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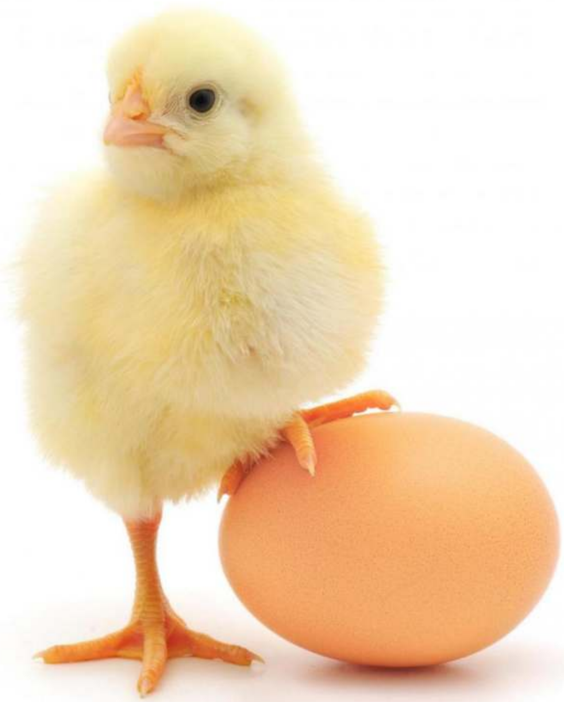

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Research Article
Effect of Low-Energy and Low-Protein Diets on Production Performance of Boiler Breeders and Hatching Parameter

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Abstract
Background and Objective: A major challenge in broiler breeder management is the nutritional requirement and the effect of feed formulation on breeder performance. Metabolizable energy and crude protein levels are two important nutritional parameters for evaluating poultry feed. The purpose of this study was to evaluate the effect of low-protein and low-energy diets on the performance of Sasso breeders. **Materials and Methods:** The experiment was performed with 120 Sasso breeders divided into 3 groups (control group, low-protein group and low-energy group) of 40 birds each. Feed intake, body weight, egg weight and egg component weights were recorded weekly. At 35 weeks of age, a total of 600 settable eggs were collected in 7 days and stored at 15°C before incubation. Prior to setting for incubation, eggs were numbered, weighed and assigned to 4 replications of 50 eggs each diet/treatment. **Results:** Results indicate that breeders of the control diet group exhibited increased body weight ($p<0.05$) with heavier eggs ($p<0.05$) and an increased ratio of albumen weight to egg weight ($p<0.01$) as compared with the groups with the low-energy diet and the low-protein diet ($p<0.05$). In addition, day-old chicks from eggs of the control group were heavier ($p<0.05$) than those from eggs of both the low-energy and low-protein diet groups. **Conclusion:** Low-protein and low-energy diets during the laying period negatively affect the feed intake and feed conversion ratio. These diets also affect the egg weight and ratios of albumen, yolk, shell and chick weight. No significant differences were observed regarding hatchability and blood serum concentration levels of total protein, triglycerides and glucose.

Key words: Protein, energy, Sasso breeder, hatchability

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The main purpose of broiler breeder rearing is to provide fertilized eggs for production of healthy and robust day-old chicks[1]. A major challenge in broiler breeder management involves reductions in laying rate, fertility and hatchability of eggs. This decrease in production parameters may be due to several factors, such as genotype, the health of the breeder flock, egg quality, egg storage, egg sanitation, climatic conditions and the age of breeders[2]. In addition to these factors, nutrition plays a major role in the fertility and hatchability of the eggs. Indeed, energy and protein are the most important macronutrients which affect the costs of feed in hen's diets and play significant roles in optimal laying performance as well as their subsequent offspring quality and performance[3,4-7]. The metabolizable energy and crude protein levels, which should be first considered when diets are formulated, are two major nutritional parameters for evaluating feed nutrition value. Previous studies demonstrated that dietary Metabolizable Energy (ME) and Crude Protein (CP) levels had significant influences on laying performance and product quality[8-10]. According to Li *et al.*[9], moderate ME and high CP resulted in optimum egg production, egg mass and Feed Conversion Ratio (FCR) of Lohmann Brown laying hens. Manipulations of maternal dietary energy and protein intake for better chick performance may provide nutritionists new insights into feed ration formulation decisions. In Sub-Saharan Africa, feed nutritive values garner little attention and researchers are not able to explore this important domain of research. Consequently, the feed provided to chickens does not meet their needs in terms of crude protein and energy levels[11]. Therefore, this study was performed to investigate the effects of interactions between maternal dietary metabolizable energy and crude protein levels on Sasso breeders and their hatching performance.

MATERIALS AND METHODS

Management of Sasso hens: One hundred and twenty Sasso hens and 12 male Brahmas chickens at 20 weeks of age were used for this experiment. These birds were produced at the Laboratory of Poultry Science (University of Lomé, Togo). They were housed per pen of 20 hens and 2 cocks each with a stocking density of 5 birds m^{-2}. Lighting and feeding throughout the rearing period were provided according to primary breeder recommendations. Indeed, according to change in body weight and development stage, Sasso hens were feed restricted following the recommended daily allowances and water was provided *ad libitum*.

Experimental design: The 120 Sasso hens and 12 Brahmas cocks were divided at random into 3 groups of 40 hens and 4 cocks each. These groups were (1) The control group (cont), (2) The group that received low-energy diets (Low-energy) and (3) The group that received low-protein diets (Low-protein). Diet compositions and calculated nutritive values are presented in Table 1. For each group, the chickens were divided into 2 replicates of 20 hens and 2 cocks each. Breeders' feed consumption, body weight, egg and egg component weights were recorded weekly. At 35 and 42 weeks of age, a total of 72 blood samples were collected in dry tubes without any anticoagulant. The samples were taken from the punctured brachial vein. A total of 5 mL of blood was obtained from each bird, of which 2 mL was centrifuged at 3000$\times$g for 15 min to separate the serum. These samples were used to determine glucose, protein and triglyceride concentrations. At 35 weeks of age, a total of 600 set table eggs were collected during 7 consecutive days and stored at 15°C and 70% relative humidity before setting for incubation. A sample of the eggs was used to determine egg component weights according to treatment. Prior to set incubation, the eggs were numbered, weighed and assigned into 4 replications of 50 eggs each according to feeding treatment. The eggs were incubated in a Petersime Vision® incubator (Olsene (Zulte), Belgium) at 37.6°C with a relative humidity of 50% and turning each hour at an angle of 90°. At day 18 of incubation, eggs were weighed and candled. Eggs with evidence of living embryos were transferred from turning trays to hatching baskets. During the last 2 days of incubation, hatching events were monitored and hatched chicks were recorded and weighed.

Egg component weights and egg weight loss during incubation: Prior to set for incubation, a sample of 30 eggs per treatment was opened to meticulously collect and weigh the shell, albumen and yolk. At day 18 of incubation, all incubated eggs were weighed. These weights and those recorded prior to incubation were used to calculate relative egg weight loss up to day 18 of incubation as follows[12]:

$$WL = \frac{W0 - W18}{W0} \times 100$$

Table 1: Diets composition and macronutrient levels according to treatment

Feed stuffs	Low energy diet (%)	Control diet (%)	Low protein diet (%)
Maize	45	55	59.8
Wheat bran	20	10	16.5
Fish meal 40%	15	11	6.2
Soya seed	10	15	11.5
Oyster shell	7	6	4
Concentrate 5%	3	3	2
EMA (kcal kg^{-1})	2582.07	2809.98	2810.15
PB (%)	18.68	18.56	16.09

where, WL is the relative egg weight loss, W0 is the egg weight recorded prior to incubation and W18 is the egg weight recorded at day 18 of incubation.

Glucose, triglyceride and total proteins level determination: For glucose, triglyceride and total protein level determination, blood samples were collected from Sasso hens at 35 and 42 weeks of age. Within each treatment, blood samples were collected from 12 Sasso hens at each age. The sampled birds were bled from the punctured brachial vein. In total, 5 mL of blood from each bird was obtained, from which 2 mL was collected and centrifuged at 3000×g for 15 min to separate serum. Triglyceride, glucose and total proteins were measured in serum samples using ELISA.

Glucose liquicolour, total protein and triglycerides were obtained by Sprinreact and SA-ctra Santa Coloma 7-E-17176 (Sant ESTEVE Hman Gmbh (65205 Wiesbaden-Germany).

In total, 1000 μL of glucose liquicolour, triglyceride® and total protein® of each reagent was added to a normal tube containing 10 μL of the serum sample. After 10 min of incubation at 25°C, the reading was performed at 500, 490 and 540 nm wavelengths to obtain glucose, triglyceride and total protein levels, respectively. These concentrations were expressed in mg dL^{-1}.

All samples were run in the same assay to avoid inter-assay variability.

Hatching time: Between 472 and 510 h of incubation, the transferred eggs were individually assessed every 2 h and the hatched chicks were recorded and weighed. At the hatching stages, the durations of incubation were defined as the time between setting and hatching for each egg. The spread of the hatch was defined as the dispersion around the average incubation duration.

Statistical analysis: Statistical software package Graph Pad PRISM 5 was used to analyse the data. GraphPad Prism is a commercial scientific 2D graphics and statistics software published by GraphPad Software, Inc., a privately held California (USA) corporation[13]. The generalized linear regression model was used to analyse the effects of diet on egg production, egg weights, egg components, feed intake, feed ratio conversion, duration of incubation and post hatch weights. A probability value of 0.05 was retained as the degree of significance. When the means of the general model were significantly different, then the means were further compared using Tukey's test. In a 2nd analysis, hatchability was considered as a binomial distribution. A two-tailed test for comparison of variances was used to analyse the influence of diets on hatchability.

RESULTS

Broiler breeders' body weights: Figure 1 presents weekly body weight according to treatment and age of broiler breeders. Overall, body weight increased as breeder age increased. From 29 to 30 weeks of age, body weights were similar for all groups. However, from 31 weeks onwards, body weights of breeders fed control diets increased more rapidly compared with those fed low-energy and low-protein diets ($p<0.05$). Between 35 and 37 weeks of age, breeders from the low-protein diet group exhibited increased body weight compared with those fed low-energy diets ($p<0.05$).

Feed intake, feed conversion ratio and blood parameters: Average daily feed consumption according to the treatment is presented in Fig. 2. Daily feed consumption in the control group was reduced ($p<0.05$) compared with low-energy and low-protein diet groups. However, daily feed consumption was similar between low-energy and low-protein diet groups.

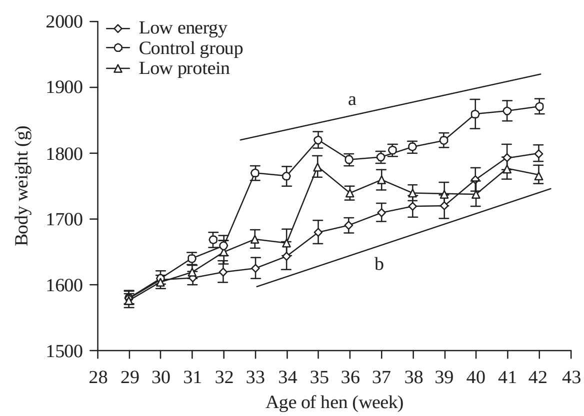

Fig. 1: Body weight according to age and treatments
Data sharing no common letter are different ($p<0.05$)

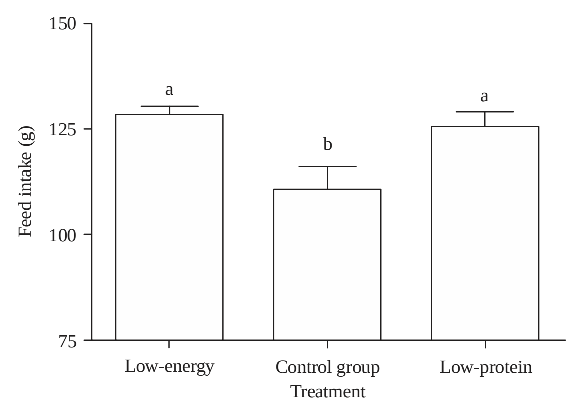

Fig. 2: Average daily feed consumption according to treatments
Data sharing no common letter are different ($p<0.05$)

Table 2: Serum concentrations of glucose, triglyceride and total protein according to age and feed treatment

Serum parameter	Age of Sasso hens	Low energy	Control group	Low protein
Glucose (mg dL^{-1})	35	2.11±0.07[a]	1.97±0.02[a]	2.11±0.11[a]
	42	2.10±0.01[a]	2.6±0.02[a]	1.89±0.04[a]
Total protein (mg dL^{-1})	35	51.80±0.90[a]	41.63±1.09[a]	49.16±1.06[a]
	42	44.56±0.39[a]	42.30±0.20[a]	57.95±1.07[a]
Trygliceride (mg dL^{-1})	35	7.28±2.36[a]	2.75±0.52[a]	5.73±0.19[a]
	42	5.48±0.07[a]	3.75±0.74[a]	5.70±2.13[a]

[a,b]Data sharing no common letter are different (p<0.05)

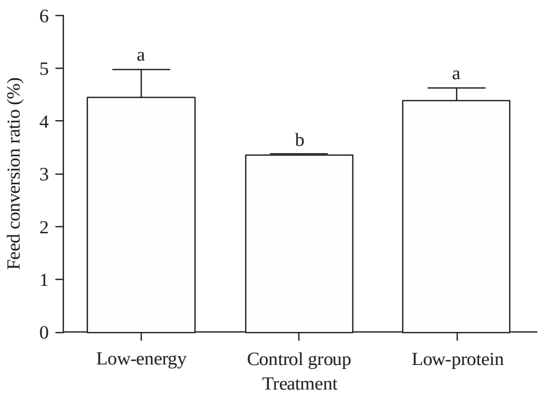

Fig. 3: Feed conversion ratio according to treatments
Data sharing no common letter are different (p<0.05)

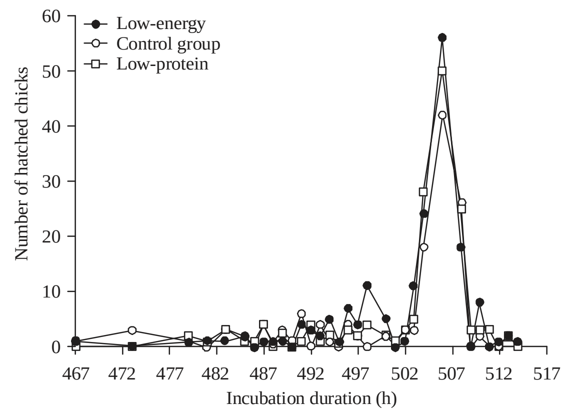

Fig. 4: Hatching curve in relation to the incubation duration according to treatments

Similarly, the lowest feed conversion ratio was observed in the control group (p<0.05), whereas the feed conversion ratio was similar for both low-energy and low-protein diet groups (Fig. 3). Blood serum concentrations of glucose, triglyceride and total protein are presented in Table 2. None of these blood parameters were affected by feed treatment, age of breeders and their interaction.

Egg weights and ratios of egg component weights to egg weights: Egg weights and ratios of egg component weights to egg weights according to diet treatments are presented in Table 3. The control group had heavier eggs and an increased ratio of albumen weight to egg weight (p<0.01) compared with the low-energy and low-protein diet groups, which were similar. Ratios of eggshell as well as yolk weights to egg weight were not affected by dietary treatments.

Diet effects on incubation parameters and day-old chick weight: Up to day 18 of incubation, relative weight loss of eggs from breeders fed a low-protein diet (8.14±0.03%) was reduced (p<0.05) compared with eggs from the control group (11.29±0.04%) and the low-energy (10.32±0.04%) group. However, we observed similarities between the 2 groups in subsequent analyses.

Figure 4 presents the spread of hatching according to treatment. The hatching curve demonstrates that the peak of hatching was similar for all groups. However, the start of hatching did not occur at the same incubation time and occurred at 497, 503 and 491 h for the low-energy diet group, low-protein diet group and control group, respectively. At 50% hatching, average incubation durations occurred in the following order: Low-energy diet (491.21±1.11 h) >low-protein diet (488.77±1.34 h) >control diet (485.89±1.34 h) (p<0.5).

Figure 5 presents day-old chick weights according to dietary treatments. Day-old chicks from eggs of the control group were heavier (p<0.05) compared with eggs of low-energy and low-protein diet groups, which were similar.

DISCUSSION

Low-energy and low-protein diets significantly reduced performance parameters, such as feed efficiency, growth rate, egg production, incubation parameters and hatchling quality. The reduced egg weight and laying rate in the low-energy and low-protein diet groups might be due to nutrient deficiency[14,15]. Bunchasak *et al.*[14] and Novak *et al.*[15] reported that birds that received low crude protein had low egg weights compared with birds that received optimum and high crude protein. In addition, Valkonen *et al.*[16] reported that hens consuming low energy produce approximately 2% fewer eggs per day compared with birds fed a high-energy diet. The

Table 3: Egg components weights to egg weight ratios and egg weights loss up to 18 days of incubation according to treatments

Treatments	Egg weight (g)	Egg weight loss (%)	Shell ratio (%)	Albumen ratio (%)	Yolk ratio (%)
Low-energy	44.89±0.13[b]	10.32±0.04[a]	13.28±0.55[a]	57.77±1.71[b]	28.95±0.97[a]
Control group	58.73±0.41[a]	11.29±0.04[a]	11.20±0.45[a]	62.72±1.59[a]	26.08±1.05[a]
Low-protein	43.40±0.20[b]	8.14±0.03[b]	12.91±0.69[a]	57.98±2.41[b]	29.11±1.70[a]

[a,b]Data sharing no common letter are different (p<0.05)

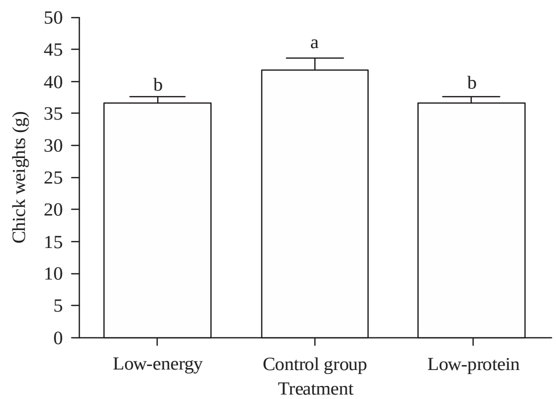

Fig. 5: Day-old chick weight according to treatments
Data sharing no common letter are different (p<0.05)

results of the present study are not consistent with those obtained by several authors who did not report any negative effect on egg production in young laying hens fed different energy levels[11,17-25]. Results of the present study demonstrated that hens fed a low-energy and low-protein diet had high yolk and low albumen proportions. This finding was consistent with Valkonen *et al.*[16]. The increase in yolk percentage was probably associated with the reduction in albumen percentage and egg size[26]. Indeed, egg yolk is produced in the liver and continuously accumulated in the ovum until ovulation. Egg yolk may not be affected by reducing dietary crude protein[27-29]. Feed consumption and feed conversion ratios were significantly increased with low-protein and low-energy diets compared with the control group. This finding might be due to chemical differences between the dietary treatments. Sasso hens fed a low-protein and low-energy diets grew more slowly as compared with the control group. Consistently, several reports noted that gains in body weight were reduced by lowering crude protein by 3-10%, indicating that the level of crude protein or amino acids was important in maintaining optimal weight gain[15,30,31].

Lower egg weight loss up to 18 days of incubation in the low-protein diet group may be associated with the lower weight of the eggs. However, given that the yolk and albumen proportions of the eggs from the low-protein diet group were similar to those of the low-energy group, more investigation is needed.

We found no effect of low-protein ratios on fertility and hatchability. This finding is consistent with previous studies of Hocking *et al.*[32], who did not identify an effect of different dietary protein levels (13 versus 15.5%) on fertility and hatchability during the rearing period. However, Walsh and Brake[33] demonstrated that a very low dietary crude protein level (11 or 14 versus 17%) during the rearing period decreased fertility and hatching during the entire laying period. No effects on incubation traits were observed in breeders from the low-energy group. This finding is consistent with Enting *et al.*[34] who fed Cobb breeders three dietary energy levels (2,200 vs. 2,500 vs. 2,800 kcal kg^{-1} AME) during the entire laying period.

Egg weight is one of the most influential factor on hatchability[35]. The results of the present study indicate that egg weights and day-old chick weights of the control group were increased (p<0.05) compared with the low-protein diet and low-energy diet groups. This finding is consistent with Lopez and Leeson[36,37], who noted the difference in the weight of broiler breeder chicks at hatching. Chicks from breeders fed lower crude protein diets exhibited significantly lower weights compared with those birds whose parents were fed with higher crude protein diets.

It is known that day-old chick weight is positively correlated with egg weight[38,39]. Low-energy and low-protein diets did not affect a hen's triglyceride blood concentration. This result is contrary to the report of Ding *et al.*[40], who noted that low-protein and low-energy diets reduced triglyceride concentrations, whereas high-energy and low-protein diets increased triglyceride concentrations. This increase in triglyceride concentration may be due to a loss of energy that was used for lipid synthesis. The results of the present study indicate that feed treatment had no effect on glucose concentration. The results of the present study are consistent with the reports of Teteh *et al.*[11] and Gonzalez-Barranco and Rios-Torres[41]. Regarding the results of the present study, it would be interesting to evaluate the effects of high-protein and high-energy diets on laying performance of Sasso breeders. Our present study can also be followed by other studies to evaluate the effects of low-protein and low metabolizable energy diets on laying and reproductive performances of breeders during the second laying phase.

CONCLUSION

It is concluded that low-protein and low-energy diets during the laying period negatively affect egg weight, feed intake, feed conversion ratio and day-old chick weight. However, no effects on hatchability rate and serum parameters were noted when birds were fed low-energy and low-protein diets.

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REFERENCES

1. Zuidhof, M.J., R.A. Renema and F.E. Robinson, 2007. Reproductive efficiency and metabolism of female broiler breeders as affected by genotype, feed allocation and age at photostimulation. 3. reproductive efficiency. Poult. Sci., 86: 2278-2286.
2. Yassin, H., A.G.J. Velthuis, M. Boerjan, J. van Riel and R.B.M. Huirne, 2008. Field study on broiler eggs hatchability. Poult. Sci., 87: 2408-2417.
3. Wu, G., P. Gunawardana, M.M. Bryant, R.A. Voitle and D.A. Roland Sr., 2007. Effects of dietary energy and protein on performance, egg composition, egg solids, egg quality and profits of hy-line W-36 hens during phase 3. Poult. Sci., 44: 52-57.
4. Lopez, G. and S. Leeson, 1995. Response of broiler breeders to low-protein diets.: 2. Offspring performance. Poult. Sci., 74: 696-701.
5. Wilson, H.R., 1997. Effects of maternal nutrition on hatchability. Poult. Sci., 76: 134-143.
6. Kidd, M.T., 2003. A treatise on chicken dam nutrition that impacts on progeny. J. Worlds Poult. Sci., 59: 475-494.
7. Calini, F. and F. Sirri, 2007. Breeder nutrition and offspring performance. Rev. Bras. Cienc. Avic., 9: 77-83.
8. Gunawardana, P., D.A. Roland and M.M. Bryant, 2008. Effect of energy and protein on performance, egg components, egg solids, egg quality and profits in molted hy-line W-36 hens. J. Applied Poult. Res., 17: 432-439.
9. Li, F., L.M. Zhang, X.H. Wu, C.Y. Li and X.J. Yang *et al*., 2013. Effects of metabolizable energy and balanced protein on egg production, quality and components of Lohmann Brown laying hens. J. Applied Poult. Res., 22: 36-46.
10. Nahashon, S.N., N.A. Adefope, A. Amenyenu and D. Wright, 2007. Effect of varying concentrations of dietary crude protein and metabolizable energy on laying performance of pearl grey guinea fowl hens. Poult. Sci., 86: 1793-1799.
11. Teteh, A., K. Aklikokou, M. Gbeassor, J. Buyse and E. Decuypere, 2010. Effects of low-protein or high energy levels diets on layer-type chick juvenile performance. Int. J. Poult. Sci., 9: 1156-1160.
12. Tona, K., F. Bamelis, W. Coucke, V. Bruggeman and E. Decuypere, 2001. Relationship between broiler breeder's age and egg weight loss and embryonic mortality during incubation in large-scale conditions. J. Applied Poult. Res., 10: 221-227.
13. Morgan, W.T., 1998. A review of eight statistics software packages for general use. Am. Stat., 52: 70-82.
14. Bunchasak, C., K. Poosuwan, R. Nukraew, K. Markvichitr and A. Choothesa, 2005. Effect of dietary protein on egg production and immunity responses of laying hens during peak production period. Int. J. Poult. Sci., 4: 701-708.
15. Novak, C., H.M. Yakout and J. Remus, 2008. Response to varying dietary energy and protein with or without enzyme supplementation on leghorn performance and economics. 2. Laying period. J. Applied Poult. Res. J., 17: 17-33.
16. Valkonen, E., E. Venalainen, L. Rossow and J. Valaja, 2008. Effects of dietary energy content on the performance of laying hens in furnished and conventional cages. Poult. Sci., 87: 844-852.
17. Wu, G., M.M. Bryant, R.A. Voitle and D.A. Roland, 2005. Effect of dietary energy on performance and egg composition of bovans white and dekalb white hens during phase 1. Poult. Sci., 84: 1610-1615.
18. D'Alfonso, T.H., H.B. Manbeck and W.B. Roush, 1996. Effect of day to day variation of dietary energy on residual feed intake of laying hens. Poult. Sci., 75: 362-369.
19. Keshavarz, K., 1998. The effect of light regimen, floor space and energy and protein levels during the growing period on body weight and early egg size. Poult. Sci., 77: 1266-1279.
20. Grobas, S., J. Mendez, C. de Blas and G.G. Mateos, 1999. Influence of dietary energy, supplemental fat and linoleic acid concentration on performance of laying hens at two ages. Br. Poult. Sci., 40: 681-687.
21. Grobas, S., J. Mendez, C. de Blas and G.G. Mateos, 1999. Laying hen productivity as affected by energy, supplemental fat and linoleic acid concentration of the diet. Poult. Sci., 78: 1542-1551.
22. Harms, R.H., G.B. Russell and D.R. Sloan, 2000. Performance of four strains of commercial layers with major changes in dietary energy. J. Applied Poult. Res., 9: 535-541.
23. Costa, F.G.P., H.C. de Souza, C.A.V. Gomes, L.R. Barros and P.A. Brandao *et al*., 2004. Levels of crude protein and metabolizable energy on the production and eggs quality of Lohmann brown layers strain. Ciencia Argot., 28: 1421-1427.

24. Jalal, M.A., S.E. Scheideler and D. Marx, 2006. Effect of bird cage space and dietary metabolizable energy level on production parameters in laying hens. Poult. Sci., 85: 306-311.
25. Jalal, M.A., S.E. Scheideler and E.M. Pierson, 2007. Strain response of laying hens to varying dietary energy levels with and without Avizyme supplementation. J. Applied Poult. Res., 16: 289-295.
26. Shim, M.Y., E. Song, L. Billard, S.E. Aggrey, G.M. Pesti and P. Sodsee, 2013. Effects of balanced dietary protein levels on egg production and egg quality parameters of individual commercial layers. Poult. Sci., 92: 2687-2696.
27. Hiramoto, K., T. Muramatsu and J. Okumura, 1990. Protein synthesis in tissues and in the whole body of laying hens during egg formation. Poult. Sci., 69: 264-269.
28. Pens, Jr. A.M. and L.S. Jensen, 1991. Influence of protein concentration, amino acid supplementation and daily time of access to high- or low-protein diets on egg weight and components in laying hens. Poult. Sci., 70: 2460-2466.
29. Novak, C., H.M. Yakout and S.E. Scheideler, 2006. The effect of dietary protein level and total sulfur amino acid:Lysine ratio on egg production parameters and egg yield in Hy-Line W-98 hens. Poult. Sci., 85: 2195-2206.
30. Pesti, G.M., 1991. Response surface approach to studying the protein and energy requirements of laying hens. Poult. Sci., 70: 103-114.
31. Babatunde, G.M. and B.L. Fetuga, 1976. Effects of protein levels in the diets of layers on the egg production rate and the chemical composition of poultry eggs in the tropics. J. Sci. Food Agric., 21: 454-462.
32. Hocking, P.M., R. Bernard and G.W. Robertson, 2002. Effects of low dietary protein and different allocations of food during rearing and restricted feeding after peak rate of lay on egg production, fertility and hatchability in female broiler breeders. Br. Poult. Sci., 43: 94-103.
33. 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.
34. Enting, H., T.A. Kruip, M.W. Verstegen and P.J. van der Aar, 2007. The effect of low-density diets on broiler breeder performance during the laying period and on embryonic development of their offspring. Poult. Sci., 86: 850-856.
35. Kingori, A.M., 2011. Review of the factors that influence egg fertility and hatchabilty in poultry. Int. J. Poult. Sci., 10: 483-492.
36. Lopez, G. and S. Leeson, 1994. Egg weight and offspring performance of older broiler breeders fed low-protein diets. J. Applied Poult. Res., 3: 164-170.
37. Lopez, G. and S. Leeson, 1995. Response of broiler breeders to low-protein diets. 1. Adult breeder performance. Poult. Sci., 74: 685-695.
38. Wondmeneh, E., I. Dawud and M. Adey, 2011. Comparative evaluation of fertility and hatchability of Horro, Fayoumi, Lohmann Silver and Potchefstroom Koekoek breeds of chicken. Asian J. Poul. Sci., 5: 124-129.
39. Wilson, H.R., 1991. Interrelationships of egg size, chick size, posthatching growth and hatchability. World Poult. Sci. J., 47: 5-20.
40. Ding, Y., X. Bu, N. Zhang, L. Li and X. Zou, 2016. Effects of metabolizable energy and crude protein levels on laying performance, egg quality and serum biochemical indices of Fengda-1 layers. Anim. Nutr., 2: 93-98.
41. Gonzalez-Barranco, J. and J.M. Rios-Torres, 2004. Early malnutrition and metabolic abnormalities later in life. Nutr. Rev., 62: S134-S139.