

EFFECT OF PROTEIN BOUND AND FREE LYSINE ON GROWTH PERFORMANCE, MEAT QUALITY, BLOOD HEMATOLOGY AND ECONOMICS IN BROILERS

M. A. Asif¹, M. M. A. Hamid¹, M. Shoaib^{1*}, M. A. Mirza¹, H. H. Iqbal¹, M. I. Khan², Najam-us-Sahar¹, S. Ashraf¹, M. M. Javed¹, S. Shehzad¹, M. S. Asif¹ and S. Jameel¹

¹Institute of Animal and Dairy Sciences, Faculty of Animal Husbandry, University of Agriculture, Faisalabad 38040, Punjab, Pakistan

²National Institute of Food Science and Technology, University of Agriculture, Faisalabad 38040, Punjab, Pakistan

*Corresponding author's email: shoaib.imtiaz43@gmail.com

ABSTRACT

The objective of this study was to study the protein bound and free lysine (Lys) on production performance in broilers. Two hundred and sixteen (216) day-old broiler chicks were distributed into three treatments, six replicates and 12 birds in each. Three isonitrogenous (CP 22.5%) and isocaloric (ME 3000 Kcal/kg) experimental diets were formulated. In control diet, total digestible Lys (1.20%) was contributed by feed ingredients like soybean meal, canola meal and fish meal. In other two diets, out of 1.2, 0.06 was free Lys that was either contributed by L-Lys Sulfate or L-Lys HCl which were assumed to be 100% digestible. Feed intake was ($P \leq 0.05$) lower in birds received free Lys than those reared on bounded Lys. Weight gain and FCR were improved ($P \leq 0.05$) in birds received protein bound Lys and free Lys as L-Lys Sulfate than L-Lys HCl. Dressing percentage, liver weight, water holding capacity, pH, cooking loss and blood hematology parameters were not affected by treatments. Production cost per kg live weight was lower in birds received free Lys as L-Lys Sulfate than others treatments. It can be concluded that use of free Lys in the form of L-Lys Sulfate had improved feed efficiency and economics efficiency without having negative effect on meat quality and blood hematology parameters.

Keywords: Bounded Lysine, Free Lysine, Growth performance, Blood hematology, Economics

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INTRODUCTION

Poultry meat has good nutritional profile and consumption of poultry meat has progressively increased from the over the years (Marangoni *et al.*, 2015). Different feed ingredients used in poultry diets have different amino acid composition and bioavailability which affects growth performance (Kheiri and Alibeyghi, 2017). Modern broilers are very proficient in converting vegetable protein into valuable animal protein for the human consumption. Rapid growth is generally associated with leg problems and impaired immune response affecting overall performance of birds. Shortage of feed ingredients is the main problem for poultry feeding. Feed constitutes approximately 70% of total production cost of a poultry enterprise (Esonu *et al.*, 2006).

Protein represents the major cost component of poultry feed. Use of vegetable protein ingredients especially soybean products in poultry birds' diets is becoming progressively more important because of consumer concerns about the safety and health of animal protein by-products (Aggrey *et al.*, 2010). The main

nutrients required by birds for rapid growth are dietary protein and energy. Crude protein and Lys have a considerable interaction which affects performance of growing broiler chicks (Rezaei *et al.*, 2004). To improve feed efficiency different amino acids like Lys can be added in feed to enhance production performance. It is demonstrated that Lys supplementation improves feed efficiency and live body weight (Corzo *et al.*, 2005; Sahar *et al.*, 2023).

Lysine is an EAA involved in body development and also acting a dynamic role in protein synthesis (Jespersen *et al.*, 2021). Lysine is an integral part of collagen as it is a precursor of hydroxy-lysine, elastin, carnitine, histones and digestive enzymes (Lee *et al.*, 2020). Lysine is assumed as limiting amino acid with corn-soybean diets for broiler which has to be supplemented as Lys sulfate or Lys HCl (Chen *et al.*, 2020). Lysine requirement is substantial that tend to change with change in genetics, gender, nutrition and management of birds (Hesabi *et al.*, 2006). Sharma *et al.* (2018) reported that weight gain and breast yield percentage increased while FCR improved by Lys supplementation. L-Lys sulfate performed better than L-Lys HCl in commercial diets (Bahadur *et al.*, 2010). The

comparison between Lys HCl and Lys sulfate was performed in pigs and fish but there was limited experimental study on bio efficacy of Lys sources in broilers (Wang *et al.*, 2007). Nutritionists have opportunity to formulate diets with low price while maintaining optimal protein consumption by broiler birds due to commercially available amino acids products. Therefore, the objective of this study is to compare the response of protein bound Lys and free Lys (L-Lys sulfate and L-Lys HCl) in early growing broiler birds.

MATERIALS AND METHODS

A biological trial involving 216 one-day old broiler chicks was conducted at the Animal Nutrition Research Farm of the Institute of Animal and Dairy Sciences, University of Agriculture Faisalabad after the approval of synopsis from the Graduate Studies and Research Board via letter no. 19933-36. Duration of the trial was 28 days.

House preparation and management: The house was cleaned thoroughly by scrubbing, removing cob-webs followed by complete washing with plain water. The house was white-washed and disinfected and sprayed with formalin solution (1:10) using back pump sprayer. Automatic nipple drinkers were used for supplying fresh drinking water round the clock. The water lines were flushed with a solution of H₂O₂ that was allowed to stay in line for almost 12 hours. Provision of fresh drinking water and feed was ensured round the clock. To avoid caking of litter, racking of bedding material was frequently done. Light was provided for 23 h at an intensity of 20 lux for the first seven days, after which birds received light of an intensity of 10 lux. All birds were reared under homogenous environmental and managerial conditions i.e., temperature, lighting, ventilation, feeding and floor space.

Experimental diets: In this experimental trial three isocaloric and isonitrogenous (CP 22.5%; ME 3000 kcal/kg) diets were formulated (Table 1 and 2). In one diet Lys is obtained from feed ingredients (bound Lys), which was compared with feeds supplemented by synthetic Lys sources, L-Lys Sulfate and L-Lys HCl (free Lys). The birds under each treatment were provided the experimental feeds *ad libitum* for the period of trial.

Experimental birds: Two hundred and sixteen (216) day-old broiler chicks were divided into three treatments, six replicates and 12 birds in each. Immediately after arrival, the chicks were checked for their physical health and weighed using a digital weighing balance. Chicks were reared in separate pens measuring (4'×3'×2.5') in an environmentally controlled house. A sugar solution of (250 gm/ liter) was supplied to the birds, on arrival to relieve them from transportation stress. The birds under

each treatment were fed the experimental diets *ad libitum* for the period of trial.

Vaccination schedule: Birds were vaccinated against viral disease like ND + IB at day 3 (eye drop), IBD at day 11 (eye drop) and ND at day 21 (drinking water). Vaccine was dissolved in standard diluent. One drop of prepared vaccine was poured in the eye of bird with a sterile dropper bottle. Before and after vaccination, Birds were given multi-vitamin (Vitamix) and electrolytes through drinking water.

Data recording: Following data for different parameters were recorded.

Body weight: On arrival, birds were weighed (initial body weight) by using digital weighing balance. At the end of each week, body weight of birds was measured.

Feed consumption: Feed consumption was recorded using following equation

$$\text{Feed intake per bird} = \frac{\text{Feed offered} - \text{Feed refused}}{\text{No. of birds per replicate}}$$

Feed conversion ratio (FCR): Feed conversion ratio was calculated using following equation

$$\text{FCR} = \frac{\text{Feed intake (g)}}{\text{Weight gain (g)}}$$

Slaughter data: At 28 day, two birds were selected and slaughtered to obtain following parameters.

$$\text{Dressing percentage} = \frac{\text{Carcass weight}}{\text{Live weight}} \times 100$$

$$\text{Breast yield} = \frac{\text{Breast weight}}{\text{Live weight}} \times 100$$

$$\text{Thigh Yield} = \frac{\text{Thigh weight}}{\text{Live weight}} \times 100$$

$$\text{Liver weight} = \frac{\text{Liver weight}}{\text{Live weight}} \times 100$$

Meat quality: Breast pectoralis major muscles obtained from birds were taken for meat quality parameters.

a) pH: At 3 h post-mortem, final pH was measured with a pH meter by inserting a glass electrode into thickest part of the breast pectoralis major (Jeacocke, 1977).

b) Water holding capacity (WHC): Fifteen-gram (15g) minced meat samples were immersed in 22 ml of 0.6 N NaCl solution. Then it was stored at -4 °C for 15 minutes and then centrifuged (Centrifuge 5804 R) at 5000 rpm for 10 min. The WHC was calculated using following equation (Pearson and Dutson, 1995).

$$\% \text{WHC} = \left(\frac{W1 - W2 - \text{Sample weight}}{\text{Sample weight}} \right) \times 100$$

c) Cooking loss: A small portion of breast meat “approximately 40 g or 2 x 5 cm” was cooked in the water bath at 80 °C for half hour. After cooling the meat, weight decrease from the meat represent cooking loss (Ahmed *et al.*, 2015).

d) Proximate composition: Proximate composition (DM, ash, EE and CP) of breast meat were analysis (AOAC, 2016).

Blood Hematology: At the end of experiment blood samples (two sample/replicate) were collected in ethylene di-amine tetra acetic acid (EDTA) vial and analyzed by using automatic Hematology Analyzer (Hemalyzer-203D Plus, Germany). Hematological values were displayed on screen and printed by attached printer (Shoab *et al.*, 2021).

Economics: Cost of production per live weight was recorded on the basis of feed cost and live bird weight.

Statistical analysis: Data were analyzed using analysis of variance technique by completely randomized design and mean values were compared using Tukey's Test (Steel *et al.*, 1997). Following mathematical model was used.

$$Y_{ij} = \mu + \tau_i + \varepsilon_{ij}$$

Where,

Y_{ij} = Observation of dependent variable recorded on i^{th} treatment

μ = Population mean

τ_i = Effect of i^{th} limestone sources ($i = 1, 2, 3$)

ε_{ij} = Residual effect of j^{th} observation on i^{th} treatment NID $\sim 0, \sigma^2$

RESULTS

Feed intake was ($P \leq 0.05$) lower in birds reared on free Lys based diet than those reared on bounded Lys based diet. However, feed intake was similar in both L-Lys HCl and L-Lys Sulfate groups. Weight gain was greater ($P \leq 0.05$) in protein bound Lys and free Lys as L-Lys Sulfate than L-Lys HCl. Improved FCR and feed efficiency were noted in birds received free Lys as L-Lys Sulfate than others treatments (Table 3). At 28 day, two birds were selected and slaughtered. Dressing %, breast and thigh yield and liver weight was determined. Statistical analysis showed that different form of Lys had no influence ($P \geq 0.05$) on these parameters (Table 4).

Meat pH under different dietary treatments i.e. Protein bound Lys, L-Lys sulfate and L-Lys HCl were 5.34, 5.37 and 5.38 respectively. Statistical analysis of the data demonstrated no significant difference on the meat pH among the treatments. Water holding capacity under different dietary treatments i.e. Protein bound Lys, L-Lys sulfate and L-Lys HCl were 65.02, 63.37 and

61.06 respectively. Statistical analysis of the data demonstrated no significant difference on the WHC among the treatments. Cooking loss under different dietary treatments i.e. Protein bound Lys, L-Lys sulfate and L-Lys HCl were 25.80, 31.88 and 28.95 respectively. Protein bound Lys demonstrated statistically same results as related to free Lys sources (L-Lys HCl and L-Lys sulfate; Table 5).

Proximate composition (DM, ash, EE and CP) of breast meat were analysis. Statistically analysis revealed that meat proximate parameters were main similar among Lys sources (Table 5). Protein bound Lys and free Lys had no effect ($P \geq 0.05$) on blood hematology parameters (Table 6). Production cost / kg live weight was lesser ($P \leq 0.05$) in birds received free Lys as L-Lys Sulfate than others treatments (Table 7).

Table 1. Ingredient composition of experimental diets.

Ingredient	%	Bound Lysine	Free lysine diets	
			L-Lys Sulfate	L-Lys HCl
Corn		44.07	47.75	47.80
Rice polishing		4.86	0.45	0.39
Soybean meal 45%		38.04	31.56	31.53
Canola meal		3.00	9.17	9.24
Fish meal 54%		2.42	3.00	3.00
Vegetable oil		4.36	4.82	4.82
Lime stone		0.85	0.79	0.79
CaHPO ₄		1.71	1.65	1.65
NaCl		0.36	0.10	0.10
NaHCO ₃		0.14	0.42	0.43
L-Lysine sulfate		0	0.12	0
L-Lysine HCl		0	0	0.08
DL-Methionine		0.08	0.06	0.06
Vitalink*		0.05	0.05	0.05
Nutrimin**		0.05	0.05	0.05
Phytase		0.01	0.01	0.01
Total		100	100	100

***Vitalink**® is a vitamin mixture, each Kg contains: Vitamin A 20000 KIU, Niacin 60000 mg, Vitamin E 48000 mg, Vitamin B1 4000 mg, Vitamin K3 4000mg, Vitamin B6 7600 mg, Folic acid 1600 mg, Vitamin B2 9000 mg, Vitamin D3 5400 KIU, Vitamin B12 20 mg, Biotin 200 mg, Pantothenic acid 20000 mg,

****Nutrimin**® is a minerals premix; each Kg of it supplied the following: Iron 10000 mg; Zinc 120000 mg; Manganese 140000 mg; Copper 12000 mg; Iodine 1800 mg; Cobalt 400 mg; and Selenium 360 mg.

Table 2. Nutrient composition of experimental diets.

Nutrient (%)	Bound Lysine	Free lysine diets	
		L-Lys Sulfate	L-Lys HCl
DM	89.8	89.8	89.8
ME (Kcal/kg)	3000	3000	3000
CP	22.5	22.5	22.5
EE	7.5	7.5	7.5
CF	3.6	3.6	3.6
Ca	0.96	0.96	0.96
P, Av.	0.48	0.48	0.48
Na	0.22	0.20	0.20
K	0.95	0.84	0.84
Cl	0.30	0.15	0.15
DEB	250	250	250
Total Lysine	1.36	1.36	1.36
Lysine Dig.	1.20	1.20	1.20
Bound Lysine	1.20	1.14	1.14
Free Lysine	0	0.06	0.06
M+C, Dig.	0.75	0.75	0.75
Threonine, Dig.	0.82	0.81	0.81
Tryptophan, Dig.	0.27	0.26	0.26
Arginine, Dig.	1.52	1.44	1.44
Leucine, Dig.	1.76	1.72	1.72
Isoleucine, Dig.	0.93	0.88	0.88
Valine, Dig.	1.02	0.98	0.98
Histidine, Dig.	0.57	0.55	0.55

Lysine contributed by feed ingredients is assumed to be 100% bound

Lysine contributed by synthetic sources (L-Lysine Sulfate and L-Lysine HCl) is assumed to be free and 100% digestible.

DM= Dry matter, ME= Metabolizable energy, EE= Ether extract, CF= Crude fiber, DEB= dietary electrolyte balance

Table 3. Feed intake, body weight gain and FCR of birds from day (1-28) in response to addition of protein bound lysine and free lysine diets.

Treatments	Bound Lysine	Free lysine diets		SEM	P value
		L-Lys HCl	L-Lys Sulfate		
Feed Intake	2452.04 ^a	2266.63 ^b	2294.58 ^b	23.9	0.0001
Body weight gain	1574.33 ^a	1417.47 ^b	1507.57 ^a	19.2	0.0001
FCR	1.56 ^{ab}	1.60 ^a	1.52 ^b	0.02	0.048
Feed efficiency/bag	32.11 ^{ab}	31.28 ^b	32.86 ^a	0.02	0.048

SEM: Standard error of the mean,

P \geq 0.05 (Non-Significant), P \leq 0.05 (Significant)

a-b values of superscript different in column differ significantly

Table 4. Dressing percentage, thigh yield, breast yield and liver weight of birds in response to addition of protein bound lysine and free lysine diets at day 28.

Treatments	Bound Lysine	Free lysine diets		SEM	P-Value
		L-Lys HCl	L-Lys Sulfate		
Dressing Percentage	60.43	58.71	59.33	0.7	0.244
Thigh yield	34.09	33.03	33.52	1.51	0.799
Breast yield	25.31	25.57	26.5	1.51	0.254
Liver weight	2.2	2.28	2.26	0.14	0.725

SEM: Standard error of the mean,

P \geq 0.05 (Non-Significant), P \leq 0.05 (Significant)

Table 5. Meat quality of broiler breast of birds in response to addition of protein bound lysine and free lysine diets at day 28.

Treatments	Bound Lysine	Free lysine diets		SEM	P-Value
		L-Lys HCl	L-Lys Sulfate		
Meat Quality Parameters					
pH	5.34	5.38	5.37	0.05	0.882
Water holding capacity (%)	65.02	61.06	63.37	2.78	0.617
Cooking loss (%)	25.8	28.95	31.88	3.04	0.371
Meat Proximate (%)					
Moisture	73.96	74.14	74.02	0.09	0.954
Ash	1.87	1.73	1.56	0.13	0.652
EE	2.19	2.71	2.76	0.26	0.252
CP	20.51	20.74	19.78	0.41	0.601

SEM: Standard error of the mean,

P \geq 0.05 (Non-Significant), P \leq 0.05 (Significant)

Table 5. Blood hematology of broiler breast of birds in response to addition of protein bound lysine and free lysine diets at day 28.

Treatments	Bound Lysine	Free lysine diets		SEM	P-Value
		L-Lys HCl	L-Lys Sulfate		
WBC 103/ul	24.14	21.02	24	2.19	0.537
RBC 106 / ul	2.57	2.49	2.1	0.32	0.545
HGB g/dl	12.88	11.43	9.88	1.37	0.328
HCT (%)	37.58	36.27	30.38	3.86	0.396
MCV (+FL)	148.87	147.58	150.14	3.29	0.861
MCH (+pg)	50.48	46.8	46.71	1.64	0.213
MCHC (g/dl)	33.93	31.67	31.84	0.814	0.124
PLT 103 /ul	357.83	248.33	181.67	84.6	0.356

SEM: Standard error of the mean,

P \geq 0.05 (Non-Significant), P \leq 0.05 (Significant)

Table 6. Economics of broiler breast of birds from day (1-28) in response to addition of protein bound lysine and free lysine diets.

Treatments	Bound Lysine	Free lysine diets		SEM	P-Value
		L-Lys HCl	L-Lys Sulfate		
Day old bird cost	30	30	30	-	-
Feed Intake	2452.04 ^a	2266.63 ^b	2294.58 ^b	23.9	0.0001
Feed Cost	68.13	67.29	67.33	-	-
Total feed cost / bird	167.06 ^a	152.52 ^b	154.49 ^b	1.61	0.0001
Miscellaneous ¹	25	25	25	-	-
Production cost / bird ²	222.06 ^a	207.52 ^b	209.49 ^b	1.61	0.0001
Av. body weight (g)	1616.11 ^a	1459.35 ^b	1548.54 ^a	19.3	0.0001
Production cost / kg	137.54 ^{ab}	142.25 ^a	135.35 ^b	1.67	0.030

¹ Miscellaneous cost include vaccination cost, farm preparation and brooding expenditures

² Production cost per bird = Bird cost + Feed cost per bird + Miscellaneous

a-b values of superscript different in row differ significantly.

DISCUSSION

Feed intake was lower in diet with free Lys sources (L-Lys sulfate) than protein bound Lys (Lys from

ingredients). This might be due to that addition of synthetic lysine reduces the high lysine ingredient proportion resulting in reduced feed intake. Results are in according with findings of Oliveira *et al.* (2014) who

showed that feed intake was significantly lower in Lys supplementation than protein bound Lys diets. Both synthetic Lys sources (L-Lys HCl and L-Lys sulfate) supplementation had similar feed intake. Ahmad *et al.* (2007) reported that both L-Lys HCl and L-Lys sulfate had non-significant effect on feed intake. Wang *et al.* (2007) showed that feed intake was similar in birds received different sources of Lys in starter phase, however, in finisher phase, feed intake was significant different. Results are in contrast with Onu and Ahaotu (2015) who revealed that there was no effect of free Lys supplementation on feed intake. Similarly, Kumari *et al.* (2016) reported that feed intake had no effect by free Lys supplementation. The results of present study were in contrast with some past experiments because the control diet of present experiment had same CP and Lys as free Lys sources supplemented diets, but contrast studies supplemented free Lys sources in Lys deficient and low CP diets. These variations might be due to differences in bird's strains, analytical procedure and weather conditions during the experimental period.

Results of present study showed that body weight gain was significantly ($P \leq 0.05$) affected by using different sources of Lys. Higher body weight gain was found in diet with protein bound Lys (Lys from ingredients) as related to diets with free Lys sources (L-Lys HCl and L-Lys sulfate) supplementation. As, lysine has an important role in broiler growth and a sufficient amount of lysine is required to meet that requirement (Brasil *et al.*, 2018). Results are in line with findings of Oliveira *et al.* (2014) reported that body weight gain was significantly higher in protein bound Lys diets as compared to diets with Lys supplementation. Both synthetic Lys sources (L-Lys HCl and L-Lys sulfate) supplementation did not show statistical difference in term of body weight gain. Similarly, Ahmad *et al.* (2007) compared L-Lys HCl and L-Lys sulfate, results showed that body weight gain was same for both free Lys sources. The result is in contract with Onu and Ahaotu (2015) who concluded that body weight gain was higher in Lys supplemented diet of low CP. Similarly, Kumari *et al.* (2016) reported that body weight gain was increased by free Lys supplementation in low CP diets. Lisnahan *et al.* (2017) reported that body weight gain was increased by additional free Lys supplementation in low CP diets. Melaku *et al.* (2015) reported that body weight gain increased by free Lys supplementation in marginal CP diet. Rehman *et al.* (2012) compared L-Lys HCl and Lys fermented broth supplemented in low CP diets. Results revealed that supplementation of both Lys sources increased body weight gain. The body weight gain of present study was in contrast with some past experiments because the control diet of present experiment had same CP and Lys as free Lys sources supplemented diets, but contrast studies supplemented free Lys sources in Lys deficient and low CP diets.

Improved FCR and feed efficiency were noted in birds received free Lys as L-Lys Sulfate than others treatments. Improved FCR was observed due to higher body weight by addition of L-Lys Sulfate. Results are in line with findings of Oliveira *et al.* (2014) reported that FCR was significantly higher in diets with protein bound Lys as compared to diets with free Lys supplementation. According to results of present study in free Lys sources the L-Lys sulfate had higher feed conversion ratio as compared to L-Lys HCl. Similarly, Ahmad *et al.* (2007) compare L-Lys HCl and L-Lys sulfate, results showed that FCR was same for both free Lys sources. The result is in contract with Onu and Ahaotu (2015) concluded that FCR was higher in Lys supplemented diet of low CP. Similarly, Kumari *et al.* (2016) also reported that FCR was improved by free Lys supplementation in low CP diets. Lisnahan *et al.* (2017) reported that FCR was improved by additional free Lys supplementation in low CP diets. Melaku *et al.* (2015) revealed that FCR improved by free Lys supplementation in marginal CP diet. Rehman *et al.* (2012) compared L-Lys HCl and Lys fermented broth supplemented in low CP diets. Results revealed that supplementation of both Lys sources showed same FCR. Tufarelli *et al.* (2020) concluded that Lys and methionine supplementation at different levels did not affect FCR. The FCR of present study was in contrast with some past experiments because the control diet of present experiment had same CP and Lys as free Lys sources supplemented diets, but contrast studies supplemented free Lys sources in Lys deficient and low CP diets.

Results of present study showed that carcass characteristics was not significantly ($P \leq 0.05$) affected by using different sources of Lys. Protein bound Lys diet had same effect on carcass characteristics as related to free Lys sources. Results of present study is in line with the results of Ahmad *et al.* (2007) who reported that no significant effect of Lys sources were observed on carcass weight, breast and thigh yield, and abdominal fat. Wang *et al.* (2007) performed experiment on broiler to assess the effect of different Lys sources. Results showed that Lys sources were equally efficacious to carcass characteristics. Similarly, Onu and Ahaotu (2015) reported that Lys supplementation had no effect on carcass characteristics. Dietary Lys had no adverse effect on moisture, CP, EE and ash percentage (Takeara *et al.*, 2010; Zampiga *et al.*, 2016). The results are in contrast with Tufarelli *et al.* (2020) concluded that Lys and methionine supplementation at different levels improved the yield of meat-cuts (breast, drumstick and wings) and no effect was detected in eviscerated carcass yield. Opoola *et al.* (2017) reported that by supplementation of Lys and other essential amino acids significantly effects live weight, carcass weight and dressing percentage. Bahadur *et al.* (2010) observed higher breast yield and meat protein in birds reared on L-Lys sulfate.

Results of present study showed that blood hematology parameters were not affected by using different sources of Lys. Protein bound Lys diet had same effect on blood hematology as related to free Lys sources (L-Lys HCl and L-Lys sulfate. The results are in line with Zhai *et al.* (2016) who showed that dietary amino acid supplementation did not affect the blood serum metabolites. Similarly, Opoola *et al.* (2017) reported that by supplementation of Lys and other essential amino acids did not reveal any significant differences on blood hematology parameters. In contrast, Tufarelli *et al.* (2020) showed that serum biochemical parameters were significantly affected by dietary L-Carnitine, Lys and methionine levels.

Production cost per kg live weight was lower in birds received free Lys as L-Lys Sulfate than others treatments. Results are in line with Sahar *et al.* (2023) who stated that production cost was lower in birds received 100% lysine than other treatments. Batool *et al.* (2018) and Abbas *et al.* (2016) stated that production cost per kg live weight was lower in birds received lysine above 1.3%. Ojediran *et al.* (2016) showed that addition of lysine in low protein diet improve economic efficiency in broiler birds.

Conclusion: It can be concluded that use of free lysine in the form of L-Lysine Sulfate had improved feed efficiency and economics efficiency without having negative effect on meat quality and blood hematology parameters.

Ethical Approval: All procedures performed in studies were in accordance with the ethical committee of University of Agriculture, Faisalabad.

Conflict of Interest: The authors declare no conflicts of interest

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