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BIOLOGICAL SCIENCES

Influence of low-protein diet with different levels of amino acids on laying hen performance, quality and egg composition

MAHMOUD ALAGAWANY, MOHAMED M. EL-HINDAWY,
MOHAMED E. ABD EL-HACK, MUMAMMAD ARIF & SABRY A. EL-SAYED

Abstract: The present study aimed to investigate the consequences of dietary levels of crude protein (CP) and total sulfur amino acids (TSAA, Met+Cys) on productive performance, egg quality and egg components for Lohmann Brown laying hens through 18-34 weeks of age. A 2×3 factorial design experiment was conducted using two levels of CP (16 and 18 %) and three levels of Met+ Cys (0.67, 0.72 and 0.77 %). A total of 144 Lohmann Brown laying hens at 18 weeks of age were randomly divided into 6 treatment groups. The best values of final body weight and body weight change were recorded by the hens fed 18 % CP diet. Increasing dietary CP up to 18 % accompanied with the best ($P > 0.01$) feed conversion, egg weight and egg mass. The combination between low-CP diet (16 %) and 0.72 % Met+ Cys gave the best percentage of egg production. The majority of egg quality traits were not significantly altered by dietary treatments. The interaction between CP and Met+Cys levels had a statistical ($P > 0.01$) impact on egg content of moisture and total solids only. It could be concluded that the best production criteria could be obtained by using 0.72% Met+Cys. Moreover, dietary level of 16 or 18 % CP with 0.72% Met+Cys is recommended for feeding Lohmann hens.

Keywords: layers, low-protein diet, amino acids, production, egg quality, blood.

INTRODUCTION

The first an important step to optimize performance and production in poultry is proper nutrition. Increasing egg yield profits is mainly depending on flock performance, feed and egg prices as well as farm management (Alagawany et al. 2014, Abou-Kassem et al. 2018). Several factors affect productive performance of laying hens. Nutrient levels in the diet should be optimized not to exceed the optimum level in order to optimize profits. Improving or maintaining laying hen performance, or both, could be achieved by maximizing the utilization of nutrients from current feedstuffs (Abd El-Hack et al. 2015). Reduction in production costs is needed although laying efficiency and high egg production are characteristics of the modern laying hen. Soybean meal and corn are the main ingredients providing crude protein and energy in commercial poultry diets (Alagawany et al. 2016). The amino acid methionine is now available at competitive prices. It is now possible to formulate poultry diets which provide a non-protein nitrogen and minimum excess of amino acids (Alagawany et al. 2015). However, we are unable to formulate diets with very low levels of crude protein that contain optimum levels of essential amino acids (Zeweil et al. 2011). But it is possible to readily reduce crude protein supply by 15 – 20% using synthetic amino acids supplements if its cost could be economic and applicable (Aarnink et al. 1993). New feeding strategies in poultry production gave a new perception with the advent of environmental problems which always come from the oversupply of nutrients, particularly protein and amino acids (Meluzzi et al. 2001, Torki et al. 2016). So the present investigation designed as an attempt to reduce nutrient oversupply through decreasing dietary crude protein level and trying to compensate amino acid deficiency by supplementing graded levels of total sulphur amino acids. The objective of this study was to investigate quantitatively describe the effect of dietary levels of crude protein and total sulfur amino acids on productive performance, egg quality and whole egg composition for Lohmann Brown laying hens.

MATERIALS AND METHODS

The current experiment was consummated at Poultry Research Farm, poultry Department, Faculty of Agriculture, Zagazig University, Egypt. All the experimental procedures were conducted in accordance with the Local Experimental Animals Care Committee, and affirmed by the ethics of the institutional committee at Faculty of Agriculture, Zagazig University. Hens were breeding for utilizing rearing guidelines got from Zagazig University standard working methodology.

Experimental design, hens and diets

One Hundred and fourth four of Lohmann Brown laying hens, 18 wk of age, were procured from a local commercial layer farm. They were randomly allocated to six treatments groups, each of which included six repeats of four hens. Each replicate was housed in one layer cage. The current study was conducted in a 2×3 factorial design experiment including two (low and normal) levels of CP (16 and 18 %) and three levels of Met+ Cys (0.67, 0.72 and 0.77 %) through the experimental period from 18-34 weeks of age (Table I). The initial average live body weight of hens in all experimental treatment groups were nearly the same and had no statistically differences. All hens were housed in a windowed poultry house under the same managerial and hygienic conditions. The hens were exposed to photoperiod 17 h light: 7h darkness per day and were fed on *ad-libitum* basis and fresh water was supplied freely during the experimental period. Vaccination and medical program were done according to the different stages of age under supervision of a veterinarian.

Laying productive performance and egg quality criteria

The layer hens were weighed at the beginning and the end day of experimental period, the live body weight change was then computed by the difference between the initial and final live body weights. On a hen-day basis, egg weight, egg production, and hen mortality were registered daily and feed intake was recorded weekly on a replicated basis. Egg mass was computed by multiplying by egg weight by hen-day egg number produced. Feed conversion ratio (FCR) was calculated as germ of feed intake/hen/day divided by gram of egg mass produced/hen/day. At the end of experimental period, 3 eggs from each replicate were chosen randomly to evaluate exterior and interior egg quality parameters such as (percentages of yolk, albumen, shell, and egg shape index (ESI), yolk index, shell thickness, Y:A ratio, Unit surface shell weight (USSW) and Haugh unit) which were measured according to Romanoff & Romanoff (1949).

Egg analysis

At 34 weeks of age (end of experimental period), 5 eggs from each treatment group were selected randomly for determination whole solids and

Table I. Composition and chemical analysis of the experimental diets.

Dietary protein levels %	16			18		
Dietary Met+Cys levels %	**0.67**	**0.72**	**0.77**	**0.67**	**0.72**	**0.77**
Ingredients%						
Maize	67.34	67.34	67.34	62.14	62.14	62.13
Soybean meal 44%	15.50	15.50	15.50	22.00	22.00	22.00
Corn gluten	4.43	4.38	4.33	4.41	4.36	4.31
Wheat bran	1.80	1.80	1.80	-	-	-
Cotton seed oil	-	-	-	0.70	0.70	0.70
Salt	0.30	0.30	0.30	0.30	0.30	0.30
Vitamin premix [1]	0.15	0.15	0.15	0.15	0.15	0.15
Mineral premix [2]	0.15	0.15	0.15	0.15	0.15	0.15
Di-calcium phosphate	1.86	1.86	1.86	1.80	1.80	1.80
Limestone	8.20	8.20	8.20	8.20	8.20	8.20
L-lysine HCL	0.17	0.17	0.17	0.11	0.11	0.11
Dl-Methionine	0.10	0.15	0.20	0.04	0.09	0.15
Chemical composition						
a- Determined analysis[3]						
Crude protein%	16.6	17.23	17.23	17.28	18.66	18.71
Crude fat %	4.47	4.83	4.88	4.20	5.00	5.20
Moisture %	9.45	10.90	9.85	9.99	10.00	10.37
b- Calculated analysis[4]						
ME, Kcal /Kg	2800	2800	2800	2801	2801	2801
Crude protein %	16.01	16.01	16.01	18.03	18.03	18.02
Calcium%	3.64	3.64	3.64	3.64	3.64	3.64
Nonphytate P %	0.45	0.45	0.45	0.45	0.45	0.45
Lysine%	0.84	0.84	0.84	0.94	0.94	0.94
Methionine%	0.41	0.46	0.51	0.39	0.44	0.49
Cystine%	0.26	0.26	0.26	0.28	0.28	0.28
Met+Cys %	0.67	0.72	0.77	0.67	0.72	0.77

[1]Layer vitamin Premix: Each 1.5 Kg consists of: Vit. A 12000.000 IU; Vit. D3, 2000.000 ICU, Vit.E 10g; Vit. K 328 mg ; Vit. B1, 1000 mg; Vit. B2, 5000 g; Vit. B6, 1500 mg, Vit. B12,10 mg; Biotin 50 mg; Pantothenic acid , 10 g; Niacin, 30 g; Folic acid, 1000 mg;
[2]Layer Mineral Premix: Each 1.5 Kg consists of Mn, 60 g; Zn, 50 g; Cu; 10g; I, 1000 mg; Si, 100 mg; Co.1000 mg.
[3]Analyzed according to AOAC (2003)
[4]Calculated according to NRC (1994).

chemical composition of the whole eggs. After breaking eggs, the yolk and albumen were mixed with shell and homogenate into an aluminum dish where a known weighted homogenies egg sample dried in hot air oven for 24 hours at 60˚c to eliminate primary moisture, then samples dried again for 3 hours at 105˚ c to eliminate secondary moisture, then weighed. The chemical proximate analysis of dried whole eggs and feed samples were carried out according to AOAC (2003) for determination of DM (ID 930.15), OM (ID 942.05), CP (ID 954.01), EE (ID 945.16) and CF (ID 978.10).

Statistical analysis

Data were statistically analyzed on a 2×3 factorial design basis according to Snedecor & Cochran (1982) using the following model:

$$Y_{ijk} = \mu + A_i + S_j + AS_{ij} + e_{ijk}$$

Where: Yijk = an observation, μ = the overall mean, Ai = effect of protein level (i=1 and 2), Sj = effect of Met+ Cys level (j =1 to 3), ASij =the interaction between the two variables and eijk= Experimental random error. Tukey's test was used for comparison among significant means.

RESULTS

Hen productive performance

Results in Table II indicated that daily feed intake and egg production percentage were not statistically different between low or normal-CP diets, although they were insignificantly improved with increasing CP level. Increasing dietary CP up to 18 % accompanied with the best (P> 0.01) feed conversion, egg weight and egg mass comparing with the low CP level. Dietary supplementation of Met+ Cys had statistical impacts on feed conversion ratio (P=0.020), egg production % (P=0.031) and egg mass (P=0.041). The intermediate level of Met+ Cys (0.72 %) achieved the best results of the aforementioned parameters in comparison to other levels. Only egg production percentage and egg weight were significantly (P> 0.01) influences as a response to the interaction among CP and Met+ Cys levels. The combination between low-CP diet (16 %) and 0.72 % Met+ Cys gave the best percentage of egg production. However, the best egg weight was found in the group fed normal-CP diet (18 %) supplemented with 0.77 % Met+ Cys comparing with other treatment groups.

Results in Table II also illustrate the impact of low-CP diet, Met+ Cys supplementation and their combinations on body weight change during the experimental period. It is obvious that body weight change was significantly (P> 0.05 or 0.01) altered due to low-CP diet. The best values of final body weight (1790 g) and body weight change (139 g) were recorded by the hens fed normal-CP diet (18 % CP) comparing with those fed the low-CP diet. The different levels of Met+ Cys supplementation did not exert any significant effect on the values of body weight change. The combination between low-CP diet and Met+ Cys levels had a statistical (P> 0.05) impact on body weight change. It is noticeable that the interaction between 18% CP diet and 0.77 % Met+ Cys gave the heaviest body weight compared with other combinations. Meanwhile, the worst values were found by the combination between 16 % CP with 0.72 % Met+ Cys as compared with other treatment groups.

Egg quality criteria

Effects of low-CP diet, Met+ Cys supplementation and their interactions on external and internal egg quality traits are shown in Table III. Results revealed that increasing dietary CP level depressed (P= 0.042) egg weight value and increased (P= 0.024) the values of USSW and yolk index. All other egg quality parameters were not affected by dietary CP levels. Excluding yolk

Table II. Effect of low-protein diet with different levels of Met+Cys on productive performance of laying hens during the experimental period.

Item		Feed consumption (kg/h)	FCR (g feed/g egg)	Egg production (%)	Egg weight (g)	Change of body weight (g)
Low-CP diet effect						
	16	12.09±0.24	2.50±0.02[a]	73.30±3.35	55.02± 0.60[b]	82±19.65[b]
	18	12.36±0.45	2.27±0.03[b]	76.48±2.13	58.15±0.54[a]	139±11.25[a]
Met+Cys effect						
	0.67	12.50±0.28	2.40±0.06[a]	74.16±1.14[b]	58.23±0.42	161±21.25
	0.72	12.21±0.48	2.20±0.05[b]	79.01±0.52[a]	57.99±0.37	91±23.25
	0.77	12.12±0.15	2.35±0.03[a]	72.16±2.09[b]	58.21±0.54	164±25.45
Interaction effect						
Low-CP diet	Met+Cys					
16	0.67	12.70±0.30	2.65±0.10	72.08±4.44[c]	55.34±1.98[b]	109±26.80[bc]
	0.72	12.21±0.45	2.33±0.02	79.37±0.86[a]	55.82±1.51[b]	42±30.20[c]
	0.77	11.50±0.22	2.54±0.03	68.45±3.30[d]	53.89±1.61[c]	98±36.80[c]
18	0.67	12.12±0.24	2.71±0.05	75.83±1.03[b]	58.16±0.98[a]	115±36.80[bc]
	0.72	12.24±0.64	2.26±0.12	78.05±0.90[a]	57.44±1.99[a]	70±16.80[c]
	0.77	12.60±0.23	2.30±0.06	75.83±4.44[b]	58.84±0.98[a]	231±36.50[a]
Probabilities						
Low-CP diet		0.321	0.002	0.082	>0.001	0.001
Met+Cys		0.094	0.020	0.031	0.354	0.324
Interaction		0.231	0.341	>0.001	0.003	0.032

Means in the same column within each classification bearing different letters are significantly different (P<0.05 or 0.01).

index, all external and internal egg quality traits were not significantly altered by Met+ Cys levels or the interaction among CP and Met+ Cys levels.

Chemical composition of whole egg

Data presented in Table IV show the impact of dietary treatments on Chemical composition of whole egg. Neither dietary CP nor Met+ Cys levels had significant impact on any of egg nutrients studied. The interaction between CP and Met+ Cys levels had a statistical (P>0.01) impact on egg content of moisture and total solids only. The combination between 18 % CP and 0.72 % Met+ Cys recorded the highest value of egg moisture and the minimum value of egg total solids compared with other combinations.

DISCUSSION

Hen productive performance

Insignificant improvements in daily feed intake and egg production percentage were noticed with increasing dietary CP level (Table II). In partially agreement, Novak et al. (2006) who indicated that feed consumption was affected by protein intake, where feed consumption linearly decreased as protein intake decreased

Table III. Effect of low-protein diet with different levels of Met+Cys on exterior and interior egg quality of laying hens during the experiment.

		Exterior egg quality		Interior egg quality						
Item		ESI[1]	USSW[2]	Albumin %	Yolk %	Shell %	Haugh unit	Yolk index	Y: A ratio	Shell thickness (mm)
Low-CP diet effect										
	16	78.29±0.27	3.85±0.00[b]	62.40±0.16	25.02±0.13	12.59±0.06	88.02±0.38	41.37±0.29[b]	0.402±0.03	0.407±0.01
	18	79.08±0.37	3.79±0.01[a]	63.16±0.30	23.97±0.20	12.82±0.13	86.07±0.78	47.60±0.49[a]	0.383±0.00	0.399±0.01
Met+Cys effect										
	0.67	78.65±0.26	3.84±0.01	63.22±0.23	24.36±0. 15	12.37±0.10	84.29±0.80	46.72±0.33[a]	0.388±0.00	0.389±0.01
	0.72	78.54±0.22	3.85±0.00	63.50±0.24	24.31±0. 19	12.20±0.13	87.92±0.36	41.75±0.62[b]	0.386±0.00	0.404±0.01
	0.77	77.29±0.38	3.91±0.00	65.74±0.30	22.38±0. 18	11.87±0.16	84.14±0.49	45.91±0.49[a]	0.344±0.00	0.425±0.01
Interaction effect										
Low-CP diet	Met+Cys									
16	0.67	78.82±1.33	3.83±0.01	62.25±0.23	25.36±0.15	12.38±0.09	86.88±0.77	47.57±1.25	0.409±0.00	0.388±0.01
	0.72	78.85±0.15	3.84±0.01	61.37±0.61	25.07±0.47	13.63±0.13	89.83±0.94	32.82±0.44	0.407±0.01	0.410±0.01
	0.77	77.20±0.60	3.88±0.03	63.58±0.46	24.63±0.53	11.78±0.14	87.34±1.79	43.71±0.62	0.390±0.01	0.422±0.01
18	0.67	79.29±0.85	3.74±0.02	62.66±0.60	23.99±0.45	13.24±0.38	85.76±4.23	47.20±1.36	0.388±0.01	0.368±0.01
	0.72	79.39±0.73	3.77±0.01	62.51±1.10	25.01±0.61	12.47±0.49	88.69±0.66	47.69±1.74	0.403±0.02	0.378±0.01
	0.77	78.57±1.85	3.86±0.02	64.30±1.25	22.92±0.86	12.76±0.42	83.76±0.18	47.91±1.95	0.358±0.02	0.452±0.01
Probabilities										
Low-CP diet		0.325	0.024	1.244	0.954	0.257	1.002	0.042	0.548	1.001
Met+Cys		0.657	1.214	0.984	0.457	0.243	0.845	0.039	0.648	0.948
Interaction		0.145	0.874	0.548	0.547	1.254	0.954	0.657	0.243	0.876

Means in the same column within each classification bearing different letters are significantly different (P<0.01 and 0.05).
ESI[1]: egg shape index, USSW[2]: unit surface shell weight.

Table IV. Effect of low-protein diet with different levels of Met+Cys on chemical composition of whole egg of laying hens during the experimental period.

Item		Moisture %	Egg solids %	Egg protein %	Ether extract %	Nitrogen free extract %	Organic matter %	Ash %
Low-CP diet effect								
	16	73.04±0.35	26.95±0.35	12.43±0.55	11.16±0.75	3.35±0.96	96.52±0.14	3.48±0.14
	18	74.30±0.35	25.69±0.35	13.47±0.55	11.04±0.75	1.17±0.96	96.37±0.14	3.62±0.14
Met+Cys effect								
	0.67	73.30±0.35	26.69±0.35	13.01±0.55	11.96±0.75	1.74±0.96	96.27±0.14	3.72±0.14
	0.72	74.32±0.35	25.67±0.35	13.58±0.55	10.41±0.75	1.68±0.96	96.47±0.14	3.52±0.14
	0.77	73.30±0.35	26.69±0.35	13.04±0.55	10.36±0.75	3.28±0.96	96.69±0.14	3.30±0.14
Interaction effect								
Low-CP diet	Met+Cys							
	0.67	72.70±0.61^{c}	27.29±0.61^{a}	12.31±0.95	10.19±1.30	4.78±1.67	96.27±0.25	3.72±0.25
16	0.72	72.40±0.61^{c}	27.59±0.61^{a}	12.22±0.95	11.72±1.30	3.65±1.67	96.25±0.25	3.74±0.25
	0.77	74.02±0.61^{b}	25.97±0.61^{b}	12.75±0.95	11.58±1.30	1.69±1.67	97.03±0.25	2.96±0.25
	0.67	73.18±0.61^{bc}	26.82±0.61^{a}	14.56±0.95	13.08±1.30	0.10±1.67	96.14±0.25	3.85±0.25
18	0.72	76.36±0.61^{a}	23.63±0.61^{c}	12.99±0.95	10.22±1.30	0.42±1.67	96.58±0.25	3.41±0.25
	0.77	73.37±0.61^{bc}	26.62±0.61^{a}	12.87±0.95	9.84±1.30	3.91±1.67	96.40±0.25	3.59±0.25
Probabilities								
Low-CP diet		0.574	0.598	0.845	0.547	0.544	0.777	0.946
Met+Cys		0.869	1.024	0.597	0.321	0.846	0.349	0.347
Interaction		>0.001	0.009	0.984	0.382	0.317	0.211	0.879

Means in the same column within each classification bearing different letters are significantly different (P< 05 or 0.01).

for Hy-line W-98 hens from 20 to 43 wk of age. On the contrary, Zeweil et al. (2011) mentioned that daily feed intake was insignificantly affected by different protein levels (12, 14 and 16% CP) in laying hens diet during the experimental period (28 – 48 wk of age). The present study showed an improvement in feed conversion, egg weight and egg mass with increasing CP level. Similarly, Moustafa et al. (2005) and Novak et al. (2006) concluded that feed conversion ratio improved when protein level of layer diet increased. Novak's results also supported ours regarding egg weight. Authors found that the highest egg weight value was for 19 g of protein/hen / day compared to 17 or 14.4 g of protein /hen/day. Also, Bouyeh & Gevorgian (2011) who mentioned that egg mass had significantly increased by dietary protein level. Whereas, Gunawardana et al. (2009) stated that the different levels of protein in the diet of commercial leghorn laying hens didn't significantly affect egg weight.

Results of the present study confirmed that adding 0.72 % Met+Cys to the diet exerted the best feed conversion, egg production and egg mass (Table III). The enhancement of feed efficiency may be due to the increase of egg mass and may be attributed to more balanced amino acids. The obtained results coincided with those found by Koreleski & Świątkiewicz (2011) and Zeweil et al. (2011) who reported that methionine supplementation significantly improved feed conversion per kg eggs**.**

Feed conversion ratio, egg production, egg weight and egg mass were significantly affected by an increase in digestible sulphur amino acids intake (Kakhki et al. 2016). Contradicting results obtained by Hassan et al. (2000) who pointed out that feed efficiency was not significantly improved with increased TSAA intake during the first phase of feeding (20 to 40 wk of age). For egg production, our results are in line with those reported by Liu et al. (2005) who reported that increasing dietary levels of total sulphur amino acids (TSAA) from improved ($p<0.05$) egg number for laying hens. Also, Abd El-Maksoud et al. (2011) stated that egg production of laying hens fed methionine supplemented diet was significantly increased versus hens fed diet without methionine supplementation. Our findings concerning the positive effect of Met+Cys supplement on egg mass are consistent with Harms & Russell (1996) and Zeweil et al. (2011) who found that egg mass increased as methionine level increased from 0.23 to 0.31% in the first productive cycle for laying hens. On the other hand, Solarte et al. (2005) reported that increasing total sulphur amino acids level from 0.684 to 0.734% had no further improvement on egg mass.

In the current study, positive responses were detected on the percentage of produced egg and values of egg weight due to the interaction between dietary CP levels and Met+Cys levels. With the same trend, Pavan et al. (2005) found significant differences for egg weight with the combination of 15.5 and 0.71; 17 and 0.71; 15.5 and 0.64; 14 and 0.71; 17 and 0.64 of CP and TSSA, respectively, showing the highest values. Also, the interaction between protein and methionine revealed that the best average egg weight was produced by hens fed 16% CP supplemented by 2.74 methionine % of CP (Zeweil et al. 2011)**.** On the contrary to our results, Zeweil et al. (2011) indicated that the interaction effect between protein and methionine showed insignificant differences in egg production at the end of experimental period.

An improvement in body weight was noticed due to normal-CP diet in the present study (Table II). This improvement may be due to the bioavailability and balanced amino acids which provided by the tested diet. However, lower body weight due to feeding the lowest dietary treatment (16% CP) was cleared by Cole (1996) who confirmed that amino acids may be absorbed in unavailable form because of fructose-lysine complex production. This would inhibit the release of trypsin and lysine utilization remains only 10% which leads to slower absorption of amino acids and consequently poor laying performance. Moreover, the reservation of body protein gradually depletes in birds fed on reduced CP diet. Our results disagree with those data reported by Abd El-Maksoud et al. (2011) and Zeweil et al. (2011) who reported insignificant difference in the body weight for laying hens fed different levels of protein. According to our findings, the combination among the highest levels of both dietary CP and supplemental Met+Cys produced the heaviest hen weight (Table II). This result agree with those found by Novak et al. (2006) who postulated that body weight gain elevated side by side with increasing dietary CP levels and with methionine supplementation. In contrast, Abd El-Maksoud et al. (2011) and Zeweil et al. (2011) showed that the interaction impact between protein and methionine revealed insignificant differences in live body weight at the end of experiment.

Egg quality criteria

As explained in Table III, no significant impacts were detected on the majority of egg quality criteria due to dietary treatments. Likewise, Novak et al. (2006) reported no significant ($p<0.05$ or 0.01) difference in albumen, yolk, shell percent and Haugh unit when increasing or decreasing CP in layer diet during 20- 43 wk of age. Moreover, Zeweil et al. (2011) revealed that the most of egg quality traits had not been affected by protein levels. Koreleski & Świątkiewicz (2011) indicated that egg shell characteristics were unchanged when methionine content in the diet was increased. Similar to our results, Pavan et al. (2005) found no significant differences in internal egg quality with the interaction between protein and TSAA in layer diets. Also, Novak et al. (2006) reported no significant ($p<0.05$ or 0.01) difference in albumen, yolk, shell percent and Haugh unit due to interaction effect between CP and TSAA in layer diet during 20- 43 wk of age. On the other hand, Haugh unit score was significantly lower in layers fed a 13% CP diet in comparison with control, but yolk colour index was higher ($P < 0.05$) for the layers fed the 14% and 13% CP diets than those fed the normal diet (Torki et al. 2016).

Chemical composition of whole egg

No significant impacts were recorded due to CP or Met + Cys levels on the chemical composition of the egg as shown in Table IIII. Similar results were obtained by Gabriel & Babatunde (1976) who reported that both the total moisture and crude protein percentages were significantly increased as the dietary protein levels increased (20%) but the differences in total ash, shell and total lipid percentages were not significantly differed and were remarkably constant in white leghorn egg. Garcia et al. (2005) suggested that Met + Cys levels had no effect on egg contents.

CONCLUSIONS

In view of the aforementioned results and discussion, conclusion could be drawn that the best production criteria could be obtained by using 0.72% Met+Cys. Moreover, dietary level of 16 or 18 % CP with 0.72% Met+Cys is recommended for feeding Lohmann hens.

Acknowledgments

The authors declare that they have no competing interests.

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MAHMOUD ALAGAWANY[1]
https://orcid.org/0000-0002-8020-0971

MOHAMED M. EL-HINDAWY[1]
https://orcid.org/0000-0002-0784-667X

MOHAMED E. ABD EL-HACK[1]
https://orcid.org/0000-0002-2831-8534

MUHAMMAD ARIF[2]
https://orcid.org/0000-0002-5073-4438

SABRY ABD EL-SAYED[3]
https://orcid.org/0000-0002-0306-1269

[1]Department of Poultry, Faculty of Agriculture, Zagazig University, 44511, Zagazig, Egypt

[2]Department of Animal Sciences, University College of Agriculture, University of Sargodha, 40100, Pakistan

[3]Department of Nutrition and Clinical Nutrition, Faculty of Veterinary Medicine, Zagazig University, P.O. Box 44511, Zagazig, Egypt

Correspondence to **Mahmoud Alagawany**
E-mail: mmalagwany@zu.edu.eg

Author Contributions

Conceptualization, M.A. and M.M.E.; Formal analysis, M.A., M.M.E.; M.E.A.; Funding acquisition, M.Ar., and S.A.E.; Investigation, M.A. and M.M.E.; Methodology, M.A. and M.M.E.; Resources, M.A., and S.A.E.; Supervision, M.M.E. and M.A.; Writing – original draft, M.A., M.M.E. and S.A.E.; Writing – review & editing, M.Ar. All authors have read and agreed to the published version of the manuscript.