International Journal for Scientific Research (IJSR)

المجلة الدولية للبحوث العلمية

IJSR

Vol. (3), No. (4) April 2024 الإصدار (3)، العدد (4)

Valine in Broiler Diets: A review

Rabia J. Abbas

Animal Production Dept., College of Agriculture, University of Basrah, Iraq

rabia.jaddoa@uobasrah.edu.iq

Abstract

Valine (Val) is the 4th limiting amino acid in a corn and soybean meal–based diet for broiler chicken, after methionine, lysine, and threonine. Valine, isoleucine, and leucine represent the branched-chain amino acids (BCAAs) family. It was reported that the performance of broilers is adversely affected by an imbalance of BCAAs in the diet. So, a low crude protein diet must supplement with Val in a range of 0.01–0.20 % for optimal growth performance. The present review reflects on the studies undertaken to assess the effect of dietary levels of Val on growth performance, immunity, gut health, carcass traits, and bone mineralization in broilers. Several studies have revealed that supplementation of valine in higher levels than the present recommendation of NRC (0.72–0.73% in the finisher phase), improves weight gain, feed: gain ratio, intestinal morphology, carcass characteristics, immune response, and increased bone density and strength. According to the data from the literature discussed in this survey, the Val to-lysine ratio recommendation might require reaching 0.86 for high-yielding broilers from 0-15 days of age. It also suggests that the ratio of digestible valine to lysine is between 75 and 84% in growing and finishing. For best feed intake, weight gain, and FCR, studies indicate that 0.903% is the recommended digestible Val level for a better overall performance of 22 to 42 d broilers. This review provides a summary of the addition of valine to the broiler diet and its potential influence on productive performance, immunity, gut health, carcass characteristics, and bone mineralization in birds.

Keywords: Growth Performance, L-valine, Broilers, Carcass Traits, Bowel Health.

Introduction

Valine (Val) can be defined as an essential aliphatic and highly hydrophobic amino acid, valine is found in numerous proteins, mostly in the inner part of globular proteins that help determine the 3D (three-dimensional) structure. A glycogenic amino acid, valine preserves mental activity, muscle coordination, and emotional calm. Val supplementation is used for muscle development, tissue reform, and energy (NCBI, 2020). Valine, leucine (Leu), and isoleucine (Ile) represent the family of branched-chain amino acids (BCAAs) (Brosnan and Brosnan, 2006), a name derived from their molecular structure. Val is an essential amino acid for birds due to its inability to synthesize by the body, so it must be supplemented in their diet. Val contributes to protein synthesis and is a precursor to other amino acids, or participates in glucose metabolism as glucogenic amino acid (Ferrando et al., 1995; Wu, 2009). L-valine is the L-enantiomer of valine. Val plays a role as a nutraceutical, micronutrient, human metabolite, algal metabolite, Baker's yeast (Saccharomyces cerevisiae) metabolite, E. coli metabolite, mouse metabolite, and plant metabolite. It is an amino acid of the pyruvate family, a proteinogenic amino acid, and L-valine is a L-α-amino acid. It is a conjugate base of an L-valinium. It is the conjugate acid of an L-valinate. It is an enantiomer of a D-valine. It is a tautomer of an L-valine zwitterion (ChEBI, 2022).

The structure of L-Valine is shown below: (Figure 1)

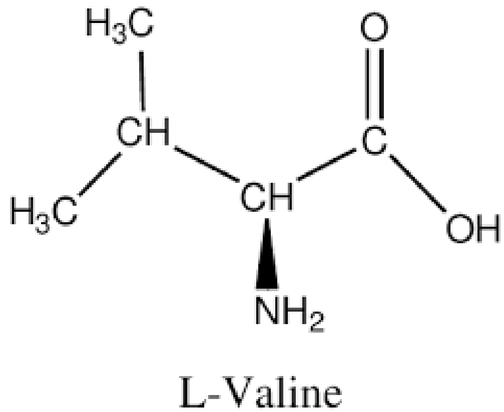

Figure (1): Structure of Valine

In chemical terms, Valine (2-amino-3-methyl butyric acid), a non-polar aliphatic amino acid. According to Chahal et al., (2008) knows valine as (α- amino-isovaleric acid), the abbreviation or symbol Val, code V, formula C5H11NO2, a molar mass is 117.148 g/mol, it has a molecular weight of 117.15 g/mol, the composition % (C 51.26, H 9.46, N 11.96, O 27.32). By specification, the L-valine additive contains ≥ 98% Val ≥ 1.5% water, and ≥ 0.1% ash (EFSA, 2008). Val is considered the 4^{th} limiting amino acid in a corn-soy-based diet for broiler chickens, after methionine, lysine, and threonine when considering live weight gain in birds (Rostagno et al., 2011). Similarly, Corrent and Bartelt, (2011) confirmed that Val is the ^{4th} limiting AA (before Arginine and Isoleucine) in vegetal broiler feed based on yellow corn or wheat. As well, an earlier study was reported by Corzo et al., (2007), who confirmed experimentally that Val was the 4^{th} limiting AA in a broiler diet based on a corn-soy-based for 21 – 42 days. In a study conducted by Corzo et al. (2009) on the broiler, used graded doses of Ile or Val, and their combination, results indicated that Val was the fourth limiting amino acid under these dietary conditions but may reach a point where Ile becomes co-limiting judging by the response observed with feed conversion (for FCR it would appear that Val and Ile were both equally needed).

Common plant feed materials contain 0.4-3.0% L-valine, while animal-derived feed materials contain much more (e.g. up to 8.50 % in blood meal). L-valine supplementation levels in compound feed, especially those with low crude protein content, range from 0.01-0.20%. Depending on the animal species, genetics, sex, and physiological condition of the animal, L-valine requirements in feed in poultry range between 0.43% (layer hens) and 1.20% (Turkeys- pullets up to 4- weeks old) (National Research Council (NRC), 1994). In broilers, the value of total dietary valine as NRC, (1994) recommended was 0.90% for the starter ration (0 -3 weeks), 0.82 % for the grower (3-6 weeks), and 0.70% for the finisher (6-8 weeks) respectively, also, these recommendations for lysine and valine ratio range from 1.10- 1.00% and 0.90 - 0.82% for the starter (0 to 3 wks), and grower (3 - 6 wks) periods, respectively. Regarded to valine requirements of broilers from 0 to 3 weeks of age, the study by Mendonca and Jensen (1989) suggested that the valine requirement exceeds 0.70 %. As well the authors suggested that the valine requirement for 3 to 6 weeks was marginally adequate at 0.72%. In one study (Corzo et al., 2004), the ideal total dietary valine level, was 0.72 % for growth performance and 0.73 % for FCR during the finisher period (42 - 56 d) in male broilers, indicating that the determined requirement of 0.73% total valine (0.67% digestible) for the males from 42 - 56 d old is slightly higher than the 0.70% recommended by the NRC. Also, in broilers diets, Corzo et al., (2011) showed that L-Val could be successfully supplemented at concentrations above 0.05% when diets were supplemented with DL-Met, L-Lys, and L-Thr. Several studies determined the valine requirements in growing and finishing broilers. These studies indicated a variance in the ratio of digestible (dig) valine to lysine (dig Val/Lys) between 75 and 84%. These differences were attributed to the use of different strains, ages, and to various statistical models for assessing the optimum needs of valine (Corzo et al., 2008, 2009; Pastor et al., 2013). Abdallah et al., (2017) reported that the most excellent inclusion level of L-

Valine in the low protein diet (LPD) is the 500 (mg/kg diet) which gave the best results for both body weight gain and feed conversion ratio, also achieved the best economic efficiency reached 103.2% and 114.2% as compared with recommended crude protein level and LPD when incorporated in the diets of broilers respectively. The NRC (1994) recommendation for the total valine-lysine ratio in the starter period of broiler chickens was 0.82. The findings reported by Farran and Thomas (1990) also indicated that valine requirements during this phase (starter) were subsequently found to be consistent with the recommendation of the NRC (1994). Kidd et al., (2009) indicated that 0.78 Val in ratio to Lys appears to optimize the performance of most broiler strains. However, in a study by Baker et al., (2002) the estimated dig valine-lysine ratio from 8 to 21 days of age is 0.78 in the diet, while this ratio was 0.75 according to the recommendations in the starter period. Foroudi and Rezamand, (2014) studied, valine-lysine ratios in the starter diets were 0.74, 0.80, or 0.86. According to the authors' results, the recommendation of the valine: lysine ratio may need to reach 0.86 for highly-yield male (Ross 308) broilers from 0 - 15 days of age. According to Kaplan and Yildiz (2017), the optimum value of valine in broiler rations was assessed at 1% for the first-period feeding (0 to 21 d) in contrast to the NRC recommendations (1994), and 0.82% for the second period (21 to 42 d) as NRC (1994) recommended. The minimal needs of the dig valine: lysine ratio for male Cobb (500) broilers during the starter phase is 0.77 (Tavernari et al., 2013), and for female Cobb (500) broilers from 8 - 21 d of age is 0.78 (Amirdahri et al., 2020). Another study (Corrent and Bartelt, 2011) reported that the requirements for true dig Val to Lys and true dig Ile to Lys for broilers are 80, and 67(%) respectively, for optimized performance. Pointing out that L-Val supplementation in a mixture with L-Thr provides the opportunity to form a feed for broilers that is technically, economically, and environmentally better. On the other hand, a study by Schedle et al., (2019) confirms the optimal dig Val: Lys ratio for Ross 308 broilers was 83.3%

for average daily gain, and 84.6 % for the average daily feed intake (ADFI) during the entire fattening period (36 days), which refers to the using a quadratic broken line model to evaluate the optimal Val requirement. Ospina-Rojas et al., (2019) showed that the standardized ileal digestibility levels required for the optimization of feed consumption, weight gain, and FCR in low CP diet for broiler chicks from day 1- 21 post hatch were estimated at 1.29 and 0.96(%); 1.28 and 0.92(%); and 1.27 and 0.91(%) respectively, nevertheless these requirements may be greater to maximize muscle fiber development in the male broiler. In a subsequent study, Ospina-Rojas et al., (2020) showed that standardized ileal digestibility (SID) leucine, valine, and isoleucine levels required for FCR optimization were estimated at 1.37, 0.94, and 0.87 (%) in starter phase; 1.23, 0.82, and 0.75 (%) in grower phase; and 1.15, 0.77, and 0.70% in finisher phase, respectively. For optimum weight gain, recommended SID leucine, valine, and isoleucine levels were estimated at 1.33, 0.96, and 0.84(%) in the starter period; 1.23, 0.83, and 0.75 (%) in the grower period; and 1.16; 0.77, and 0.68 (%) in finisher period, respectively. The later authors found that leucine was the most important BCAAs in the fitted models for broiler performance, and it affects the dietary levels of valine and isoleucine. Indicating dietary leucine content should be considered in the estimation of the ideal level of valine and isoleucine in a low protein diet. From this given background, the present review aimed to describe the response of broiler chickens to dietary valine levels, and their impact on performance, immune, gut health, carcass characteristics, and bone mineralization.

Influence of Dietary Valine

- Effects on Growth Performance

Poultry meat production focuses on maximizing performance parameters, i.e. rapid growth of chickens with low feed intake, and optimal health status of the birds. Amino acids can stimulate the growth and functioning of the body, which translates to both chicken health and improved production criteria. Among these amino acids, the focus of this review is on valine. In broiler chickens, the benefits in body weight gain (BWG), feed conversion ratio (FCR), and feed utilization as well as the minimum mortality rate were seen because of the different levels of valine supplementation in the diet (Corzo et al., 2004; Thornton et al., 2006; Berres et al., 2010b; Dozier et al., 2011; Tavernari et al., 2013; Minanda et al., 2015). Data by Farran and Thomas, (1990) showed that dietary levels of 11.6 (g/kg) for leucine, 9.0 (g/kg) for valine, and 7.8 (g/kg) for isoleucine have been proposed to support maximum weight gain and FCR in male broilers to 21- day post-hatch. Also, Dozier et al., (2012) found optimal FCR in male (Ross x Ross 708) broilers from 4- 6 wks of age receiving a diet consisting of a high Val to Lys ratio (82), when the dig Ile: dig Lys increased from 63 to 68. Tavernari et al., (2013) investigated the effect of dig valine (% of lysine) of 69, 72, 75, 78, 81, and 84% on the growth performance of male Cobb × Cobb 500 broilers in comparison with a control diet containing adequate lysine (11.5 g/kg) and valine (8.8 g/kg). Results revealed that during the starting phase (8 to 21 d of age), broilers that received a higher Val: Lys ratio, body weight gain, and FCR improved by 5.5% compared to those fed the control diet. The broilers in the grower period (30 to 43 d of age), as well had improved performance (by7 to 8%) when the test diets had higher Val: Lys ratios, indicating that the optimal dig Val: Lys ratio for broilers was 77%, whereas, for the birds in the finisher phase (30 to 43 d of age), a dig Val: Lys ratio of 76% is suggested. From 21 to 42 days of age, Berres et al. (2011) reported needs of 8.5 and 8.2 g dig Val/kg for body weight gain, 8.4 and 8.1 g dig Val/kg for an FCR, and 8.5 and 7.3 g dig Val/kg for abdominal fat using quadratic, and broken-line models, respectively for (Ross ×Ross 508) broiler males, when fed an essential diet formulated with 6.4 g dig Val/kg, and summit diet with 9.7 g dig Val/kg. Similarly, Duarte et al., (2014) conducted an experiment to investigate the impact of dietary digestible valine on the performance and carcass characteristics in broiler chickens from 22 -42 d of age by including 0.816, 0.848, and 0.903% of dig Val levels, corresponding to dig Val: lysine ratios of approximately (76.00, 79.00, and 84.12%), along with 0.8265 % dig Val considered as standard diet. Authors found that the broilers fed dig Val provided the best feed consumption, weight gain, and FCR respectively, indicating that 0.903% is the recommended dig Val level for a better overall performance of 22-42-day-old broilers. Additionally, Potença et al., (2015) found that levels of 0.90% dig valine, corresponding to a valine: lysine ratio of 66%, were sufficient to maximize broiler performance at the first 14 days of bird age; However, the higher percentage (76%) is needed to maximize muscle fiber growth. Indicating that valine has been proven to be an essential amino acid for the development of feathers during the early life stages of broiler chickens. However, some research has shown no positive effects of using dietary valine in broilers. In this regard, Foroudi and Rezamand, (2014) showed that supplemental dietary valine (0, 0.08%, and 0.16%) did not alter either body weight gain, feed intake, or feed conversion ratio. The use of vegetable feeds consisting of a corn-soybean meal has also been shown to reduce production costs without changing the performance of broilers, indicating that valine was identified as the 4th limiting amino acid in this kind of diet (Corzo et al., 2007). Also, Gyurcso et al., (2011) showed that crystalline L-valine supplementation does not significantly impact chick weight gain during the starter period (between 1-28 days of age). On other hand, Berres et al. (2010a) reported that the performance of live broilers was more sensitive to Val supplementation in the diet. A recent report has shown a non-significant effect on body weight, weight gain, and livability of broilers fed with different levels (0.04, 0.08, 0.12, and 0.16%) of valine in the diet (Selvarau and Amutha, 2022). However, a minimum dietary level of valine is crucial to achieving optimal growth, FCR, and carcass yield (Corzo et al., 2008). Regarding low-protein diets (LPD), previous studies indicated the importance of amino acids (AA), including valine, in diets LPD, especially the age period from 1-21 days. In this regard, Ardekani and Chamani (2012) showed that providing a low level of protein (18 and 16%) in the diet of female broilers up to 21 days of age, supplemented with the amino acids valine, threonine, arginine, leucine, and tryptophan (Trp) compared to the control group (20% CP, without supplementing AA), a significant increase in live body weight for 16% protein treatment and significant improvement of FCR for 18% protein treatment compared to control. Conversely, early work by Parsaeimehr et al., (1989), reported that broiler chicks 3 to 6-week-old, when received diets with a 0.1 or 0.2% valine to a 16% protein diet, failed to equal the body weight gain and feed efficiency obtained with a 20% protein diet. Indicating that a level of 0.72% valine was marginally adequate for this age broiler. In another study, Ospina-Rojas et al. (2014) indicated that pooled additions of Val and Ile to an LPD (190 g/kg) corn and soybean meal broiler diet significantly increased weight gain (WG) by 11.0% (867 versus 781 g/ chick) from 1 to 21 d post-hatch. Weight gain of chicks given this treatment was statistically similar to those fed a high protein (220 g/kg) control; however, no significant responses were observed for the FCR of valine and isoleucine. Besides, chicks were given diets containing 190 and 160 (g/kg) proteins from 22 to 42 d post-hatch. The transition from high to low protein diets reduced WG (1578 versus 1817 g/chick), but the tandem addition of Val plus Ile significantly improve the WG by 11.7% (1762 versus 1578 g/chick). As well, FCR was decreased (2.048 versus 1.816) but, individually, Val and Ile significantly improve FCR by 5.03% and 4.00% respectively. Together, Val and Ile significantly improved FCR by 6.84% (1.908 versus 2.048). These results indicate that synthetic BCAAs (Val, Leu, and Ile) are essential for poultry performance. Lee, (2020) conducted an experiment to evaluate individual feed-grade AA in commercial reduced crude protein (CP) diets fed to broilers from 0 to 48 d, L-Val and L-Ile were supplemented in addition to L-Met, L-Lys, and L-Thr to further reduce dietary CP in corn and soybean meal-based diets. Also, a Peanut meal or animal protein blend was used to replace partial amounts of soybean meal. The author confirmed that broilers maintained performance when fed reduced CP diets, independent of diet composition. Furthermore, broilers fed L-Val and L-Ile had increased breast meat yield and lower nitrogen excretion. Along with that, the partial replacement of soybean meal with an animal protein blend alleviated footpad dermatitis, whereas feed-grade L-Val and L-Ile did not. In a study conducted on Japanese quail, Emadinia et al., (2020) explained that the dietary groups included 24, 22, 20, and 18% crude protein each supplemented in order to fulfill the Val requirement (100%) and 10% more than the basic needs (110%), shows that 24% CP and 110% Val levels had a positive influence on growth performance criteria, as well, the SLC71 expression significantly improved with incremental levels of CP and Val supplementation. Adabi et al., (2019) conducted an experiment to investigate interaction effects resulting from the supplementation of low-protein feed consisting of seven treatments including two levels of dig leucine (Leu) (1.07 and 1.50%), and three levels of dig Val (0.64, 0.74, and 0.84%), as well as the diet containing 1.07% dig Leu and 0.84% dig Val supplemented with 0.34% glycine (Gly) and 1.32% glutamic (Glu) as an additional treatment (T7). The results showed that the broiler chickens fed a diet containing 0.84% Val led to a significant improvement in the feed conversion rate with 1.07% Leu, but 0.74% Val is sufficient with 1.50% Leu, and the T7 diet also led to an improvement in the feed conversion rate in broilers from 11 to 24 days. Furthermore, Toprak et al., (2021) concluded that maintained growth performance and even improved protein utilization can be achieved due to the dig amino acid-based formulation strategy and supplementing broiler diets with L-valine alone or together with L-isoleucine and L-arginine, which enables to reduce the crude protein level in broiler diets. Miranda et al., (2015) studied the formulation of diets for broilers without minimum crude protein level but using amino acids to Lys ratios as in four feeding programs (PRG) from day 1 - 7, 8

- 21, 22 – 35, and 36 - 42, as follows: PRG 1, CP restricted to 224, 211, 198, and 184 (g/kg) with minimum dig amino acid to lysine (Lys) ratios only set for total sulfur amino acid (TSAA) (0.72) and threonine (Thr) (0.65); PRG 2, as PRG 1 without CP restriction with amino acid ratios to Lys extended to valine (0.77) and isoleucine (0.67); PRG 3, as PRG 2 supplemented with L-Val and PRG 4, as PRG 3 supplemented with L-Ile, the results showed a competitive growth performance and carcass yield, as well, using L-Val and L-Ile led to improved FCR of Cobb 500 male broilers. As well, Abou-Elkhair et al., (2020) reported that reducing dietary crude protein content (CP-2%) combined with amino acid supplementation (Thr, Val, and Trp) achieved greater final body weight, weight gain, and improved FCR in broiler chickens. Kidd et al. (2021) carried out an experiment to investigate the influence of Val and Leu to evaluate their limitation and interactive effects in broilers. Three-levels (1, 0, + 1), a three-factor Box-Behnken design study was performed to evaluate dietary BCAA ratios to Lys of 65, 75, and 85 for Val, 58, 66, and 74 for Ile, and 110, 130, and 150 for Leu in males and females of Lohman Indian -River broilers from 22 - 35 days of age. The results showed that male broilers fed an increase in Ile had improved carcass yield as Leu and Val were reduced, whereas broiler females had enhanced BWG and FCR when Leu and Ile were at their lowest levels, independent of Val. Furthermore, increasing dietary Ile and Val in female broilers increased breast meat production, whilst the author indicated that increasing Leu tended to diminish the response. More recently, the inclusion of amino acids and prebiotics in the poultry diet also has been studied, to investigate their impact on the growth and health of birds. In this regard, Ahmed et al., (2021) conducted a trial to investigate the influence of chitosan oligosaccharide (COS), and valine on the growth performance, and carcass traits of broiler chickens, based on a factorial design (2×4), using eight treatments for two levels of COS (C1: 100 mg/kg, and C2: 150 mg/kg); and four levels of valine (V1: 0.57%; V2: 0.72%; V3: 0.87%; and V4: 1.02%) of the diet. The results revealed that the average body weight, weight gain, and carcass weight were increased, while the abdominal fat reduced linearly for both dietary treatments (COS and Val), with a higher reduction response value at COS (150 mg/kg), and V4 (1.02%). The authors suggest that these supplements will improve the meat quantitates and qualitative.

- Effects on Carcass Characteristics

A dietary valine has positive effects on carcass characteristics and organ development in broilers as shown by previous authors. The results obtained by Miranda et al., (2015) showed that breast yield declined after broilers were fed diets with low-protein content, while it increased when birds got extra valine in their feed. The authors concluded that breast meat is considered a higher price of carcass than the other components. Nowadays, producers are trying to direct feeding toward improving breast yield. BCAAs (Branched-chain amino acids) such as valine provide approximately 18% of muscle myofibrillar protein and hence have an important role in the composition of broiler carcasses (Baracos and Mackenzie, 2006). Corzo et al., (2011) carried out an experiment to investigate the influence of L-Val on broilers' growth in a finisher-phase from 28 to 42 days of age by feeding various L-Val inclusion levels ranging from 0 - 1.3 (kg/ metric ton), this was accomplished by blending a diet with no L-Val with one that contained 1.3 (kg/ metric ton) of L-Val. The authors indicated that the birds fed diets consisting of 0.52 (kg/metric ton) L-Val showed supported suitable growth and meat yield when compared with a diet freed from L-Val. While the inclusion of L-Val levels greater than 0.52 (kg/metric ton) caused poor feed conversion ratio, breast meat weight, and breast meat yield (%), indicating that, L-Val supplementation at levels below 0.52 (kg/metric ton) showed the ability to support good production and could potentially offer a useful feed cost lowering alternate. Allameh and Toghyani (2019) conducted a trial to investigate the effects of valine supplementation in a low protein diet (100%

(CP100); 90% (CP90); and 85% (CP85) on broilers' breast yield. The results showed that birds fed a diet including valine improved significantly breast yield broilers compared to those fed on CP90 and CP85 diets without Val supplementing. In Ross 308 broilers, an intake of 10% and 20% valine significantly increased breast weight compared to the recommended level (Parsaeimehr et al., 2022), the authors confirmed that the intake of high levels of valine and tryptophan in the low-protein diet resulted in improved carcass characteristics. Abul-Khair et al. (2020) showed that the inclusion of compound amino acids (Thr, Val, and Trp) in a low crude protein diet resulted in an increase in the eviscerated carcass weight, and thus the carcass, breast, and meat yield of broilers. Thornton et al., (2006) stated that the supplementation of 7.2g Val/kg of broilers' diet had more abdominal fat than those given 8.2g Val/kg, whereas, no significant changes in growth or other carcass measurements were noted. In contrast, previous studies indicate that the supplementation of various levels of valine in different phases did not affect carcass development in broilers (Corzo et al., 2007, 2008; Kaplan and Yildz, 2017; Agostini et al., 2019). Kumar et al., (2015) stated that the formulation diets based on deficiencies of specific second-line amino acids (valine, isoleucine, and tryptophan) negatively affect carcass yield. As well, the supplementing of dig valine (0.866, 0.935, 1.009, 1.084, and 1.158%) in the diet formulated with lower-protein (2% reduction of CP) diets reduced muscle fiber diameter without affecting carcass and parts yields, or abdominal fat percentage in 42-days old broilers (Nascimento et al., 2016). As regards to Val: Lys ratio in broilers, Corzo et al., (2008), revealed that the carcass weight, total boneless-skinless breast meat, and drumsticks were optimum when the dietary valine level was 0.82, 0.82, and 0.83%, respectively. On the contrary, Tavernari et al., (2013) did not get significant changes in carcass characteristics (carcass, breast, and thigh yields) related to the effect of the different Val: Lys ratios in male Cobb broilers (30 to 42-day-old).

Another study, by Dozier et al., (2012) evaluated the impact of 0.74, 0.78, or 0.82 of dietary dig Val: Lys ratios on growth performance and carcass characteristics of broilers. The study concluded that no significant impact was indicated on performance or carcass traits when male broilers (Rose -708) were fed a dig valine: lysine ratio, indicating that the 0.74 digs Val: dig Lys ratio could be sufficient. In another study, by Agostini et al., (2019), no significant impact on the carcass or breast meat yield (%) was observed when male broilers (Cobb 500) were fed the optimum analyzed Val to Lys ratio for 42 days. A study carried out by Schedle et al., (2019), to evaluate the dig Val requirements of growing - finishing broilers (Ross-308), showed that valine is a limiting amino acid in broiler diets, and when broilers are fed crude protein- lowered diets with a dig Val: Lys ratio less than 80%, growth performance but not carcass composition was significantly influenced. On other hand, Ospina-Rojas et al., (2017a) confirmed the significance of the leucine and valine interaction in low-crude protein finisher diets for broiler chicks from 21 - 42 d of age, on performance, the results showed no significant interaction appeared for carcass yield and diameter of the muscle fibers between these two amino acids Recently, Kop-Bozbay and Ocak (2022) reported that administered BCAAb (Branched-chain amino acids blend), L-leucine, L-isoleucine, and L-valine) in ovo (2 mg/ml) or in the starter diet (2 g/kg) improved earlier growth performance, and enhanced the fiber traits of the Pectoralis major muscle in the Turkey poults until 21-d old.

- Effect of Valine on the Immune System

One way to improve immune response and avian health is by using nutritional supplements. The importance of amino acids to immunity has become apparent in recent years due to studies that have supplemented AA in bird diets. In this context, studies have shown that amino acids play an important role in regulating immune responses, including activation of lymphocyte cells, natural killer cells, macrophages, lymphocytes proliferation, regulation of intracellular redox balance, gene expression, and the production of cytokines (Calder, 2013). Previously, the study by Corzo et al., (2007), and Zhang et al., (2016), demonstrated that the immune status of broiler chickens enhanced, with an improvement in the function of immune organs. Increase activity, and an increase in the weight of lymphoid organs (Thymus, bursa of Fabricius, and spleen), for example, can cause more antibody production, which positively affects avian health. On other hand, Monirujjaman and Ferdouse, (2014) reported that in the liver, among branched-chain amino acids (BCAAs) (Valine, leucine, and isoleucine), mainly valine prompts the lymphogenesis of granular lymphocytes cells as well as increases natural killer cells. BCAA (Leu, Ile, and Val) specifically contribute to the synthesis of glutamine in skeletal muscle and are essential for lymphocyte proliferation in response to immune stimulation (Newsholme and Calder, 1997). Therefore, dietary BCAA limitation weakens several aspects of immune function and increases susceptibility to various pathogens (Li et al., 2007). In broilers, it has been shown that valine, which constitutes about 18% of myofibrillar protein, can be associated with a decline in the weight of immune organs (Konashi et al., 2000; Baracoset and Mackenzie, 2006). Previously, some reports revealed that valine excess or deficiency in the diet can lead to impaired immune function, along with increased susceptibility to disease by impairing the proliferation of liver-associated lymphocytes (LAL), and cytotoxic lymphocytes (Tsukishiro et al., 2000; Nakamura 2014). Therefore, adequate inclusion of valine in the diet may lead to the resumption of defense mechanisms of the host, for example, natural killer cells activity, and the phagocytic function of neutrophils (Weichhart and Saemann, 2009). With regard to the impact of valine levels in diet on the immune response, an earlier report by Bhargava et al., (1971) revealed that the deficiencies of valine reduced antibody production against the Newcastle disease (ND) virus in chickens. Over the experiment of 3 to 6 weeks, Ross -508 broilers fed on valine

International Journal for Scientific Research, London Vol (3), No (4), 2024
https://doi.org/10.59992/IJSR.2024.v3n4p1 E-ISSN 2755-3418

which increased from 6.4 - 8.65 g/kg, no changes were noted in the immune organs or antibodies titer against ND, concluding that a minimal deficiency of valine will not compromise immunity because the requirements for immunity may be less than the requirements for the growth of the bird, and these results suggest that valine is essential for growth and physiological functions; but its ratio to other amino acids, specifically the other BCAAs (valine, leucine, and isoleucine), is essential for optimal response (Thornton et al., 2006). The same author concluded that dietary valine levels had no effect on the innate or adaptive immune functions in broilers that were measured. On other hand, Foroudi and Rezamand (2014) confirmed that dietary valine supplementation has an immunomodulatory effect on the production of specific antibodies against the ND virus in Ross-308 male broilers. As well, valine supplements with 11.2 (g/kg) in a pre-starter diet (1 to7 days of age) improved lymphocyte proliferation in the spleen of broilers (Silva et al., 2021). Kaplan and Yildz (2017) reported that the lymphoid organs (spleen and bursa of Fabricius) in broiler were not affected by different levels of valine in the diet, whereas a significant effect in thymus development in the group fed with a ratio containing 1% valine on either 0 to 21 days or 21 to 42 days, indicating that immune response can be affected by valine. Further study with male broilers of Ross 308 receiving diets provided with valine, 10% above control (diet with recommended levels of valine), and 20% higher than the control diluted in a diet containing 2% protein, indicated that diets containing 20% valine significantly increased the hemagglutination-inhibiting (HI) antibody, and humoral immune responses, the total secondary response and IgM secondary response to SRBC (sheep red blood cell injection), as well level of 20% valine, significantly improved the cellular immunity as compared to control and the lower level of valine. On the other hand, different levels of valine had a significant effect on the injection reaction of PHA-P, while no significant effect on the weight of the spleen, bursa of Fabricius, liver, and white blood cell of broiler chickens (Parsaeimehr et al., 2021). In a subsequent study Parsaeimehr et al., (2022) evaluated the influence of feeding nine levels of dietary valine and tryptophan in low protein diets on the immune system and carcass characteristics of broilers, these treatment groups included:1) recommended level (Rec) of valine (Val) + Rec of tryptophan (Trp); 2) Rec Val + 5% more than Rec Trp; 3) Rec Val + 10% more than Rec Trp; 4) 10% more than Rec Val + Rec Trp; 5)10% more than Rec Val + 5% more than Rec Trp; 6) 10% more than Rec Trp + 10% more than Rec Trp; 7) 20% more than Rec Val + Rec Trp; 8) 20% more than Rec Val + 5% more than Rec Trp; 9) 20% more than Rec Val + 10% more than Rec Trp. The results showed that the addition of 20% valine increased thymus and bursa weights, and humoral immunity, besides a significant effect on immunoglobulin M secondary response SRBC, whereas the effect on the PHA-P injection response was not significant. Furthermore, the inclusion of 10% tryptophan increased the blood lymphocytes of broilers at 21 days of age. In a study in which in ovo injection of critical amino acids, Leu, Ile, and Val at a dosage range of 4-7 (mg) in 0.5 (ml) sterile water, resulted in a 21% increase in first-week body weight, besides a rise in humoral, and cellular immunity as compared to control in broiler chickens (Bhanja and Mandal, 2005). Abou-Elkhair et al., (2020) showed that the inclusion of combined amino acids (Thr, Val, and Trp) in a low-protein (a 2% CP reduction) diet improved phagocytic activity, and phagocytic index, as well as up-regulation of the immune-related genes in broiler chickens.

- Effects on Gut Health

According to research by Oviedo-Rondón et al., (2019), gut health has a significant impact on poultry productivity, animal welfare, and food safety. In broilers, the gut is exposed to many challenges that alter the performance, health, welfare, and livability of birds. Preventive strategies are required to mitigate the effects of these challenges on gut health while reducing the need for antimicrobial use (Chalvon-

Demersay et al., 2021). To demonstrate the functional role of amino acids in intestinal health, Wu (2013) revealed that amino acids are energy sources, precursors of functional molecules and proteins, modulate gene expression and protein phosphorylation, and can serve as microbiota modulators. Allameh and Toghyani (2019) observed that the villus height to crypt depth ratio was higher in broiler chicks (Ross 308) who received diets supplemented with Val in low crude protein (CP) diets (with 90% or 85% CP) than those fed on CP100%, indicating that dietary Val supplementation had a beneficial effect on intestinal morphology. Adabi et al., (2019) conducted an experiment to investigate the interaction effects on jejunum villus that resulted from supplementation of low protein diets consisting of seven treatment groups including two levels of dig Leu (1.07 and 1.50%), and three levels of dig Val (0.64, 0.74, and 0.84%), as well the diet with 1.07% dig Leu and 0.84% dig Val was supplemented with 0.34% Gly and 1.32% Glu as an additional group. Results showed a significant interaction between (Leu × Val) for villus height (VH), crypt depth (CD), and goblet cell (GC) numbers. As well, Val at 0.84% maximized the growth of the jejunum at the lower Leu level, while GC and CD were decreased by an increment of valine at the higher level of leucine in broiler chickens at 24 d old, indicating that, the amino acids Val, Leu, and the possibility of glycine-glutamic fortification must be considered when formulating reduced protein diets for broiler chicks. Silva et al., (2021) reported that the inclusion of 11.2 (g/kg) valine in pre-starter diets (1to7 days of age) improved nutrient metabolizability coefficient, increased VH, and VH: CD ratio in the duodenum, jejunum development, and lymphocyte proliferation in the spleen of broiler chicks at 7 days of age, without improving their growth performance.

- Bone Mineralization

Studies with several broiler species suggest that dietary protein and several amino acids may be beneficial for bone health. Rostagno et al., (2011) reported that tibiotarsus breaking strength was maximized in broiler chicks from day 1-21 with the dietary levels of Leu, and Val at 14.2 and 9.0 (g/kg) respectively. Foroudi and Rezamand, (2014) mentioned that broiler chicks fed levels of valine slightly higher than the NRC recommendations (1994) can better boost the immune system, and assimilate higher levels of calcium in the femur and tibia bone, however, the phosphorous concentration was slightly decreased in these bones. Besides that dietary valine levels influenced some bone characteristics in birds, in this regard Farran and Thomas (1992b) indicated that feeding broilers on a valine-deficient diet led to a decrease in bone calcium and ash concentrations and lower bone weight, suggesting a reduction in osteoblast activity by the low levels of this amino acid. According to the authors, valine deficiency per se increased calcium excretion in urine and induced leg abnormality in young chickens. On other hand, Ospina-Rojas et al., (2017b) did not notice any significant changes in bone concentrations of calcium, phosphorus, and ash, diameter, and Seedor index of the tibiotarsus bone at age of 21 or 42 days, when broiler's diet was supplemented with standardized ileal digestible Leu and Val at levels ranging from 10.0 to 19.6 (g/kg), and 6.0 to 12.0 (g/kg) from day 1 to 21 post-hatch, respectively, while day 21 to 42 post-hatch ranged from 10.0 to 18.0 g Leu/kg, and 5.2 to 11.2 g Val/kg. As well, the authors found that tibiotarsus breaking strength was maximized in birds from day 1-21 with the dietary levels of Leu and Val at 14.2 and 9.0 (g/kg) respectively. Adabi et al., (2019) reported that dietary groups in which a reduced protein diet was supplemented with L- Leucine (1.07 and 1.50%), L-Valine (0.64, 0.74, and 0.84%), and glycine (0.34%) and glutamic acid (1.32%), the increasing dietary Val from 0.64 to 0.74 (%) significantly improved bone density and strength at the minimum level of leucine, whereas in treat 7 (1.07% Leu, 0.84% Val, 0.34% Gly, 1.32% Glu) significantly improved tibia breaking strength in broiler chickens at age 24 days. On the other hand, Kop-Bozbay and Ocak, (2020) stated that a mixture of Leu, Ile, and Val in

3:1:2 ratios enhanced early embryonic development of neonatal from Turkey poults by promoting skeletal muscles development.

- The Effects of Valine Deficiency in the Broiler Diet

In diets consisting mainly of corn and soybean meal-based, there is no significant deficiency of amino acids such as isoleucine, valine, arginine, and tryptophan. Nonetheless, a deficiency of these amino acids in a diet based on plant -protein sources can be even more serious. So, valine could be the next limiting amino acid next to or after threonine in the diet unprocessed with animal-protein sources (Thornton et al., 2006). On other hand, BCAAs (which include Leu, Ile, and Val), are among nine essential amino acids (EAAs) which are fundamental dietary needs for the growth and metabolism of all animals. They are not degraded by liver enzymes, and can easily diffuse into body tissues (Miranda et al., 2015; Lee et al., 2020). Conversely, for other BCAAs, valine is a limiting amino acid in the corn and soybean meal-based diets, and it is more susceptible to antagonism and enzymatic degradation than isoleucine in response to added leucine in the diets. Thus, Val must often be supplemented with a low CP diet (Nascimento et al., 2016). According to Kim et al., (2022), the functional role of valine in poultry includes increasing plasma glucose, increasing anti-filamentary cytokines, decreasing pro-filamentary cytokines, and improving dendritic cell function. A previous study by Harper et al., (1984) revealed that for poultry, a supplement of sufficient valine is essential for maintaining higher productive performance, and an excess or deficiency of valine could result in antagonism among BCAAs. Focusing on valine deficiency, feather, and leg abnormalities occur (Farran and Thomas, 1992 a, b), affecting the antibody titer (Bhargava et al., 1971) and a failure of lymphoid organs development (Konashi et al., 2000A few studies on valine have reported that performance is negatively affected if optimal rates cannot be provided (Corzo et al., 2008). A previous study by Farran and Thomas (1992a) investigated the effect of Valine deficiency on growth parameters, bone calcium, feather protein, and feather amino acids. Three dietary treatments groups [(a BCAA-deficient diet with 0.96% Leu, 0.52% Ile, and 0.63% Val); a Val-deficient diet (which contained 1.37, 0.82, and 0.63% of Leu, Ile, and Val, respectively); and a Val-supplemented diet (which contained 1.37, 0.82, and 0.83% of Leu, Ile, and Val, respectively)]. The authors found that valine deficiency significantly decreased weight gain, feed conversion ratio, bone calcium, and feather protein. Also, Val-deficient decreased the level of cystine in feathers, while increasing those of amino acids (Met, Lys, His, Asp, Glu, and Tyr) in the feathers of 3-week-old male broilers. On the other hand, Amirdahri et al., (2020) noted that the inclusion of ingredients containing more valine is essential, as a diet with valine deficiency can lead to poor growth performance along with defective feathers and legs in female Cobb broilers. On other hand, formulation of diets based on deficiencies of specific second-line amino acids (SLAA; valine, isoleucine, and tryptophan) resulted in decreased performance, carcass yield, and poor utilization of metabolic energy, crude protein, and amino acids linearly to the extent of commercial poultry deficiency (Kumar et al., 2015). As well, Barsila, (2020) confirmed that the deficiency (16-50%) of branched-chain amino acids like isoleucine, leucine, and valine reduces the antibody titers against SRBC in broilers.

Disadvantages of Excess Valine in Broiler Diet

In regard to high valine diets for broiler chickens, an early study conducted by Edmonds and Baker, (1987) stated that the addition of excessive (4 %) L- valine to broiler diets caused minor effects on weight gain (- 4%; P≥0.05), while the feed intake was depressed significantly by 6 %. As well, Carew et al., (1998) reported that broilers fattening fed a diet inclosing 3.15 % L-valine showed a significantly declined growth rate, but without influence on feed intake in chicks up to 3 weeks of age. In laying hens diets, Azzam et al., (2015) suggest that high concentrations of L-Val (1, 2, 3, and 4 g/kg) are tolerated, and can be successfully supplemented into diets without detrimental effects on laying performance or immune function of laying hens.

Conclusion

Valine is an important essential amino acid for birds. It is one of the branched-chain amino acids (BCAAs), including leucine, isoleucine, and valine, an essential amino acid important for animal growth and development. It is clear from those studies whose results are discussed in this review, that valine is an essential amino acid for growth and physiological functions; but its ratio to other amino acids, especially BCAAs, which essential for optimal response. A diet supplemented with valine improves muscle growth and gut health, leading to better absorption of nutrients, and ultimately improving the carcass traits of broiler chickens. Feeding with levels of valine slightly higher than the recommendations of NRC (1994) can better boost the immune system, and absorb higher concentrations of calcium in the femur and tibia bones, maximizing bone-breaking strength. Valine -deficient diet can lead to poor growth performance besides defects in the feather and legs. Excessive excess of valine in the diet also leads to depressed feed intake.

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