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Research Article

The Effect of Varying Dietary Crude Protein and Keeping Amino Acid Constant on Egg Quality Characteristics

Elohozino Oghale Benneth[1-3]*, Oluwaseun Peace Ajakaye[1], Abdulsabur Adebayo Aderemi[2], Emmanuel Onche[2], Isaac Babatunde Fasipe[2], Samuel Ijabo Ogah[4,5] and Gbemiga Oladimeji Adeyemo[1]

[1]*Department of Animal Science, Faculty of Agriculture-University of Ibadan, Nigeria*

[2]*Department of Animal Welfare Science, Food and Agricultural Technology Unit-The Pan African Research Group, Nigeria*

[3]*Animal Welfare Research Unit, One Health and Development Initiative, Nigeria*

[4]*Department of Aquaculture, Food and Agricultural Technology Unit - The Pan African Research Group, Nigeria*

[5]*Department of Fisheries and Aquaculture, Faculty of Agriculture, Federal University of Gashua, Nigeria*

***Corresponding Author:** Elohozino Oghale Benneth, Department of Animal Science, Faculty of Agriculture-University of Ibadan, Nigeria.

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Abstract

Studies have shown that animal proteins have a more balanced amino acid profile compared with plant proteins. Commercial layers over the years have played a key role in contributing generously to the percentage of animal proteins in form of eggs and meat. Also belonging to the monogastric group of animals, they have been found to possess an exceptional ability in efficiently converting nutrients to high quality animal protein. Since there is no single source of protein that will provide all the amino acids in the feed ration, a combination of proteins from different feedstuffs can be formulated to meet this requirement. Some researchers have reported that the reduced inclusion of Crude Protein (CP) in the diet will neither impair egg production in birds nor affect their welfare but it will reduce the egg production of that bird. Some studies show that the external characteristics of eggs are not influenced by nutrient density in the diets of laying birds except the inclusion level of amino acids, calcium, and phosphorus is altered in the diet. Other studies report that within the bounds of accepted commercial practice, the internal characteristics of eggs are largely unaffected by the nutrition of a bird. The aim of this study was to determine if egg quality characteristics as well as the welfare of laying hens will be affected by maintaining the amino acid amount required by the birds but varying the crude protein level in the diets of laying hens. It was also done to ascertain a permissible inclusion level of crude protein in the diet of commercial laying hens. 240 Black Hacko birds were used for 8 weeks feeding experiment at 25 weeks of age. Dietary treatments 1,2,3,4 and 5, with crude protein inclusion levels at 15.96%, 15.02%, 14.04%, 13.05% and 12.05% respectively, were allotted to the randomly divided birds of 8 per replicate and six replicates per treatment. The amino acid amount (methionine - 0.10% and Lysine - 0.15%) were kept constant across the treatments. For both the internal and external egg quality characteristics, there was no significant difference ($p > 0.05$) between the treatments. Conclusively, the welfare of commercial layers with regards to behaviour and production will not be negatively affected by varying the CP inclusion level between 15.96% - 12.05% provided the required amino acid is kept constant.

Keywords: Egg; Crude-Protein; Amino-Acids; Yolk; Albumen; Eggshell

Introduction

Food is very essential and necessary for the survival of the human race and it is a constituent of many nutrients either in their combined state or in their individual state [5]. Some of these nutrients include carbohydrates, protein, vitamins, minerals, fats and oil etc. and are essential for proper growth, body maintenance and reproduction. Presently, there is a higher demand for protein-based food than its supply. According to [4] the protein requirement for normal body functioning daily is estimated at 89.5g of which a recommendation of 34g of animal protein is required. Studies have shown that animal proteins have a more balanced amino acid profile compared with plant proteins and as such can be used to bridge the protein deficiency gap in many developing countries [6]. Animal protein should therefore be given more attention to improve the nutrient intake of individuals in developing countries of the world. Unfortunately, animal protein sources such as egg, meat and milk have been unable to adequately bridge the protein deficiency gap due to the increasing demand for them which is far higher than supply [14,10] reported that the monogastric animal holds the greatest promise to this improvement because of their exceptional ability in efficiently converting nutrients to high quality animal protein. Luckily poultry production represents one of the fastest means of increasing animal protein supply in developing countries.

According to [20] poultry production provides a comparatively ready and cheap source of animal protein especially through table eggs whereby its protein quality is 100% standard and its biological value in terms of nutrition reaches 93.7%. It has been identified as the reference protein because it is complete in all nutrients and has a balanced amino acid profile. Therefore, an in-depth knowledge of the nutritional requirements as well as the available feedstuff ingredients needed for poultry is very essential in improving the welfare of the birds and poultry products especially eggs. The main source of protein in poultry rations are either animal proteins or plant proteins [5]. Animal proteins include fish meal and bone meal while plant proteins include Soybean Meal (SBM), Groundnut Cake (GNC), Mustard Seed Meal (MSM), Cottonseed Meal (CSM), Sesame Meal, etc. According to [15] the vegetable protein source constitutes about 30% of the total compounded poultry diet. The amino acid composition of most of the vegetable protein sources is deficient in one or more essential amino acids like methionine, lysine etc. It is for this reason that making use of a single source of vegetable protein is not sufficient to make it the sole source of protein in the diet of laying hens. Protein deficiency in the diet of laying hens leads to poor development in young birds and affects the overall vitality of adult birds [19]. But when in excess, it undergoes deamination first then converts to uric acid and is dispersed as fecal nitrogen into the environment which requires more energy from the bird and is harmful to the environment.

At each phase of a bird's life, the body has a nutritional requirement that can satisfy the desired growth as well as its productivity which demands that a diet balanced of proteins is made available to satisfy such requirements [2]. Since there is no single source of protein that will provide all the amino acids in the feed ration, a combination of proteins from different feedstuffs can be formulated to meet this requirement [3]. Therefore, it is vital that birds are given adequate protein at their non-laying adult stage and laying stage in order to attain maximum growth and enhanced performance. [7] states the requirement of pullets to be 23% for chicks, 16% for growers, and 18% for adult/laying birds. This study was done to determine an acceptable inclusion level of crude protein in the diet of commercial layers that will not be deleterious to the welfare of the birds, nor affect egg production or quality when the required number of amino acids for the diet is unaltered. We hypothesized that there will be no difference in the egg quality characteristics from layers fed with varied crude protein levels and constant amino acid amounts in the diet.

Materials and Methods

Experimental design

All experimental measures and animal maintenance were carried out according to the standards of the Animal Welfare Group requirements of the Department of Animal Science, University of Ibadan. For the duration of the experiment, the research was conducted at the Zartech research pen of the poultry section of the Teaching and Research Farm, Faculty of Agriculture with Latitude: 7° 23' 28.19" N and Longitude: 3° 54' 59.99" E. The experiment lasted for eight weeks and was conducted using a completely randomized design of five dietary treatments and six replicates per treatment.

Birds and their management

Two hundred and forty commercial laying Black Hacko birds at 25 weeks of age were randomly divided into 5 dietary treatments of 8 birds per replicate and 6 replicates per treatment. Fresh feed and water was given to the birds on a daily basis in their feeders and drinkers in accordance with experimental diets per treatment. Prior to the experiment, birds were given ad libitum access to a conventional layers diet. Birds were weighed in the evening prior to the commencement of the experiment.

Experimental diets

For the dietary treatments, the test ingredients that were used at varied levels are Soybean meal, Groundnut cake, Palm-kernel cake, and Maize while Wheat offal was slightly varied. The feed ingredients were purchased, milled and mixed at a reputable commercial poultry feed milling site. The composition of the experimental diets is shown in table 1.

Egg quality analysis

Two eggs were selected per replicate from each treatment at the end of every week throughout the experimental phase amounting to a sum of 60 eggs per week to be analyzed. Selection was done based on the eggs being good representatives of each treatment and replicate for that week. Eggs laid during the last two days of every week were used for the egg analysis. Egg parameters taken during the experiment includes total weight of eggs per replicate per week, average weight of eggs per replicate per week, total number of eggs per replicate per day/week, eggshell thickness (broad end, mid-section and narrow end), yolk width and depth, albumen width and depth. In addition, the average weight of each bird per replicate was taken for every treatment.

Ingredients	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Maize	46	47.5	49.5	51.5	53
Wheat offal	21	21	21	20	20
Soybean meal	6.25	8.25	6	3.5	1.7
Groundnut cake	10.5	5	4	3.2	1.5
Palm kernel cake	5	7	8.25	10.5	12
Oyster shell	3.4	3.4	3.4	3.4	3.4
Bone meal	7	7	7	7	7
Methionine	0.10	0.10	0.10	0.10	0.10
Lysine	0.15	0.15	0.15	0.15	0.15
Layer premix	0.25	0.25	0.25	0.25	0.25
Toxin binder	0.10	0.10	0.10	0.10	0.10
Salt	0.25	0.25	0.25	0.25	0.25
Crude protein	15.96	15.02	14.04	13.05	12.05
Calcium	3.71	3.71	3.71	3.71	3.71
Phosphorus	1.31	1.31	1.31	1.31	1.31
Crude fiber	4.5	4.48	4.46	4.48	4.49
Energy (Kcal)	2504.14	2499.39	2502.64	2505.55	2501.06

Table 1: Percentage composition of treatment diets fed to commercial layers.

Ingredients	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Maize	46	47.5	49.5	51.5	53
Soybean meal	6.25	8.25	6	3.5	1.7
Groundnut cake	10.5	5	4	3.2	1.5
Palm kernel cake	5	7	8.25	10.5	12

Table 2: Test ingredients that were used at varied levels.

Parameters - percentage	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Crude protein inclusion level	15.96	15.02	14.04	13.05	12.05
Methionine	0.10	0.10	0.10	0.10	0.10
Lysine	0.15	0.15	0.15	0.15	0.15

Table 3: Varied dietary crude protein inclusion level in the diets with constant amino acid inclusion level.

Egg parameters

For egg weight, eggs collected were weighed replicate by replicate according to various treatments using a sensitive weighing scale. For eggshell, the eggshell thickness was measured in three regions - the broad, middle and narrow end using a micrometer screw gauge, and it was calculated as the average of the three regions measured. For the Yolk, the width and depth was measured using the Vernier caliper. For the Albumen, the width and depth was also measured using the Vernier caliper.

Statistical analysis

The data collected from the experiment was subjected to analysis of variance and the differences between the weekly means of egg parameters taken were tested using Duncan's multiple range test by the general linear model procedure of SAS software. All statements of significance were based on testing at 5% level of probability.

Results

For egg number, the result showed that over the eight weeks of study the number of eggs produced in weeks 1,7, and 8 were significantly different ($p < 0.05$) from the other weeks. The number of eggs produced by treatment 1, 2, and 3 were not significantly different ($p > 0.05$) from each other but were significantly different ($p < 0.05$) from the number of eggs produced by treatments 4 and 5. Treatment 4 and 5 recorded the least mean value of [16] while treatments 1, 2 and 3 recorded the highest mean value of [18]. For egg weight, the result showed that the total weight of eggs produced by the birds for the eight weeks of study were not significantly different ($p > 0.05$) from each other. Treatment 1 recorded the highest mean value of 929.92g while treatment 5 recorded the least mean value of 800.8g for total weight of eggs. The average weight of each egg for the period of eight weeks showed no significant difference ($p > 0.05$) between the treatments. Treatment 5 recorded the least mean numerical value as (48.19g) while treatment 1 recorded the highest mean numerical value as (50.87g).

For shell thickness, the result showed that the average shell thickness obtained from each treatment was not significantly different ($p > 0.05$) from each other. Treatment 1 had the lowest mean numerical value for average shell thickness as 0.28 mm. Looking at the individual parameters of shell thickness, for the narrow end of the shell there was no significant difference ($p > 0.05$) within the treatments. Treatment 2 recorded the least mean numerical value for shell thickness at the narrow end as 0.21mm while treatment 1 had the highest mean value as 0.25 mm. For the middle section, the shell thickness obtained from each treatment was not significantly different ($p > 0.05$) within the treatments however treatments 3 and 5 had the highest and the least numerical mean values as 0.36 mm and 0.31mm respectively. For the broad end, shell thickness was not significantly different ($p > 0.05$) within the treatments. Treatments 3,4, and 5 recorded the lowest numerical mean value as 0.22 mm while treatment 2 had the highest numerical mean value of 0.25 mm.

For yolk depth, the result for each treatment over the period of eight weeks showed that there was no significant difference ($p > 0.05$). Treatment 5 recorded the highest numerical mean value of 1.43 cm while treatments 1 and 2 recorded the least numerical mean value of 1.40 cm. Yolk depth is also referred to as Yolk Height. For yolk width, the result showed that over the period of eight weeks there was no significant difference within the treatments. Treatments 5 and 1 had the least and highest numerical mean values of 3.59 cm and 3.86 cm respectively. The yolk index for treatment 1 was significantly different ($p < 0.05$) from treatments 2,3, 4, and 5 at week six of the experiment while treatment 5 was significantly different ($p < 0.05$) from treatments 1,2,3, and 4 at week 7 of the experiment. The results showed that treatment 1 recorded the least numerical mean value of 0.31 cm for yolk index while treatment 5 had the highest mean value of 0.4 cm.

Parameters - mm	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Shell - narrow	0.25	0.21	0.23	0.22	0.23
Shell - midway	0.35	0.34	0.36	0.35	0.31
Shell - broad end	0.24	0.25	0.22	0.22	0.22
Average weight of eggs - grams	50.87	48.81	49.93	48.19	48.10

Table 4: Mean exterior egg quality parameters for birds fed with different dietary levels of crude protein for the period of eight weeks.

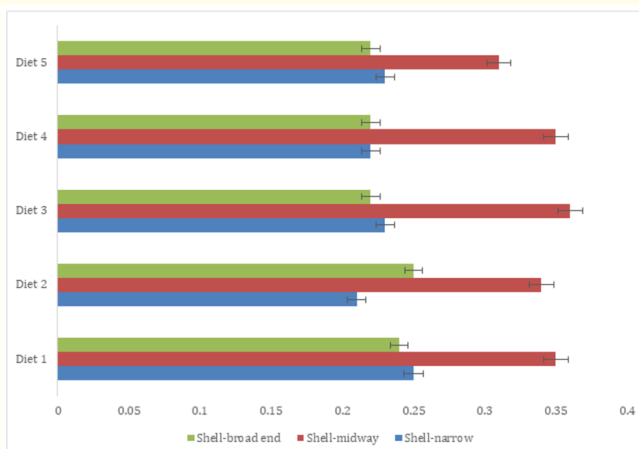

Figure 1: Mean exterior egg quality parameters for birds fed with different dietary levels of crude protein for the period of eight weeks.

For Albumen, the result for albumen depth over the period of eight weeks showed that there was no significant difference (p >

0.05) within the treatments. Treatments 1,2, and 4 had the highest numerical mean value as 0.76 cm and treatment 3 the least mean value as 0.74 cm. For the albumen width, there was no significant difference within the treatments over the period of eight weeks. However, treatment 3 and 5 had the highest and lowest numerical mean values of 9.18 cm and 8.76 cm respectively. For the albumen index, there was no significant difference (p > 0.05) over the eight weeks of experiment and there were no highest or lowest numerical mean values recorded.

Parameters - cm	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Yolk Depth	1.40	1.40	1.42	1.41	1.43
Yolk Width	3.86	3.73	3.69	3.75	3.59
Albumen Depth	0.76	0.76	0.74	0.76	0.75
Albumen Width	9.17	8.89	9.18	9.01	8.76
Yolk Index	0.36^{b}	0.38^{ab}	0.38^{ab}	0.38^{ab}	0.40^{a}
Haugh Unit	89.60	90.49	88.89	89.93	90.23

Table 5: Mean interior egg quality parameters for birds fed with different dietary levels of crude protein for the period of eight weeks. Note - Means with the same superscript on the same row are not significantly different (p > 0.05).

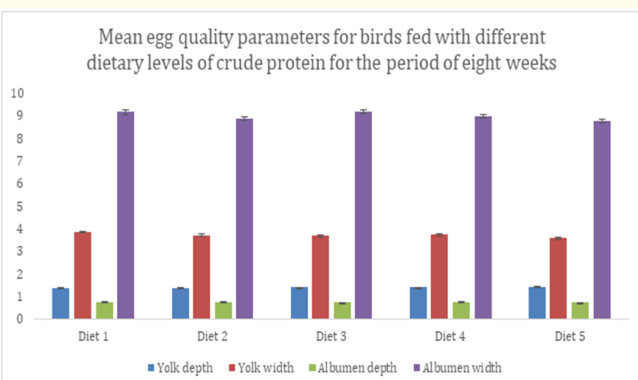

Figure 2: Mean interior egg quality parameters for birds fed with different dietary levels of crude protein for the period of eight weeks. 0.05).

Discussion

[8] reported that the reduced inclusion of Crude Protein (CP) in the diet will neither impair egg production in birds nor affect their welfare but it will reduce the egg production of that bird. The result shown infers that though treatments 4 and 5 had the least CP inclusion in their diets at 13.05% and 12.05% respectively, egg production from birds in these treatments was not impaired but only reduced which corroborates the findings of [8,13] reported that with reduced inclusion of Soybean Meal (SBM) in the diet; egg production is reduced not impaired especially when included in minute amounts and depending on its method of processing. Egg production in treatments 4 and 5 which had the least inclusion of SBM in their diets at 3.5% and 1.7% respectively was not impaired but only had a reduction in egg production which agrees with the report of [13]. The result shown infers that there were no significant differences between the treatments, only differences between their numerical mean values.

For the total weight of eggs and average weight of eggs, the result of the study showed that treatment 1 having CP inclusion at 15.96% recorded the highest numerical mean values while treatment 5 having CP inclusion at 12.05% recorded the lowest mean values. The values for egg weight could be because of the inclusion level of CP in the diet which agrees with the work of [11] who reported that increasing the CP level in the diet increases egg weight but increasing the inclusion level beyond the required amount will have no significant difference on egg weight. This study also shows that birds that consumed diets with a lower level of CP inclusion had lower mean values than birds that consumed diets with a higher level of CP. It also agrees with the work of [9] which showed that egg weight from birds fed with high CP diets had significant differences from birds fed with low CP diets.

For average shell thickness, the results shown as obtained from each treatment were not significantly different from each other. Treatment 1 with 15.96% CP inclusion had the highest mean value while treatment 5 with 12.05% had the lowest mean value. According to [12], CP inclusion level has no influence on eggshell thickness. [21] further emphasized that shell thickness is not influenced by nutrient density in the diets of laying birds except the inclusion level of amino acids, calcium, and phosphorus is altered in the diet. Therefore, the results obtained for shell thickness, could be due to environmental factors which are in support of [7]. From their findings, the average shell thickness of eggs laid by birds during the first few weeks of lay is 0.34mm but is usually thinner in the tropics than in the temperate regions. In their opinion, shell thickness is reduced when birds are subjected to high environmental temperature. [16] pointed out that the increased productivity of a laying hen gradually leads to a reduction in eggshell quality and an improvement of albumen quality which also agrees with [7], that egg production increases with the age of the birds and later drops gradually from peak to about 65% before the bird reaches molting.

For albumen quality, the results showed that there were no significant differences between the treatments. For albumen depth, treatments 1,2, and 4 had the same numerical mean value recorded which was the highest while treatment 3 recorded the least numerical value. The result obtained infers that the level of CP in the diet has no significant difference on albumen quality since the amino acid amounts were constant. This agrees with the work of [18,21] which showed that varied inclusion of CP with constant amino acid amount in the diet does not affect albumen quality. If inclusion of CP is varied and amino acid amount is also varied, albumen quality will reduce. Also, [17] reported that within the bounds of accepted commercial practice, albumen quality is largely unaffected by the nutrition of a bird. According to them, albumen quality might be related to the protein source in the diet consumed by the laying bird.

The results for the yolk quality showed that there were significant differences between the treatments for only yolk index. For yolk depth and width, only their numerical mean values had differences. The highest mean value for yolk depth was recorded for treatment 5 and the least mean value for treatments 1 and 2. This result agrees with the work of [1,21] who reported that yolk height is not affected by only CP inclusion level but by varying both the inclusion level and the amino acid amount in the diet. It also infers that since only the CP inclusion level was varied and the amino acid amount kept constant between the treatments, there was no significant difference in yolk depth. [13] further reported that increasing the Soybean Meal (SBM) inclusion level in the diet and leaving the amino acid amount constant will have no significant effect on yolk depth and width.

According to [1,18] increase in egg weight increases yolk depth and width. From the results shown, treatment 1 recorded the highest mean values for average egg weight and yolk width but recorded the least mean value for yolk depth. Treatment 5 recorded the least mean values for average egg weight and yolk width but recorded the highest mean value for yolk depth. This result does not agree with the findings of [1] because the decrease in egg weight of treatment 5 due to low CP in the diet but constant amino acid amount did not have any effect on the increase in its yolk depth.

For the yolk index, there were significant differences between the treatments with treatment 5 recording the highest mean value having 12.05% CP inclusion and treatment 1 recording the least mean value having 15.96% CP inclusion. This result agrees with the findings of [21] who discovered that in increasing the CP content of the diet and leaving the amino acid amount constant at the required level for the birds, there will be no effect on the yolk index values between the treatments. They also reported that treatments with higher CP content in the diet give lower values while those with lower CP content give higher values provided the amino acid amount is kept constant. Additionally, they pointed out that it's the same case with haugh units for eggs. The haugh unit measures the freshness of eggs and from the results shown, the CP inclusion level in the diet had no influence on the haugh unit. Treatments 2 and 5 had the highest mean values while the remaining treatments had similar mean values for their haugh units

Conclusion

The results of this study showed that the varying levels of CP in the diet with constant amino acid amount at the required level for the bird, had no adverse effect on the egg quality (especially for the interior quality) of the birds nor did it elicit any deleterious effect on their welfare (no abnormal behaviour was observed). The result even revealed that in almost all the parameters considered for egg quality, the best result in cases where there were differences in treatments, came from treatment 5 in which the CP inclusion level was the least (12.05%). A real scrutiny of the result showed that treatment 5 with 12.05% CP inclusion gave the best result for internal egg quality while treatment 1 with 15.96% CP inclusion gave the best result for external egg quality and performance characteristics of the birds. Therefore, crude protein inclusion level in the diet can be as low as 12.05% with the required level of amino acid amount kept constant, without having much significant difference on egg quality parameters or exerting any form of danger on the welfare of the birds.

Recommendation

Having all these facts from this study, the authors recommend that crude protein inclusion level in poultry for layers can be as low as 12.05% if the experimental aim is at egg quality provided the required amino acid amount is kept constant. Further research should also be carried out to further emphasize these findings. In addition, more research can be done to find out if Crude protein inclusion as low as 12.05% with varied amino acid amount OR Crude protein inclusion lower than 12.05% with required constant amino acid amount, will have any significant difference, adverse effects on the egg quality of layers or trigger any abnormality in the behavior or welfare of the birds.

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Conflict of Interest

The authors all declare that they have no conflict of interest or whatsoever as regards this article.

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