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Effects of Zinc-Methionine on Body Performance for Broiler Infected with Newcastle Disease

Wijdan Mokhlef Abd[1], Balqees Hassan Ali[2]

[1,2]College of Veterinary Medicine - University of Baghdad
Corresponded E-mail: Wejdan.Abed2107m@covmuobaghdad.edu.iq

Abstract

This study aimed to determine whether Zinc Methionine supplements have a beneficial effect on the body performance of ROSS 308 strain broilers vaccinated against Newcastle disease (ND). A total of 120 broiler chicks were randomly divided into 6 groups: five were treated and one served as a control group. The experimental groups were: G1: 20 chicks, control group; G2: 20 chicks, Zn-Met 90 mg/kg in diet (vaccinated at 1 day old with ND killed vaccine + ND eye drop vaccine and at 14 days old with ND eye drop vaccine); G3: 20 chicks, Zn-Met 90 mg/kg in diet (vaccinated at 7 and 21 days old with ND live vaccine in drinking water); G4: 20 chicks, Zn-Met 90 mg/kg in diet; G5: 20 chicks, vaccinated at 1 day old with ND killed vaccine + ND eye drop vaccine and at 14 days old with ND eye drop vaccine; G6: 20 chicks, vaccinated at 7 and 21 days old with ND live vaccine in drinking water.

Live body weight of chickens in the second, third, and fourth weeks showed significant results for G2. In the fifth week, G2 and G3 showed significant results. Body weight gain was significantly higher ($P < 0.05$) in G2, G3, and G4 during the second, third, and fourth weeks of age. Feed intake in the fourth week was significantly higher ($P < 0.05$) in G2, G3, and G4 compared with other groups, indicating positive effects of Zinc Methionine on feed intake. Feed conversion ratio in the third and fourth weeks showed highly significant effects compared with groups not receiving Methionine and Zinc.

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Conclusion: There was an increase in growth performance in the groups supplemented with Zinc Methionine compared to those that did not receive it. We recommend adding Zinc Methionine to feed along with administering the vaccines (killed and eye drop).

Key words: Zinc, Methionine, Newcastle, body performance.

Introduction

Despite advances made in nutritional aspects, several aspects of poultry nutrition remain unsolved and continue to challenge researchers (1,2). Substituting Zinc Methionine in poultry rations is one such effort to reduce costs while enhancing the nutritional quality of poultry meat (3). Zinc Methionine could be advantageously incorporated into broiler feed at lower levels compared to inorganic Zinc due to its higher bioavailability and lower excretion of zinc into the environment (4). Zinc Methionine (Zn–Met), as an organic zinc source, is superior to inorganic Zinc in improving immunity and reducing stress (5).

(6) (2019) reported that supplementation with Zn–Met was associated with antidiarrheal effects and growth promotion by increasing average daily gain (ADG), reducing diarrhea rate, and lowering serum D-lactate content.

Newcastle Disease Virus (NDV) is a member of the Avulavirinae subfamily within the family Paramyxoviridae, specifically belonging to the genus Avian orthoavulavirus-1 (7,8). This disease is capable of causing 100% mortality in unprotected birds (9). Newcastle disease affects more than two hundred avian species (10) and is enzootic in parts of Asia, Africa, the Middle East, and some countries in South America (11). Isolated outbreaks of Newcastle disease have been found sporadically in some European countries

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and Central America (12,13). The disease is transmitted through direct contact with infected birds or indirectly via inanimate carriers. Five pathotypes of the virus have been distinguished according to the severity of clinical signs and incidence. Velogenic strains, the most virulent, can cause 100% mortality in unprotected birds (14,15). Newcastle disease is a major issue for the poultry industry, with a particularly severe impact in developing countries where traditional poultry farming is prevalent and represents a critical source of income and animal protein for households (16,17).

The aim of the study is to investigate the effect of Zinc Methionine (Zn-Met) on the body performance of birds exposed to infection with Newcastle Disease Virus (NDV). This study was conducted after twenty-eight days of rearing, during which the velogenic NDV strain was prepared. The strain, identified by accession number MH638994.1 on NCBI, was subjected to titration and the determination of the EID50.

Methodology

The present experiment was conducted in the animal house of the Department of Pathology, College of Veterinary Medicine, Baghdad University, Iraq. A total of 120 unvaccinated 1-day-old ROSS 308 broiler chicks were obtained from a commercial hatchery. The chicks were kept in isolation units (in separate chambers). Feed and water were freely available to all birds. Standard management procedures were followed to maintain the birds. The chicks were reared in separate pens under good hygienic conditions and housed in floor bins with a litter of wood shavings. Each chamber was equipped with a feeding tray (38 cm in diameter) and 4-liter fountains for three weeks. The levels of the fountains and feeding trays were maintained at an optimal height to facilitate easy access to water and feed. The environmental temperature was 33°C during the first week of life and gradually decreased by 2°C each week until reaching 21°C by the end of the experiment. Starter crumbles were used from 1 to 14 days, grower pellets from 15 to 28 days, and finisher feed from 29 to 35 days.

Broilers fed with the basal diet were kept as control group 1 (G1). Group G2

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consisted of broilers fed with Zinc Methionine (90 mg/kg) in the basal diet, vaccinated at 1 day old with ND killed vaccine (Clone 30) and ND eye drop vaccine (B1 Hitchner), and at 14 days old with ND eye drop vaccine (Lasota). Group G3 included broilers fed with Zinc Methionine (90 mg/kg) in the basal diet, vaccinated at 7 and 21 days old with ND live vaccine (Lasota strain) administered by crop dosage. Group G4 consisted of broilers fed with Zinc Methionine (90 mg/kg) in the basal diet. Group G5 included broilers vaccinated at 1 day old with ND killed vaccine and ND eye drop vaccine, and at 14 days old with ND eye drop vaccine. Group G6 comprised broilers vaccinated at 7 and 21 days old with ND live vaccine administered by crop dosage(18), application was employed. In this study, the least significant difference (LSD) test (ANOVA) was utilized to make a meaningful comparison between all of the means.

Vaccine	Vaccine type	Trade name	Company	Route of admin
ND (clone 30)	Killed vaccine	Nobilis	MSD/Hollond	injection s/c
B1 Hitchner	Live vaccine	BIO-VAC B1	Fatro/ Italy	eye drop
Lasota	Live vaccine	BIO-VAC Lasota	Fatro/ Italy	dosage by crop

Result

Live body weight:

Table (1) showed that there were significant differences in the vertical form between the groups, in the first week of age did not find significant differences, but in second, third and fourth weeks G2, G3 and G4 shows significant results compared with control, G5 and G6. But in the five week the G1 and G4 shows decrease in body weight. But G2 and G3 have significant results and weight arrived to (1980±15.2, 1920±18.2) compared with all another groups (G1, G4, G5 and G6).

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Table (1) Live body weight (gm/bird) of experimental groups in different period (mean ± SE).

Time	G1	G2	G3	G4	G5	G6	LSD
1st week	160±12.2 D a	173±13.6 D a	170±13.3 D a	172±12.3 D a	161±11.5 D a	160± 22.45 D a	7.89
2nd week	355±18.2 C b	401±19.45 C a	397±17.4 C a	395±16.2 C a	351±12.8 C b	349±14.67 C b	23.35
3rd week	670±20.3 B a	755±18.4 B b	758±18.0 B b	752±15.4 B b	701±11.7 B c	703±17.36 B c	43.38
4th week	1122±21.4 A b	1296±17.3 A a	1300±16.4 A a	1286±15.2 A a	1135±20.2 A b	1132± 23.38 A b	48.27
5th week	1130±201 A b	1980±15.2 A b	1920±18.2 A b	1320±19.9 A b	1710±18.8 A b	1660±21.4 A b	22.58
LSD	84.22	89.17	99.47	83.18	95.66	98.84	-

Capital litter represented vertical comparison of data and small litter represented horizontal comparison of data; a significant differences was P value ≤ 0.05.

The body weight gain:

The table (2) show there was an more significant increase (P< 0.05) in body weight gain in the (G2, G3 and G4) during the second, third and fourth weeks of age, this increase began to become low body weight gain in the last two groups and group one (G1, G5 and G6), while after challenge with NDV in five week of age the G1 and G4 have very low weight gain and arrived to (8±3.3, 34 ± 18.7) respectively G5 and G6 have middle weight gain (575±21.6, 528±19.8) respectively compared with G2 and G3 have high weight gain arrived to (684±15.45 and 620±17.3) respectively.

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Table (2): Body weight gain (gm) for experimental groups in different period / (mean ± SE).

Time	G1	G2	G3	G4	G5	G6	LSD
1st week	112±12.3 D a	120±13.5 C a	117±13.2 C a	118±13.4 D a	113±11.4 D a	113±9.32 D a	7.2
2nd week	195±11.4 C b	228±19.4 C a	227±17.3 D a	223±16.3 C a	190±11.4 C b	186± 14.7 C b	66.45
3rd week	315±20.3 B b	354±18.4 B a	361±18.1 C a	357±15.2 B a	350±11.1 B a	352± 9.56 B a	11.45
4th week	452±21.3 A b	540±16.8 B a	542±18.5 B a	544±19.7 A a	434±20.8 A b	432± 17.5 A b	25.68
5th week	8 ± 3.3 E b	684±15.45 A b	620±17.3 A b	34 ± 18.7 E b	575±21.6 A b	528±19.8 A b	23.95
LSD	28.4	41.3	54.87	42.9	62.36	25.78	-

Capital litter represented vertical comparison of data and small litter represented horizontal comparison of data; a significant differences was P value ≤ 0.05

Feed intake (g/bird) of chickens:

There is no significant results between control group and treated groups of feed intake in the first week of age and arrived to (172-186) gram, in the second week the feed intake in the G2, G3 and G4 feed intake arrived between (321-323) gram compared with G1, G5 and G6 have feed intake average between (293 -295) gram and this consider significant results more than (P< 0.05) in feed intake due to the effects of Methionine and Zinc on intestine condition that lead to increase feed intake in this group , in the third week of age the feed intake in G2, G3, G4 is (495,501, 495) gram respectively and this result consider good result because had significantly (p>0.05), in the fourth week of age the feed intake in G2, G3, G4 is (750,753, 751) gram respectively and this result had significantly (p<0.05) compared with G1, G5, G6 have feed intake (700, 670, 671) gram respectively and this results shows positive results of

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Methionine and Zinc for feed intake. In the fifth week of age the feed intake in the G1 and G4 have feed intake (30, 70) gram respectively and that consider low consumption due to challenge with NDV and this group did not vaccinated against NDV in the same time G1 and G2 have high feed intake (975,887) gram respectively and have significant ($p<0.05$) result with G1, G4, G5, G6 have feed intake (30,70,860 and 830) respectively because the effects of methionine and zinc on immunity and give good condition for intestine and that lead to increase production.

Table (3): measurement of Feed intake (g/bird) of experimental groups in different period (mean ± SE).

Time	G1	G2	G3	G4	G5	G6	LSD
1st week	186±7.8 C a	172±8.3 D a	175±6.9 C a	175±11.45 D a	186±12.9 D a	185± 13.6 D a	13.75
2nd week	295±8.9 C b	321±5.4 C a	321±9.4 C a	323±10.3 C a	293±11.4 C b	294± 20.45 C b	66.35
3rd week	485±10.2 B a	495±11.3 B a	501±9.2 B a	495±11.2 B a	530±10.8 B a	528± 14.63 B a	55.69
4th week	700±21.3 A b	750±16.8 A a	753±18.5 A a	751±19.7 A a	670±20.8 A b	671± 22.78 A b	33.68
5th week	30 ± 1.8 A b	957 ± 15.7 A b	887 ± 16.2 A b	70 ± 19.1 A b	860 ± 19.9 A b	830 ± 20.2 A b	28.5
LSD	10.9	70.8	22.4	32.71	33.92	60.58	-

Capital litter represented vertical comparison of data and small litter represented horizontal comparison of data; a significant differences was P value ≤ 0.05

The Feed conversion intake of chickens:

The table (4) shows Methionine and Zinc give significant results in first week on feed conversion in G2,G3 and G4 (1.433, 1.495 and 1.483) respectively and the results summarized by increase the feed conversion compared with G1,G5 and G6 (1.669, 1.646 and 1.65) respectively in the same time the results of feed conversion in the second week

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came similar results in the first week (1.407, 1.414 and 1.448) respectively for G2,G3 and G4 but G1,G5 and G6 (1.512, 1.542 and 1.55) respectively. But the third and fourth week Methionine and Zinc give high significant effects on feed conversion so that the results became with high significant result between G2, G3 and G4 in the third week (1.398, 1.387 and 1.386) and (1.388, 1.383 and 1.378) in the fourth week compared with groups did not taken Methionine and Zinc G1, G5 and G6 (1.539, 1.514 and 1.504) and (1.548, 1.543 and 1.55) respectively. the conversion feed ratio in G2 and G3 ((1.425 and 1.430), G5 and G6 (1.495 and 1.571) but G1 and G4 this groups did not taken vaccine shows increased the conversion feed ratio (3.75 and 2.075) due to high effects of challenge with NDV.

Table (4) Feed conversion ratio between experiential groups in different period (mean ± SE).

Time	G1	G2	G3	G4	G5	G6	LSD
1st week	1.669±0.45 B a	1.433±0.36 A b	1.495±0.28 A b	1.483±0.0915 A b	1.646±0.071 A a	1.65± 0.157 A a	0.061
2nd week	1.512±0.083 B a	1.407±0.065 C b	1.414±0.061 C b	1.448±0.044 C b	1.542±0.037 A a	1.55± 0.24 A a	0.053
3rd week	1.539 ±0.084 B a	1.398 ±0.069 A b	1.387 ± 0.083 A b	1.386 ± 0.055 A b	1.514 ± 0.084 A a	1.504± 0.18 A a	0.072
4th week	1.548 ± 0.052 B a	1.388 ± 0.043 A b	1.383 ± 0.079 A b	1.378 ±0.062 A b	1.543±0.074 A a	1.55± 0.21 A a	0.085
5th week	3.75± 0.9 A a	1.425± 0.4 A c	1.430± 0.1 A c	2.058± 0.09 A b	1.495± 0.09 A c	1.571± 0.17 A c	0.117
LSD	0.13	0.177	0.148	0.29	0.39	0.11	-

Capital litter represented vertical comparison of data and small litter represented horizontal comparison of data; a significant difference was P value ≤ 0.05

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Discussion

Live body weight: This study was agreement with (19) who was recorded that the effects of Methionine on the nutrition of amino acid as increased live body weight. The live body weight of chickens can vary depending on the breed, age, sex and healthy condition of the bird. Different chicken breeds have been selectively bred for various purposes, such as meat production, egg-laying, or ornamental purposes, which can influence their size and weight (20), Broiler chickens are specifically bred for meat production and tend to have larger body sizes. At around 3 to 4 weeks of age, a broiler chicken can weigh between 3.5 to 5 pounds (1122 to 1300 grams) or more; G2 and G3 were more efficiency in the live body weight than other groups, they were recorded as 1980±15.2 and 1920±18.2 grams respectively.

The body weight gain: Our results were disagreement with (21) that was showed mixed vaccination of the chicken was well tolerated. Mixed vaccination did not affect immune response of the chickens. There was no significant difference ($p>0.05$) in both feed consumption and weight gain among chickens in the different his groups.

It was also agreement with (22) who was illustrated that Methionine is closely related to the immune function of livestock and poultry, which is not only has effects on the growth and development of immune organs, but also on the specific and nonspecific immune function of organism, in addition, Methionine plays a key role in protein synthesis and catabolism of the immune system. Body weight gain in chickens is influenced by various factors, including breed, genetics, nutrition, management practices, and age. Different chicken breeds have been selectively bred for specific purposes, such as meat production or egg-laying, which can affect their growth rates and body weight (23). In meat-producing chickens, also known as broilers, rapid weight gain is desirable. These chickens are typically raised for meat consumption and are bred to grow quickly and efficiently convert feed into muscle mass. The growth rate of broiler chickens can be quite rapid, with significant weight gain occurring within a relatively short period (24).

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Feed intake (g/bird) of chickens: These findings suggest that the higher levels of Methionine supplementation resulted in increased final body weight, weight gain, and feed intake. However, the best feed conversion ratio was observed in birds fed a lysine-deficient diet. The results were agreement with (25) who was indicated that birds fed a diet with 1.12% dietary lysine had the highest final body weight (2.16 kg), total weight gain (2.12 kg), and feed intake (3.11 kg). On the other hand, birds fed a lysine-deficient diet (No lysine) exhibited the best feed conversion ratio of 1.37, as well as he was found statistical analysis of the data revealed significant differences ($P \leq 0.05$) among the various dietary treatments for feed intake, weight gain, final body weight, and feed conversion ratio. The two groups containing the vaccine with zinc and the amino acid Methionine played a role in significantly increasing the weekly feed intake the birds. Supplementing chicken diets with methionine is a common practice in poultry nutrition, particularly for optimizing growth, production, and overall health. Methionine is an essential amino acid required for protein synthesis and various metabolic functions in chickens (20). Methionine is considered an essential amino acid because it cannot be synthesized by chickens in sufficient quantities. It must be provided in the diet to meet the bird's nutritional requirements (26).

The feed conversion intake of chickens: The study not found any significant differences ($P > 0.05$) in the third and fourth groups of chicken during feed conversion intake ratio with in the groups; but between groups this difference was become significant decreased in the G2 and G3 while increased in the other groups; feed conversion ratio (FCR) is a measure used to evaluate the efficiency of feed utilization in poultry production. It is calculated by dividing the amount of feed consumed by the weight gain of the chickens over a specific period. A lower FCR indicates better feed efficiency, meaning that fewer feed resources are required to produce a unit of weight gain (27), so the table (4) showed G2 and G3 have lower FCR ratio between groups of chicken.

References

1. Abas FW, Abed Al-Hajo NN, Shlij Al Mjbe, AA and Abdulwahid AS. Zinc-Methionine and it's effect on chicken meat quality. Plant Archives 2020. Vol. 20 No. 1, pp. 913-918.

2. Mohammed FA, Alkhalisy AF and Hussein FM. Association of MC4R gene polymorphisms with feed intake and body weight in local chicken. Biochem. Cell. Arch. 2019, (19) 2: 2923-2927. DOI`: 10.35124/bca.2019.19.2.2923.

3. Sunder GS, Kumar CV, Panda AK, Raju MVLN and Rama Rao SV. Effect of supplemented Zn and Mn on broiler performance, Bone measures, tissue mineral uptake and immune response at 35 days of age. Current Res. in poultry Sci. 2013. 3(1): 1-11.

4. Saleh AA, Ragab MM, Ahmed EAM, Abudabos AM and Ebeid TA. Effect of dietary zinc-methionine supplementation on growth performance, nutrient utilization, antioxidative properties and immune response in broiler chickens under high ambient temperature. J. Appl. Anim. Res. 2018. 46 (1): 820-827. https://doi.org/10.1080/09712119.2017.1407768.

5. Wei J. Effects of Different Zinc Sources on the Intestinal epithelial Barrier and Jejunal Mucosal Proteomics of Newborn Calves Challenged with Escherichia Coli K88. Beijing: Chinese Academy of Agricultural Sciences. 2019.

6. Alani GA and Albadri AA. Reasons related to the deterioration of poultry industry for broilers in the middle and southern region of Iraq. Iraqi J. Agric. Sci. 2021. 52(2): 429-436. https://doi.org/10.36103/ijas.v52i2.1304.

7. Dzogbema KF-X, Talaki E, Batawui KB and Dao BB. Review on Newcastle disease in poultry. Int. J. Biol. Chem. Sci. 2021. 15(2): 773-789.

8. AL-Zuhariy MTB, Abdulmaged SH, Rabee RHS and AL-Baldawi AAA. Isolation and identification of the Newcastle disease virus from field outbreaks in broiler and layer flocks in Iraq. Iraqi Journal Vet. Medicin 2017. 41(1): 23 - 27. DOI: https://doi.org/10.30539/iraqijvm.v41i1.73.

9. Al-Murshedy NAK, Al-Zubaidi HJ, Alabedi GT, Azhar Alkaby A.

Histopathological and Immunohistochemical Study of Newcastle Disease in Chicken in Al-Najaf Province. Journal of Survey in Fisheries Sciences. 2023. 10(3S) 14-25.

10. Al-Shammari AM, Hamad MA, AL-Mudhafar MA, Raad K, and Ahmed A. Clinical, molecular and cytopathological characterization of a Newcastle disease virus from an outbreak in Baghdad, Iraq. Vet Med Sci. 2020. 00:1-8.

11. Ulaiwi AH. Determination of dopamine and serotonin with immune state CD4 and CD8 of the Newcastle infection in broilers. Iraqi J. Agric. Sci. 2023. 54(4): 957-962. DOI: https://doi.org/10.36103/ijas.v54i4.1785.

12. Ulaiwi AH. Diva molecular detection of suspected case of Newcastle and encephalomyelitis disease in layers. Iraqi J. Agric. Sci. 2023. 54(3): 890-895.

13. Al-Mola MAMA. Pathological lesions of respiratory system in pigeons in Mosul area. Iraqi J. Vet. Sci. 2012. 26 (Suppl. IV): 421-427. 10.33899/IJVS.2012.168767.

14. Al-Chalabi DA, Ali AA and Hussein FM. Diagnostic environmental monitoring system in a poultry house. Iraqi Journal Agriculture Science. 2017. 48 (3). https://doi.org/10.36103/ijas.v48i3.399.

15. Ali B H, Ali A J and Yosif EH. Isolation and Molecular Characterization of Mycoplasma Synovia from Infected Chickens with Respiratory Signs. Iraqi J. Agric. Sci. 2020. 51(5):1466-1473. https://doi.org/10.36103/ijas.v51i5.1157.

16. Al-Shammary AM, Hassani HH and Ibrahim UA. Newcastle disease virus (NDV) Iraqi strain AD2141 induces DNA damage and FasL in cancer cell lines. Journal of Biology and Life Sciences. 2014. 5(1), 1.

17. Ahmed A I and Odisho S M. Isolation Identification and Pathotyping of Newcastle Disease Viruses from Naturally Infected Chickens in Iraqi Kurdustan Region. Iraqi J. Agric. Sci. 2018. Vol. 49 No. (1). https://doi.org/10.36103/ijas.v49i1.216.

18. SAS. 2012. Statistical Analysis System, User's Guide. Statistical. Version 9.1th ed. SAS. Inst. Inc. Cary. N.C. USA.

19. Ruan T, Li L, Peng X and Wu B. Effects of methionine on the immune function in animals. Health, 2017. 9(5),

857-869.
http://www.scirp.org/journal/health.

20. Abdel-Lattif FH. The linear association between live body weight and some body measurements in some chicken strains. Plant Archives, 2019. 19(1), 595-599.

21. Manjula P, Park HB, Seo D, Choi N, Jin S, Ahn SJ and Lee JH. Estimation of heritability and genetic correlation of body weight gain and growth curve parameters in Korean native chicken. Asian-Australasian Journal of Animal Sciences, 2018. 31(1):26-31. doi:10.5713/ajas.17.0179.

22. Jarosz Ł, Marek A, Grądzki Z, Kwiecień M and Kalinowski M. The effect of feed supplementation with zinc chelate and zinc sulphate on selected humoral and cell-mediated immune parameters and cytokine concentration in broiler chickens. Research in veterinary science, 2017. 112, 59-65.

23. Tripodi F, Castoldi A, Nicastro R, Reghellin V, Lombardi L, Airoldi C and Coccetti P. Methionine supplementation stimulates mitochondrial respiration. Biochimica et Biophysica Acta (BBA)-Molecular Cell Research, 2018. 1865(12), 1901-1913.

24. Faluyi OB, Agbede JO and Adebayo IA. Growth performance and immunological response to Newcastle disease vaccinations of broiler chickens fed lysine supplemented diets. Journal of Veterinary Medicine and Animal Health, 2015. 7(3), 77-84. DOI:10.5897/JVMAH2014.0328.

25. Del Vesco AP, Gasparino E, Grieser DO, Zancanela V, Voltolini DM, Khatlab AS and Neto ARO. Effects of methionine supplementation on the expression of protein deposition-related genes in acute heat stress-exposed broilers. PLoS One, 2015. 10 (2), e0115821. doi: 10.1371/journal.pone.0115821.

26. Balami AG, Enam SJ, Sule AG, Patrobas, MN, Abdu PA, Chiroma, MA and Aluwong, T. The relationship between feed conversion ratio, feed intake and body weight gain of broilers fed moringa oleifera leaf supplemented feed following challenged with very virulent infectious bursal disease virus. Advances in Animal and Veterinary Sciences. 2018. 6(6) 227-233. DOI:10.17582/journal.aavs/2018/6.6.227 .233.

27. Prakash A, Saxena VK and Singh MK. Genetic analysis of residual feed intake, feed conversion ratio and related growth parameters in broiler chicken: A review. World's Poultry Science Journal, 2020. 76(2), 304-317.