.5	0.5
Vitamin premix[4]	0.3	0.3	0.3	0.3	0.3	0.3	0.3
V-fur	2	2	2	2	2	2	2
Calculated values							
ME-(Kcal/Kg)	2856.3	2848.12	2850.56	2750	2753.58	2846.36	2754.06
CP	18	19	20	10	14	16.0239	16.16375
Lysine (%)	0.96	1.02	1.08	0.68	0.81	0.835	0.842
Methionine (%)	0.43	0.42	0.42	0.34	0.38	0.348	0.345
Meth. + Cystine (%)	0.73	0.73	0.74	0.57	0.66	0.65	0.66
Energy: Protein	157.9	150.5	142.7	273.9	195	178	170
Cost/kg feed (Rs)	28.2	28.7	29.6	22.7	25.8	28.6	27.2
Analyzed values (% DM)							
Moisture	9.2	9.22	9.23	9.14	9.27	9.24	9.17
CP	18.08	18.93	19.98	10.04	14.12	16.01	15.98
Ether extract	4.06	4.16	4.14	5.12	4.55	4.16	4.2
Crude fibre	4.23	4.26	4.22	5.03	4.91	4.92	4.82
Total ash	9.45	8.74	9.43	9.98	10.17	10.54	10.61
Acid insoluble ash	2.62	2.58	2.6	2.72	2.63	2.66	2.54
Nitrogen free extract	64.18	63.91	62.23	69.83	66.25	64.37	64.39
Calcium	0.92%	0.93%	0.90%	0.92%	0.93%	1.17	2.97
Av. phosphorus	0.48%	0.45%	0.45%	0.48%	0.45%	0.57	0.42

[1]*Supplied: Ca 32%, P 6%, Mn 0.27%, Zn 0.26%, I 0.01%, Cu 0.01%, Fe 0.01%, F 0.03%*

[2]*Supplied per kg: Cu 15 g, I 1 g, Fe 60 g, Mn 80 g, Se 0.3 g, Zn 80 g*

[3]*Supplied per 500g: Dinitolmide 125g*

[4]*Supplied per g: Vit A 82500 IU, Vit B_2 50 mg, Vit D_3 16500 IU, Vit K_3 10 mg, Folic acid 10 mg, Vit E 200 mg, Se 400 µg, Vit B_1 4 mg, Vit B_6 8 mg, Vit B_{12} 40 µg, Ca pantothenate 40 mg, Niacin 60 mg.*

Table 3; Energy requirement models employed

Week	Formula	ME Model
3 to 8	$D=W^{0.75}(174-1.88\times T)+2.83WG$	
9 to 14	$D=W^{0.75}(174-1.88\times T)+2.5WG$	Sakomura et al. (2003)
15 to20	$D=W^{0.75}(174-1.88\times T)+3.24WG$	
Laying hen (24-50)	$D=W^{0.75}(165.74-2.37\times T)+6.68WG+2.4EM$	Sakomura (2004)

Feed/bird/day(g) = (D/2750) × 1000

Where,

W = Metabolic BW in (kg) of the bird

T = Ambient Temp (^{0}C)

WG = Daily wt gain required (g)

EM = Daily egg mass (g)

D = Metabolizable energy requirement/bird/day

Table 4; Mean weekly predicted ambient temperature during 6-20 weeks

Weeks	Predicted temperature (^{0}C)		
	Minimum	Maximum	Effective
6	19	36	30.3
7	18	36	30.0
8	17	38	31.0
9	19	39	32.3
10	21	40	33.7
11	24	41	35.3
12	25	41	35.7
13	26	42	36.7
14	23	40	34.3
15	21	38	32.3
16	26	40	35.3
17	27	40	35.7
18	24	40	34.7
19	28	41	36.6
20	27	42	37.0

Table 5; Mean hen-day egg production (%) of treatment groups during different period

Treatment		24-30wk	31-40wk	41-50wk	24-50wk
		Pre-peak	Peak	Post-peak	Overall
1	18-HB-14	31.88^{a}±.2.12	62.84^{ab}±2.96	62.41^{ab}±3.90	53.43^{ab}±2.49
2	18-HB-10	20.52^{c}±2.22	62.82^{ab}±3.20	60.64^{ab}±4.38	48.41^{abcd}±2.69
3	18-LB-14	30.16^{ab}±2.42	70.10^{a}±.3.51	58.47^{abc}±4.54	53.05^{ab} ±2.85
4	18-LB-10	17.29^{c}±2.22	57.40^{b}±.3.39	56.05^{bc}±4.54	42.34^{cd} ±2.61
5	19-HB-14	21.97^{c}±2.35	64.54^{ab}±3.29	70.38^{a}±.4.38	55.18^{a} ±.2.85
6	19-HB-10	23.28^{bc}±2.07	61.54^{ab}±2.96	56.43^{bc}±3.80	48.83^{abcd}±2.49
7	19-LB-14	24.38^{bc}±2.22	59.70^{ab}±3.12	55.99^{bc}±3.90	49.21^{abcd}±2.61
8	19-LB-10	23.32^{bc}±2.59	54.18^{b}±.3.63	51.63^{bc}±4.54	45.24^{bcd} ±3.05
9	20-HB-14	33.78^{a}±.2.17	62.35^{ab}±3.04	57.10^{abc}±4.00	51.75^{ab} ±2.55
10	20-HB-10	24.04^{bc}±2.29	68.26^{a}±.3.29	60.38^{ab}±4.38	53.45^{ab} ±2.76
11	20-LB-14	30.10^{ab}±2.42	62.59^{ab}±3.39	53.82^{bc}±4.38	50.07^{abc} ±2.85
12	20-LB-10	19.32^{c}±2.50	55.62^{b}±.3.51	46.33^{c}±4.54	40.89^{d} ±2.94
Source of variation		*Probability*			
SCP		0.099	0.348	0.217	0.958
BW		0.175	0.047	0.003	0.002
GCP		0.000	0.051	0.074	0.000
SCP*BW		0.244	0.214	0.645	0.597
SCP*GCP		0.000	0.449	0.397	0.552
BW*GCP		0.538	0.014	0.902	0.136
SCP*BW*GCP		0.979	0.441	0.240	0.235

$^{a\text{-}d}$*Means within a column without superscript differ significantly (P≤0.05).*

Table 6; Estimates of correlation for BW, CP, ME intake and ratio of ME & CP with different phases of egg production

Parameters	24-30wk	31-40wk	41-50wk	24-50wk
	Pre-Peak	Peak	Post-Peak	overall
Cumulative CP intake				
0-5wk	-0.117	0.091	0.241	0.109
6-20wk	0.423*	0.346*	0.333*	0.478**
0-20wk	0.396*	0.356*	0.370*	0.489**
Cumulative ME intake				
0-5wk	-0.130	0.054	0.221	0.095
6-20wk	-0.437**	-0.453**	-0.345*	-0.539**
0-20wk	-0.332*	-0.179	0.019	-0.187
Ratio of cumulative ME & CP				
0-5wk	-0.101	-0.058	0.075	0.017
6-20wk	-0.426**	-0.354*	-0.335*	-0.483**
0-20wk	-0.429**	-0.363*	-0.346*	-0.488**
Body weight				
5th wk	0.060	0.215	0.354*	0.430**
20th wk	0.322	0.188	-0.110	0.163

*Correlation is significant (P≤0.05), **Correlation is significant (P≤0.01)

Table 7; Fertility and hatchability of treatment groups during different period

	Treatment	30wk				40wk				50wk				Overall			
		Fertil-ity on Egg Set	Hatchability		Chicks on to-tal Egg Set	Fer-tility on Egg Set	Hatchability		Chi cks on to-tal Egg Set	Fer-tility on Egg Set	Hatchability		Chic ks on total Egg Set	Fer-tility on Egg Set	Hatchability		Chic ks on to-tal Egg Set
			Total Egg Set	Fertile Egg			Total Egg Set	Fertile Egg			Total Egg Set	Fertile Egg			Total Egg Set	Fertile Egg	
1	18-HB-14	91.56^{ab}	84.83^{a}.	92.83^{a}	84.00^{a}	91.7^{ab}	72.4	78.9	72.4	95.21	80.2	84.32	80.22	93.01^{ab}	81.41	87.55	80.5
2	18-HB-10	86.24^{abcd}	73.05^{cde}	84.76^{bcd}	71.53^{bcd}	91.6^{ab}	67.8	73.8	67.8	94.96	83.7	88.15	83.68	91.32^{ab}	77.25	84.56	76.6
3	18-LB-14	85.37^{bcd}	77.58^{bc}	90.92^{ab}	75.80^{b}	93.9^{ab}	78.4	83.5	78.4	95.50	87.9	92.14	86.11	90.81^{ab}	79.61	87.66	78.7
4	18-LB-10	78.65^{d}	66.7^{f}	84.81^{bcd}	64.66^{ef}	97.1^{a}.	84.4	86.8	83.1	95.30	81.0	85.20	78.87	91.4^{ab}	78.33	85.7	77.0
5	19-HB-14	87.59^{abc}	68.55^{ef}	78.19^{de}	66.91^{def}	91.6^{ab}	75.6	82.6	75.6	95.88	80.5	83.81	79.47	91.34^{ab}	77.66	85.04	76.7
6	19-HB-10	90.69^{ab}	75.88^{cd}	83.68^{cd}	74.87^{b}	85.9^{b}	70.2	81.2	70.2	97.37	81.6	83.75	80.53	91.4^{ab}	77.75	85.09	77.3
7	19-LB-14	80.37^{cd}	68.14^{ef}	84.81^{bcd}	67.15^{cdef}	91.9^{ab}	77.3	84.2	77.3	95.68	78.9	82.30	78.89	89.47^{b}	77.78	86.93	77.0
8	19-LB-10	86.48^{abcd}	66.35^{f}	76.69^{e}	63.05^{f}	93.4^{ab}	77.1	82.1	75.7	95.17	85.3	89.87	84.29	92.4^{ab}	78.70	85.06	77.0
9	20-HB-14	93.53^{a}.	82.78^{ab}	88.52^{abc}	82.78^{a}.	95.4^{a}.	79.0	82.7	78.4	95.09	79.0	82.95	77.34	94.77^{a}	80.11	84.46	79.5
10	20-HB-10	80.77^{cd}	70.86^{def}	87.73^{abc}	70.24^{bcde}	85.2^{b}	70.2	82.3	68.7	97.13	79.8	82.32	79.81	90.01^{b}	77.18	85.74	76.5
11	20-LB-14	80.28^{cd}	72.85^{cde}	91.24^{ab}	72.85^{bc}	94.1^{ab}	80.5	85.5	80.5	97.41	78.5	80.63	78.54	90.38^{b}	79.47	87.95	79.2
12	20-LB-10	89.91^{ab}	76.8^{c}	85.52^{bc}	74.62^{b}	92.2^{ab}	75.1	81.5	74.4	96.2	84.5	87.92	81.09	93.01^{ab}	80.5	86.54	78.9
SEM		0.024	0.018	0.021	0.018	0.028	0.05	0.045	0.05	0.021	0.05	0.046	0.039	0.012	0.023	0.019	0.02
Source of variation		*Probability*															
SCP		0.874	0.000	0.000	0.000	0.337	0.949	0.756	0.968	0.705	0.699	0.470	0.558	0.602	0.665	0.818	0.541
BW		0.002	0.000	0.817	0.000	0.035	0.044	0.167	0.046	0.959	0.478	0.429	0.624	0.317	0.703	0.282	0.933
GCP		0.478	0.001	0.004	0.000	0.182	0.308	0.533	0.204	0.851	0.492	0.492	0.575	0.956	0.429	0.316	0.250
SCP*BW		0.344	0.187	0.922	0.198	0.956	0.488	0.382	0.535	0.792	0.973	0.991	0.982	0.938	0.869	0.842	0.831
SCP*GCP		0.015	0.000	0.161	0.000	0.169	0.567	0.977	0.542	0.965	0.639	0.665	0.612	0.321	0.611	0.676	0.559
BW*GCP		0.008	0.234	0.032	0.579	0.063	0.291	0.800	0.343	0.475	0.993	0.766	0.648	0.007	0.339	0.600	0.560
SCP*BW*GCP		0.004	0.000	0.048	0.000	0.806	0.874	0.613	0.900	0.851	0.391	0.275	0.390	0.297	0.885	0.776	0.832

$^{a-c}$*Means within a column without superscript differ significantly (P≤0.05).*

Table 8; External egg quality of treatment groups during different period

	Treatment	Egg weight (g)						Egg shape index (%)					
		25th wk	30th wk	35th wk	40th wk	45th wk	50th wk	25th wk	30th wk	35th wk	40th wk	45th wk	50th wk
1	18-HB-14	47.29^{ab}	47.357^{ab}	49.38	57.88^{abc}	54.92^{bc}	59.78^{ab}	76.36^{a}	77.30	77.30^{ab}	74.40	77.50	75.30^{ab}
2	18-HB-10	43.13^{bc}	45.857^{ab}	49.17	55.30^{bc}	57.06^{abc}	58.12^{b}	71.33^{b}	74.60	77.00^{ab}	77.20	76.60	75.90^{a}
3	18-LB-14	46.36^{abc}	45.727^{ab}	49.14	56.96^{abc}	52.35^{c}	60.49^{ab}	76.46^{a}	73.40	75.50^{b}	75.00	74.70	73.60^{b}
4	18-LB-10	43.86^{abc}	43.714^{b}	51.29	54.71^{bc}	55.20^{abc}	59.16^{b}	76.27^{a}	76.80	76.10^{ab}	76.20	77.50	75.30^{ab}
5	19-HB-14	49.14^{a}	48.200^{ab}	50.80	56.98^{abc}	56.80^{abc}	58.80^{b}	75.52^{a}	74.40	79.00^{a}	77.30	75.10	73.80^{b}
6	19-HB-10	45.80^{abc}	45.500^{ab}	52.11	53.60^{c}	59.51^{ab}	55.53^{b}	76.36^{a}	76.40	76.10^{ab}	76.60	75.90	75.10^{ab}
7	19-LB-14	41.38^{c}	48.857^{ab}	50.50	58.27^{ab}	56.88^{abc}	60.80^{ab}	74.08^{ab}	73.70	76.40^{ab}	75.20	75.00	72.10^{b}
8	19-LB-10	48.19^{ab}	47.750^{ab}	48.71	57.58^{abc}	55.97^{abc}	59.97^{ab}	75.86^{a}	74.80	77.00^{ab}	75.90	76.60	74.90^{b}
9	20-HB-14	45.04^{abc}	47.545^{ab}	50.25	60.92^{a}	59.93^{a}	65.20^{a}	76.93^{a}	75.50	77.90^{ab}	76.90	87.60	73.10^{b}
10	20-HB-10	43.25^{bc}	47.500^{ab}	50.86	56.97^{abc}	58.20^{ab}	59.45^{ab}	76.60^{a}	77.00	77.80^{ab}	75.90	75.60	74.40^{b}
11	20-LB-14	44.57^{abc}	51.222^{a}	52.44	56.90^{ab}	55.40^{abc}	57.33^{b}	76.78^{a}	74.10	75.90^{ab}	76.80	76.20	74.10^{b}
12	20-LB-10	46.00^{abc}	45.727^{ab}	52.00	56.78^{abc}	57.08^{abc}	61.48^{ab}	77.69^{a}	74.20	77.00^{ab}	77.10	76.50	75.00^{ab}
SEM		1.73	1.8	1.72	1.29	1.46	1.77	1.09	1.19	1	1.05	2.03	1.1
Source of variation				*Probability*									
SCP		0.495	0.164	0.407	0.162	0.015	0.271	0.049	0.713	0.523	0.396	0.272	0.378
BW		0.591	0.869	0.800	0.918	0.009	0.709	0.302	0.048	0.049	0.548	0.260	0.492
GCP		0.561	0.043	0.788	0.005	0.187	0.170	0.605	0.189	0.799	0.400	0.263	0.030
SCP*BW		0.277	0.393	0.332	0.038	0.871	0.070	0.086	0.755	0.931	0.458	0.274	0.413
SCP*GCP		0.121	0.909	0.865	0.970	0.452	0.894	0.040	0.805	0.522	0.225	0.270	0.819
BW*GCP		0.015	0.489	0.765	0.130	0.920	0.047	0.073	0.344	0.112	0.756	0.257	0.601
SCP*BW*GCP		0.178	0.404	0.356	0.059	0.497	0.609	0.609	0.528	0.248	0.274	0.153	0.840

$^{a-c}$*Means within a column without superscript differ significantly (P≤0.05).*

Table 9; Internal egg quality of treatment groups during different period

	Treatment	35th wk				50th wk			
		Shell Thickness (mm)	Haugh Unit	Yolk Index	Albumen Index	Shell Thickness	Haugh Unit	Yolk Index	Albumen Index
1	18-HB-14	0.408	66.35	0.320^{d}	0.058	0.400^{ab}	72.84	0.440	0.067
2	18-HB-10	0.353	61.10	0.423^{abc}	0.042	0.413^{ab}	80.35	0.452	0.087
3	18-LB-14	0.308	73.56	0.442^{abc}	0.071	0.358^{b}	77.31	0.441	0.075
4	18-LB-10	0.419	68.00	0.459^{ab}	0.056	0.449^{a}	82.06	0.436	0.086
5	19-HB-14	0.430	53.77	0.380^{c}	0.036	0.371^{ab}	78.15	0.425	0.080
6	19-HB-10	0.324	59.44	0.403^{bc}	0.045	0.454^{a}	80.20	0.298	0.084
7	19-LB-14	0.341	64.54	0.400^{bc}	0.058	0.371^{ab}	77.44	0.450	0.080
8	19-LB-10	0.649	68.21	0.412^{bc}	0.053	0.404^{ab}	73.29	0.445	0.077
9	20-HB-14	0.411	68.12	0.442^{abc}	0.060	0.370^{ab}	73.66	0.446	0.07
10	20-HB-10	0.293	70.66	0.438^{abc}	0.061	0.432^{ab}	75.35	0.413	0.07
11	20-LB-14	0.449	59.50	0.444^{abc}	0.043	0.386^{ab}	74.31	0.467	0.074
12	20-LB-10	0.382	71.02	0.478^{a}	0.063	0.414^{ab}	75.74	0.452	0.075
SEM		1.15	6.81	0.02	0.012	0.026	5.219	0.044	0.011
Source of Variation			*Probability*						
SCP		0.362	0.395	0.003	0.503	0.959	0.642	0.36	0.601
BW		0.383	0.293	0.003	0.314	0.520	0.982	0.16	0.825
GCP		0.350	0.598	0.011	0.923	0.012	0.470	0.26	0.391
SCP*BW		0.438	0.328	0.054	0.316	0.775	0.645	0.33	0.866
SCP*GCP		0.452	0.404	0.208	0.286	0.745	0.622	0.54	0.545
BW*GCP		0.270	0.779	0.382	0.852	0.431	0.615	0.43	0.719
SCP*BW*GCP		0.349	0.829	0.105	0.623	0.046	0.922	0.51	0.943

$^{a-d}$*Means within a column without superscript differ significantly (P≤0.05).*

CONCLUSION

From the findings of the present study, it may be concluded that the cumulative CP intake and ratio of ME to CP intake (0-20 week) had significant effect on egg production of broiler breeders. Broiler breeder pullets with cumulative CP intake of more than 1350 g during growing period (0-20 week) had better egg production and fertility than pullets with cumulative CP intake of 1075-1108 g during the same period. During growing period (0-20 week), pullets having ratio of ME:CP consumption of 18-19 had better egg production. Higher value of more than 23 of ME:CP intake ratio reduced egg production.

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