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INFLUENCE OF BRANCHED-CHAIN AMINO ACID SUPPLEMENTATION ON GROWING MOUNTAIN RABBIT'S PRODUCTIVE PERFORMANCE

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SUMMARY

The objective of this study was to measure the productive performance of growing rabbits as influenced by the two different level of dietary protein under three levels of branched-chain amino acids (BCAAs) supplementations. A 90-day feeding trial was conducted. A total rabbits were 72 at the age of 8 weeks were weighed when rabbits arrival at the farm and randomly distributed to six experimental groups. (G1): rabbits fed control diet contain recommended protein level (18% CP) without any supplementation. (G2 and G3): rabbits fed control diet contain recommended protein (18% CP) supplemented with 2 g BCAAs/kg diet 2:1:1 and with 2 g BCAA/kg diet 3:1:2 (luecine: Iso luecine: Valine). (G4): rabbits fed control diet contain low protein level (17% CP) without any supplementation. (G5 and G6): rabbits fed control diet contain low protein (17% CP) supplemented with 2 g BCAAs/kg diet 2:1:1 and 2 g BCAAs/kg diet 3:1:2 (luecine: Iso luecine: Valine). Group rabbits fed (G3) achieved the highest significantly ($P<0.05$) DM, OM, CP, EE and NFE digestion coefficients. Also, nutritive values in term of DCP and TDN, followed them group fed (G2) and followed by (G6), (G1) then group fed (G5). Rabbits group fed (G3) achieved significantly the highest final LBW, total gain, and daily gain, followed them in the values the group fed recommended dietary protein (G2) and (G6), which did not show any significant differences between them in the final body weight of rabbits, Group fed (G3) recorded the best feed conversion ratio compared to the other groups. rabbits fed recommended protein (G3) achieved The highest significantly ($P<0.05$) carcass weight values, followed them in the values of the group fed recommended protein (G2) and (G6), rabbits fed (G6) achieved the highest significantly ($P<0.05$) Arginine, Isoleucine, Histidine, Leucine, threonine, , phenylalanine, Valine and tryptophan values, followed them in the values of the group fed (G2) and (G6), Rabbits fed (G1) and (G4) achieved the highest significantly ($P<0.05$) TVN and TBA values, rabbits fed (G3) achieved The highest significantly ($P<0.05$) antioxidant activity presented in GPx, SOD and CAT (U/mg protein) values, followed them in the values the group fed (G2) and low protein (G6), While the lowest values were significantly recorded for the 18% and 17% groups at 0g BCAA level for oxidative activity. Rabbits fed (G3) achieved the highest significantly ($P<0.05$) T.P globulin, albumin, creatinine, urea, AST and ALT, Also, immunity values in term of IgG and IgM. And the highest relative economic efficiency recorded by (G6 and G3). Overall, Group 3 recorded the best results obtained, while Group 3 and 6 recorded the best results in economic efficiency calculations.

Keywords: *branched-chain amino acid, productive performance, nutrient digestibility, blood parameters.*

INTRODUCTION

The meat of rabbits is consider an excellent nutritional value due to it is high in essential amino acids, polyunsaturated fatty acids, minerals and vitamins, lacks in uric acid when compared to other meats, and has a low cholesterol level (Lamiaa *et al.*, 2022). The ability of weaned rabbits to grow up well and defend themselves from significant mortality during the fattening stage is important for rabbit farm profitability (Selim *et al*, 2021).

Proteins are macromolecules in the body that are essential for all cellular processes. Each protein is made up of a chain of (amino acid) AA in a specific sequence (Toyama and Hetzer, 2013). An AA is a molecule with two functional groups (carboxyl- and amino groups) and an organic substituent (R group) that accounts for the unique features of each AA. Amino acids serve a variety of functions in the body.

The majority of the metabolic pool of AA is utilized to create proteins, with a lesser amount required to synthesize specialized nitrogenized compounds such as epinephrine and norepinephrine, neurotransmitters, and purines and pyrimidine precursors. 9 of the 20 amino acids required for protein synthesis cannot be synthesized by animals, or cannot be synthesized in sufficient amounts; hence, they must be given through feed and are referred to as indispensable/essential AA. Some AA are classified as semi-essential AA because they can be created from other necessary AA, while endogenous synthesis may not be sufficient depending on the individual's stage of development and their health , and should thus be supplemented by nutrition. Non-essential or dispensable AA are those that can be produced in the body (Boisen, 2003).

Branched-chain amino acids (BCAAs) which include (isoleucine, leucine and valine) essential amino acids. All three BCAAs contain a hydrophobic side chain and are structurally identical to branched-chain fatty acids. The chemical formula for isoleucine is (2-amino-3-methyl-pentanoic acid), leucine is (2-amino-4-methyl-pentanoic acid), and valine is (2-amino-3-methyl-butanoic acid) (Adeva-Andany *et al*., 2017) (Figure 1).

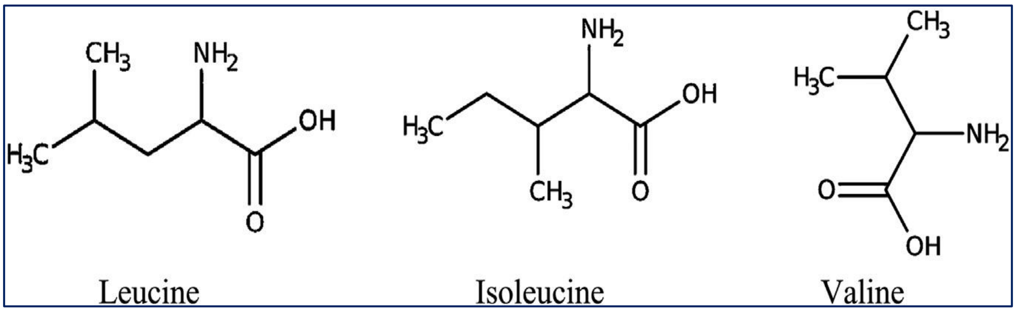

Figure (1): Branched-chain amino acid structures

Valine is the limiting amino acid in the corn and soybean diet, unlike the other BCAAs, and it is more vulnerable to antagonism and enzymatic breakdown, than iso-leucine in response to dietary leucine addition. In a low CP diet, valine needs to often be supplied (Nascimento *et al*., 2016). Each of the three BCAAs have a similar structural and are broken down by two different enzymes: branched-chain aminotransferase (BCAT) and branched-chain a-keto acid dehydrogenase complex (BCKD), which catabolizes coenzyme A molecules irreversibly (Brosnan and Brosnan, 2006). One of the BCAAs, most frequently leucine, stimulates this enzymatic activity, which causes the catabolism of other BCAAs. As a result, an excess of one BCAA may cause the catabolism and depletion of other BCAAs found in the less concentration. Supplement of BCAAs, which include isoleucine, leucine and valine can allow decreasing the quantity of crude protein (CP) in the diet.

When low CP diets are designed by limiting protein sources and boosting leucine-rich cereals, the possibility of antagonistic effects of leucine on other BCAA rises. In poultry, a high dose of leucine combined with an imbalance of other AA may accelerate AA breakdown and decrease muscle accretion (Ospina-Rojas *et al.,* 2020). Given the minimal needs for each BCAA, the optimal ratio in a low protein diet may differ from the right ratio in a high protein or sufficient protein diet. A high protein meal may be better used by animal during their early growth period, and it would give a larger concentration of limiting AA (Ospina-Rojas *et al.,* 2020). This may avoid AA deficiency issues, but the high protein level may not assure appropriate utilization of BCAA provided in low concentrations or other AA present in excess. A lack of balance in dietary BCAA has been shown to have a negative impact on productive performance of broilers (Ospina-Rojas *et al.,* 2020). Konashi *et al*. (2000) showed in a broiler research that a 50% shortage of each of the three BCAA reduced the body weight of 24-day-old chicks by one fourth comparing to the control, but birds fed a diet that was 50% deficient in sulfur-containing AA lost approximately one-third of their weight.

The scientists additionally found that a low BCAA diet dramatically reduced the weight in percentage of the bursa of Fabricius and the thymus compared to the control, indicating that BCAA plays an important role in lymphoid organ development and immunological response in broilers (Konashi *et al.*, 2000). BCAA influence gene expression and signal transmission for protein synthesis, in addition to being used in many metabolic pathways (Bai *et al*., 2015).

The combined quantity of the three BCAAs is known to constitute for one-third of total protein in muscles, which means that they play an important function in avoiding protein breakdown under heat stress and stimulating muscle growth and development (Kop-Bozbay and Ocak, 2015)

According to Busquets *et al.* (2000), BCAAs prevent lysosomal proteolysis (protein breakdown) of muscles in the skeleton in the short run and possibly decrease ATP-dependent the proteolysis process over the long term in rats. In addition to having an impact on muscle protein synthesis, a lack of BCAAs increases b-oxidation of fatty acids via the AMPK-,mTOR-,FoxO1 pathways (Bai *et al.*, 2015).

Leucine has been shown to be more powerful than other BCAAs in promoting protein synthesis via the mTOR pathway and to have a larger role in immunological function (Wu, 2010). Mattick *et al*., (2013) discovered that BCAA might lower oxidative stress by eliminating reactive oxygen species, in addition to improving immunological function.

The population of bacterial species in addition to other microorganisms living in a bird's intestines, often known as the gut microbiota or gut microbiome, has an impact on the utilization of feed components, overall growth performance, and immunological state (Singh and Kim, 2021). Before recommending a BCAA ratio for the diet, it is important to assess how BCAAs affect the variety of the intestinal microbiota in poultry. Other than the lysine, methionine and threonine that are the 3 limiting amino acids in maize and soybean meal for poultry diets (Singh *et al.*, 2019), BCAA may additionally be limiting, and specialists agree on what could be recognized as the fourth and future essential AA in the diets of poultry. Previous research resulted in supported for both of the amino acid isoleucine or valine (Corzo *et al*., 2010). Several studies suggest there BCAA should be considered co-limiting totally dependent on the dietary CP content and feed components (Maynard *et al.*, 2020). It has been attempted to categorize the BCAA requirements for animals during the previous ten years. It is more difficult to come to a conclusion because of the interactions between BCAAs caused by the shared enzymes in their degradation, which might modify how much valine and iso Leucine is needed (Maynard *et al.*, 2020).

The requirement for BCAAs is affected by the breed, diet type and age of animal, several studies were looking at the effects of BCAAs in low protein diets as a way for lowering nitrogen excretion, additionally, researches on the inclusion ratio of BCAAs supplementation is limited (Ospina-Rojas *et al*., 2020).

The purpose of this study was to prove the effects of BCAAs on performance, immunity, meat quality, meat antioxidants, meat amino acid profile, carcass characteristics, blood parameters, and economic feed efficiency of mountain growing rabbits. It also provides a comparison of different levels of BCAA requirements in commercial rabbit guides, with those recommended protein ratios by NRC (1994) and low dietary protein ratio. Making BCAAs ratio recommendations for rabbits' diet.

MATERIAL AND METHODS

This research was done on a private farm El Dear, Kalubia, Egypt. Analyzed samples of feed, faces, meat, and blood were conducted at the faculty of veterinary medicine at Benha University, Egypt, food analysis lab. The growth trial was done from 10/1/2023 to 15/4/2023. Climatic data of the experimental site (Qalubia) in January 2023 to April 2023 (winter season, the average actual temperature was 27.2 ºC and average relative humidity was 42.75 %)

Animals, diets and experimental design:

Feeding trials were conducted out. The study used eight-weeks-old male local mountain rabbits with an average body weight of 803.89±28.78 g. They were housed in galvanized metal wire cages with water and food to ensure their health and growth. 72 rabbits were split into six equal groups consisting of 12 animals (4 replicates, 3 rabbits each). The rabbit growth experiment continued for 90 days. Branched chain amino acids were purchased from Technogen Company, Dokki, Giza.

- The first group (G1): rabbits fed control diet contain recommended protein (18% CP) without any supplementation.
- The second group (G2): rabbits fed control diet contains recommended protein (18% CP) supplemented with 2 g BCAA/kg diet 2:1:1 (luecine: Iso luecine: Valine)

- The third group (G3): rabbits fed control diet contain recommended protein (18% CP) supplemented with 2 g BCAA/kg diet 3:1:2 (luecine:Iso luecine: Valine)
- The fourth group (G4): rabbits fed control diet contain low protein (17% CP) without any supplementation
- The fifth group (G5): rabbits fed control diet contain low protein (17% CP) supplemented with 2 g BCAA/kg diet 2:1:1 (luecine: Iso luecine: Valine)
- The sixth group (G6): rabbits fed control diet contain low protein (17% CP) supplemented with 2 g BCAA/kg diet 3:1:2 (luecine:Iso luecine: Valine)

  - The feed materials were mixed together, and then branched chain amino acids (BCAA) were added before the feed compositions were pressed into pellets. A chemical analysis of the feed was done just before the start of the experiment to check the amounts of the extra BCAA.

Growth performance:

During the trial, all rabbits were weighed at the start (0day).and at the end of the study (90 days). The given feeds were examined in order to ensure that they matched the maintenance and production requirements of each animal. Every day at 6:00 a.m., 2:00 p.m., and 10:00 p.m., pelleted feed was provided. The requirements were calculated in accordance with a ministerial (1996) directive issued by the Ministry of Agriculture and Land Reclamation in 1996. Feed refusal had been collected every day when experimental diets were administered. Every week, body weights were taken in. If there were any health issues, rabbits were treated directly and were regularly monitored. The components of the experimental basal diet are displayed in Table (1).

Table (1): Ingredients Composition of basal diets (dietary protein 18% and 17% CP)

Composition		Composition	
Ingredient	**(18%CP)**	**Ingredient**	**(17%CP)**
Yellow corn	9.4	Yellow corn	9.4
Wheat bran	7.2	Wheat bran	7.2
Soybean meal (44%CP)	22.85	Soybean meal (44%CP)	18.85
Barley	25.78	Barley	27.78
Clover hay	28.6	Clover hay	30.6
Molasses	3	Molasses	3
Limestone	0.7	Limestone	0.7
Di- Calcium phosphate	1.3	Di- Calcium phosphate	1.3
NaCl	0.3	NaCl	0.3
DL-Methionine	0.3	DL-Methionine	0.3
Premix[1]	0.57	Premix[1]	0.57
Total	100	Total	100

[1]Premix is delivered per kilo gramme of diet- 8 mg riboflavin- 1.3 milligrammes menadione- 40 mg nicotinamide- 2.2 mg thiamin- 600 mg choline chloride- 10 milligrammes of calcium pantothenate; 0.04 milligrammes of biotin- mg folic acid- 4 mg pyidoxine HCl,; 80 mg ferrous - 3,000 IU vitamin D3,- 10,000 IU vitamin A and 30 IU vitamin E.

Table (2): Chemical analysis (on DM basis) of diets with different levels of branched chain amino acids (BCAA).

Nutrient analysis	G1	G2	G3	G4	G5	G6
Moisture (%)	9.1	9.0	9.1	9.3	9.2	9.2
Crude Protein (%)	18.1	18.3	18.3	16.9	17.0	17.1
Crude fiber (%)	12.5	12.3	12.4	12.6	12.4	12.3
Crude fat (%)	2.6	2.5	2.5	2.6	2.7	2.7
Ash (%)	7.8	8.0	7.9	7.9	7.8	7.9
Leucine (%)	0.15	0.24	0.25	0.10	0.21	.21
Iso-leucine (%)	0.09	0.13	0.14	0.07	0.11	.11
Valine (%)	0.10	0.15	0.17	0.08	0.14	.16
Lysine (%)	1.27	1.27	1.25	1.26	1.23	1.24
Methionine (%)	0.60	0.58	0.57	0.59	0.58	.56

Cysteine (%)	0.49	0.46	0.49	0.47	0.46	.47
Calcium (%)	1.06	1.04	1.05	1.05	1.06	1.03
Phosphorus (%)	0.75	0.75	0.74	0.75	0.73	0.72
Sodium (%)	0.25	0.23	0.23	0.23	0.24	0.25
Potassium (%)	0.13	0.12	0.13	0.14	0.14	0.13

G1: Rabbits fed control diet contain recommended dietary protein (18% CP) without any supplementation.
G2: Rabbits fed control diet contains recommended dietary protein (18% CP) supplemented with 2 g BCAAs/kg diet 2:1:1 (luecine: Iso luecine: Valine).
G3: Rabbits fed control diet contain recommended dietary protein (18% CP) supplemented with 2 g BCAAs/kg diet 3:1:2 (luecine:Iso luecine: Valine).
G4: Rabbits fed control diet contain low dietary protein (17% CP) without any supplementation
G5: Rabbits fed control diet contain low dietary protein (17% CP) supplemented with 2 g BCAAs/kg diet BCAAs/kg diet 2:1: (luecine: Iso luecine: Valine)
G6: Rabbits fed control diet contain low dietary protein (17% CP) supplemented with 2 g BCAAs/kg diet 3:1:2 (luecine:Iso luecine: Valine).

Fresh water was present at all times during the study. Dry matter intake (DMI), body weights (BW), and average daily weight gains for each individual animal were recorded every two weeks. The ratio of total feed consumption (g) to total body weight gain (g) has also been used to calculate the feed conversion ratio (FCR).

Digestibility coefficient trial:

Five rabbits were randomly chosen from each group at the ending of the feeding experiment and kept in separate cages with a way to separate faeces and urine, followed by a 3-day collection of faeces. Daily dietary intake and total faecal output of each rabbit were exactly documented during the collection period (Perez *et al.,* 2010).

Blood parameters:

Five rabbits from each group had their jugular veins sampled for blood. Four hours after feeding, each rabbit had blood drawn (5 ml) into a clean, dry tube without the use of anticoagulants. To get blood serum, blood samples were centrifuged at 4000 rpm for 30 minutes. For further examination, serum was divided into 2-ml clean, dry Eppendorf tubes and stored at 20°C.

Globulin was computed by subtracting albumin from total protein according to the Doumas *et al.* (1971) technique for determining albumin. According to Roschlau (1974). Results for aspartate aminotransferase (AST) and alanine aminotransferase (ALT) were calculated in accordance with Reitman and Frankel (1975) and represented as IU/L. Using the readily accessible commercial kits offered by Biomerieux, France, creatinine expressed as mg/dL was applied using the Julian (2000) approved method. According to Patton and Cronch (1979), the blood urea nitrogen was measured using an enzymatic colorimetric method. Following the instructions, we used commercial bio diagnostic kits from Bio Diagnostic Company (Giza, Egypt) and a spectrophotometer (Shimadzu, Japan) to measure the immunoglobulin G (IgG) and M (IgM) levels in the rabbit serum.

The chemical composition:

According to AOAC (2000), dried samples of feed and faeces were initially ground and then analyzed as dry matter.

The carcass characteristics:

Four rabbits from each group were randomly chosen, haven't fed for the night, individually weighed, and then slaughtered. According to Blasco and Ouhayoun (1996), the weight of the carcass was recorded after the whole bleeding process, and the carcass was then eviscerated. The weight of the organs and the carcass % were measured.

Meat pH value, total volatile basic nitrogen (TVBN), and thio-barbituric acid (TBA):

According to Pearson (1976), the pH of meat was measured and Total Volatile Nitrogen (TVN) was determined in accordance with Egyptian Organization for Standardization (ES: 63/9/2006).

Malonaldehyde (MDA), the result of lipid peroxidation, was measured to determine the thio-barbituric acid (TBA). Egyptian Organization for Standardization (ES:63/10/2006) used a spectrophotometer (UNICAM969AA Spectronic, USA) to measure the sample's absorbance at wavelength 538. (TBA value = sample absorbance × 7.8 (Malonaldehyde mg / Kg))

Antioxidant activates of rabbit's meat:

According to Wang *et al.* (2011), Glutathione Peroxidase (GPx) serves as an Antioxidant capacity was measured commercially using GPx (kits Randox, Crumlin, UK). The techniques presented by Wang *et al.* (2011) were used to analyse the activities of catalase (CAT) and superoxide dismutase (SOD). According to Wang *et al.* (2011), malondialdehyde (MDA) levels in rabbit serum were calculated and represented as U/mg protein.

Economic efficiency:

To calculate the economic feed efficiency for meat production, the management elements (heating, medications and vaccinations) were held constant throughout all experimental groups. The amount of feed consumed during the period of the experiment was recorded.

When the research was being prepared, the cost of the experimental diets was determined using the local market's current ingredient prices. As a result, it was easy to calculate the cost of feed used for each experimental group.

At the ending of the trial period, the live body weight (kg) from each experimental group was multiplied by 90 LE, which reflects the live body weight pricing on the local market at the time of the study. The net revenue per unit of feed cost, as defined by Bayoumi (1980), was used to determine economic efficiency.

Cost of branched-Chain Amino Acid = Amount of Branched-Chain Amino Acid (g) × price of Branched-Chain Amino Acid

- Cost of concentrate = Amount of concentrate (g) × price of concentrate intake (Kg).
- Average feed cost (h/d/LE) = Cost of Branched-Chain Amino Acid + Cost of concentrate.
- Average revenue of daily gain (LE) = price of 1 Kg live body weight × Average daily gain.
- Net feed revenue (LE) = Average revenue of daily gain - Average feed cost.
- Economic feed efficiency % = $\frac{\text{Net feed revenue}}{\text{Average feed cost}} \times 100$
- If relative economic efficiency to T1 (control group) =100%.
- Relative economic efficiency to T2 = $\frac{\text{Economic feed efficiency to T2}}{\text{Economic feed efficiency to T1}} \times 100$
- Relative economic efficiency to T3 = $\frac{\text{Economic feed efficiency to T3}}{\text{Economic feed efficiency to T1}} \times 100$
- Relative economic efficiency to T4 = $\frac{\text{Economic feed efficiency to T4}}{\text{Economic feed efficiency to T1}} \times 100$
- Relative economic efficiency to T5 = $\frac{\text{Economic feed efficiency to T5}}{\text{Economic feed efficiency to T1}} \times 100$
- Relative economic efficiency to T6 = $\frac{\text{Economic feed efficiency to T6}}{\text{Economic feed efficiency to T1}} \times 100$

Statistical analysis:

The SAS programme (SAS® institute, 2004) was used to calculate the statistical analysis, (two-way analysis of variance) and Duncan's Multiple Range Test (Duncan, 1955) was used applied to identify the significant mean differences among the experimental group means.

RESULTS AND DISCUSSION

Effect of two Different level of dietary protein under three levels of BCAAs supplementations on digestion coefficients and nutritive value of growing rabbits:

Results of digestibility coefficients are shown in Table 3. Statistical analysis revealed that rabbits fed recommended protein diet (18% CP) recorded significantly ($P<0.05$) higher DM, OM, CP, EE and NFE digestion coefficients. Also, nutritive value in term of TDN found to be ($P<0.05$) higher in favor of recommended dietary protein (18% CP) compared with the rabbits fed Low dietary protein (17% CP).

Regarding to the levels of BCAAs supplementations, at level 2g (BCAAs) (3:1:2) (luecine: Iso luecine: Valine), rabbits show significant ($P<0.05$) effect on DM, OM, CP, NFE digestion coefficients, DCP and TDN , followed by group fed level 2g (BCAAs) (2:1:1) (luecine: Iso luecine: Valine), comparing with the group fed zero level 0g (BCAAs) which recorded lower values. And there were no significant differences were found between different levels in the term of CF and EE digestion coefficients.

Regarding to the interaction between two different levels of crude protein under three levels of BCAAs supplementations, rabbits fed recommended protein (18% CP) + 2g (BCAAs) (3:1:2) achieved the highest significantly ($P<0.05$) DM, OM, CP, EE and NFE digestion coefficients,. Also, nutritive values in the term of DCP and TDN, Followed them the group fed recommended dietary protein (18% CP) + 2g (BCAAs) (2:1:1) and followed by Low dietary protein (17% CP) + 2g (BCAAs) (3:1:2), 18% at zero BCAAs then group fed (17% CP) + 2g (BCAAs) (2:1:1). While, the lowest values were significantly recorded for the group fed 17% at zero BCAAs level. The reason for the improvement in digestibility at high levels of protein with the addition of BCAAs Leucine, valine and isoleucine are three types of essential amino acids together known as BCAAs (Kidd *et al.*, 2021). These amino acids are necessary for many physiological functions, such as the synthesis of muscle protein, the production of energy, and immunological function. While BCAAs are most recognized for their function in building muscles and recovery, they can also have an effect on digestion. However, it is important to remember that research in this area is limited, and further studies are needed to completely understand the interaction between BCAAs and digestion.

Some research suggests that BCAAs may be beneficial to gut health. (Gojda and Cahova, 2021) discovered that supplementing mice with BCAAs helped restore the function of the gut, which is critical in preventing risky substances from entering into the bloodstream. BCAAs supplementation may assist enhance the function of intestinal barriers in individuals with liver disease, according to (Gluud *et al.*, 2017).

There is minimal evidence that BCAAs may alter gut motility, or the passage of nutrients through the gastrointestinal tract. Oral BCAAs supplementation enhanced small intestinal passage in rats, according to (Chen *et al.*, 2015). However, further study is needed to identify the impact of BCAAs on animal gastrointestinal motility and the mechanisms.

BCAAs have no direct role in the protein digesting process. They are absorbed whole and subsequently metabolized in the liver. However, because of their function in muscle protein synthesis, BCAAs can have an indirect effect on protein digestion. BCAAs may aid boost muscle repair and avoid breakdown of muscles by stimulating muscle protein synthesis, which can have an indirect effect on total protein metabolism. Individual responses to the intake of BCAAs may vary, and the effects on digestion can be affected by factors such as time, dose and health problems (Na *et al.*, 2023).

The gastrointestinal tract is capable of supporting both BCAAs production and breakdown. Different nitrogen sources, such as endogenous amino acids, urea, and ammonia, are used by bacteria in the digestive system to synthesize amino acids (Metges, 2000). Because of the production of enzymes linked to amino acid catabolism, it is theoretically possible for gut microbiota to catabolize nearly all types of amino acids. Additionally, due to the high diversity and quantity of microorganisms for amino acid degradation in the large intestine, there is significant amino acid catabolism there (Dai *et al.*, 2011).

Clostridium bifermentans, Peptostreptococcus spp., Clostridium difficile and Clostridium sporogenes indicate a preference for BCAAs catabolism to Branched chain fatty acids (BCFA) synthesis, which is a sign of BCAAs fermentation in the large intestine of individuals (Na *et al.*, 2023). Furthermore, dietary composition of macronutrient decides the gastrointestinal tract microbiota composition and bacteria metabolic activity, thus affecting the availability of BCAAs and BCAAs fermentation products to the host. For example, a protein-rich diet is related to increased abundance of *Bacteroides, Fusobacterium, Proteobacteria, Desulfovibrio, Bilophila wadsworthia, Clostridium, Ruminociccus, Eubacterium, A. putredinis and Bacteroides sp*. for BCAA degradation, and decreased abundance of *Firmicutes, Archaea, Megasphera, Selenomonas, Acidaminococcus, Bifidobacterium* and *Prevotella* for BCAA synthesis (David *et al*., 2014 and Na *et al.*, 2023). Additionally, the structure of the microbiota in the gut and the rate of metabolism of the bacteria are determined by dietary macro-nutrient composition, which has an impact on the ability of the body to access BCAAs and the products of BCAAs fermentation. For instance, a diet high in protein is associated with increased numerous amounts of *Bilophila wadsworthia* , *Bacteroides,Eubacterium, A., Desulfovibrio, Proteobacteria, Clostridium, Bacteroides sp., Ruminociccus* and *putredinis* for BCAA degradation and a reduced number of *Archaea, Firmicutes*, *Acidaminococcus*, *Bifidobacterium*, *Prevotella*, and *Megasphera* for Synthesis of BCAAs (David *et al*., 2014 and Na *et al.*, 2023).

Effect of two Different level of dietary protein under three levels of BCAAs supplementations on productive performance of growing rabbits:

Productive Performance of growing rabbits at different experimental groups was presented in Table (4).

Table (3): Effect of dietary protein levels, levels of BCAAs supplementations and their interaction on digestibility coefficients and nutritive values of growing rabbits

Items	Digestion coefficients %						Nutritive value %	
	DM	**OM**	**CP**	**CF**	**EE**	**NFE**	**DCP**	**TDN**
Protein levels (P)								
High protein (18% CP)	61.73[a]	61.31[a]	77.34[a]	21.30	73.27[a]	66.40[a]	13.45	54.06[a]
Low protein (17% CP)	49.85[b]	49.28[b]	70.96[b]	17.33	63.57[b]	55.93[b]	12.68	46.45[b]
±S.E	± 2.74	± 2.77	± 1.72	± 1.81	± 2.76	± 2.47	±0.31	±1.72
Sig.	**	**	**	NS	**	**	NS	**
Levels of amino acids (A)								
Zero level 0g (BCAA)	48.61[b]	47.95[b]	69.84[b]	17.51	67.34	55.02[b]	11.84[b]	46.00[b]
2g (BCAA) (2:1:1)	55.97[ab]	55.58[ab]	74.13[ab]	18.11	64.71	61.09[ab]	13.49[a]	49.94[ab]
2g (BCAA) (3:1:2)	62.79[a]	62.37[a]	78.50[a]	22.33	73.20	67.39[a]	13.87[a]	54.82[a]
±S.E	± 3.37	± 3.40	± 2.11	± 2.22	± 3.38	± 2.03	± 0.38	± 2.10
Sig.	*	*	*	NS	NS	*	***	*
The interaction between P×A								
Recommended protein (18% CP) + zero level (BCAA)	58.96[b]	58.63[b]	73.67[b]	21.61	67.58[b]	64.32[b]	12.52[b]	52.05[ab]
Recommended protein (18% CP) + 2g (BCAA) (2:1:1)	56.78[b]	56.27[b]	75.82[ab]	19.06	71.02[b]	61.52[b]	13.73[a]	50.96[ab]
Recommended protein (18% CP) + 2g (BCAA) (3:1:2)	69.46[a]	69.04[a]	82.53[a]	23.24	81.21[a]	73.35[a]	14.11[a]	59.17[a]
Low protein (17% CP) + zero level (BCAA)	38.26[c]	37.26[c]	66.00[c]	13.42	67.12c	45.72[c]	11.16[c]	39.95[c]
Low protein (17% CP) + 2g (BCAA) (2:1:1)	55.16[b]	54.89[b]	72.43[b]	17.15	58.40[d]	60.66[b]	13.25[a]	48.92[b]
Low protein (17% CP) + 2g (BCAA) (3:1:2)	56.13[b]	55.70[b]	74.45[b]	21.42	65.19[b]	61.42[b]	13.63[a]	50.47[b]
±S.E	± 4.75	± 4.80	± 2.89	± 3.14	± 4.78	± 4.28	±0.45	± 2.98
Sig.	**	**	*	NS	*	**	**	**

a,b,c,…… different superscript are significantly (P<0.05) differ between means in the same row

G1: Rabbits fed control diet contain recommended dietary protein (18% CP) without any supplementation.

G2: Rabbits fed control diet contain recommended dietary protein (18% CP) supplemented with 2 g BCAAs/kg diet 2:1:1 (luecine: Iso luecine: Valine).

G3: Rabbits fed control diet contain recommended dietary protein (18% CP) supplemented with 2 g BCAAs/kg diet 3:1:2 (luecine:Iso luecine: Valine).

G4: Rabbits fed control diet contain low dietary protein (17% CP) without any supplementation

G5: Rabbits fed control diet contain low dietary protein (17% CP) supplemented with 2 g BCAAs/kg diet BCAAs/kg diet 2:1: (luecine: Iso luecine: Valine).

G6: Rabbits fed control diet contain low dietary protein (17% CP) supplemented with 2 g BCAAs/kg diet 3:1:2 (luecine:Iso luecine: Valine).

Table (4): Effect of dietary protein levels, levels of BCAAs supplementations and their interaction on productive performance of growing rabbits

Items	Productive Performance parameters					
	Initial BW	Final BW	Total gain	Daily gain	CON DMI	Feed conversion
Main factors						
Protein levels (P)						
recommended protein (18% CP)	814.22	2543.44^{a}	1729.22^{a}	19.21^{a}	105.00	5.61^{b}
Low protein (17% CP)	819.37	2337.59^{b}	1518.22^{b}	16.87^{b}	105.00	6.51^{a}
±S.E	± 33.92	±60.48	±53.03	±0.59	± 0.00	±0.22
Sig.	NS	***	***	***	NS	**
Levels of branched-chain amino acids (BCAAs) **(A)**						
Zero level 0g (BCAAs)	811.39	2266.44^{b}	1455.06^{b}	16.17^{b}	105.00	6.74^{a}
2g (BCAAs) (2:1:1)	824.39	2460.89^{ab}	1636.50^{ab}	18.18^{ab}	105.00	5.94^{b}
2g (BCAAs) (3:1:2)	814.61	2594.22^{a}	1779.61^{a}	19.77^{a}	105.00	5.50^{b}
±S.E	±4.15	±7.40	±49.6	±0.72	±0.00	±0.27
Sig.	NS	**	**	**	NS	***
The interaction between P×A						
Recommended protein (18% CP) + zero level (BCAAs)	803.89	2399.56^{c}	1595.67^{b}	17.73^{b}	105.00	6.09^{b}
Recommended protein (18% CP) + 2g (BCAAs) (2:1:1)	832.67	2522.33^{b}	1689.67^{b}	18.77^{b}	105.00	5.74^{b}
Recommended protein (18% CP) + 2g (BCAAs) (3:1:2)	806.11	2708.44^{a}	1902.33^{a}	21.14^{a}	105.00	5.00^{c}
Low protein (17% CP) + zero level	818.87	2133.33^{d}	1314.44^{c}	14.60^{c}	105.00	7.39^{a}
Low protein (17% CP) + 2g (BCAAs) (2:1:1)	816.11	2399.44^{c}	1583.33^{b}	17.59^{b}	105.00	6.14^{b}
Low protein (17% CP) + 2g (BCAAs) (3:1:2)	823.11	2480.00^{b}	1656.89^{b}	18.41^{b}	105.00	6.00^{b}
±S.E	±5.87	±10.47	±9.18	±1.02	±0.00	±0.39
Sig.	NS	**	***	***	NS	***

a,b,c,…… different superscript are significantly (P<0.05) differ between means in the same row

G1: Rabbits fed control diet contain recommended dietary protein (18% CP) without any supplementation.

G2: Rabbits fed control diet contain recommended dietary protein (18% CP) supplemented with 2 g BCAAs/kg diet 2:1:1 (luecine: Iso luecine: Valine).

G3: Rabbits fed control diet contain recommended dietary protein (18% CP) supplemented with 2 g BCAAs/kg diet 3:1:2 (luecine:Iso luecine: Valine).

G4: Rabbits fed control diet contain low dietary protein (17% CP) without any supplementation

G5: Rabbits fed control diet contain low dietary protein (17% CP) supplemented with 2 g BCAAs/kg diet BCAAs/kg diet 2:1: (luecine: Iso luecine: Valine).

G6: Rabbits fed control diet contain low dietary protein (17% CP) supplemented with 2 g BCAAs/kg diet 3:1:2 (luecine:Iso luecine: Valine).

It was found that the initial live body weight for all experimental groups were nearly similar and ranged from 803.89 g to 832.67 g with no significant differences among them. This may create a suitable condition to show the effect of dietary treatments during the subsequent experimental periods. Concerning protein levels, rabbits fed recommended dietary protein (18% CP) recorded significantly higher final LBW, total gain, and daily gain values (2543.44,1729.22 , 19.21g, respectively), than those fed Low dietary protein (17% CP) diet being (2337.59, 1518.22,16.87 g, respectively).

Regarding to the levels of BCAAs supplementations, at level 2g (BCAAs) (3:1:2), rabbits show significant effect on final LBW, total gain, and daily gain values. While, recorded the lower value in the term of the feed conversion ratio, followed by group fed level 2g (BCAAs) (2:1:1), comparing to group fed zero level 0g (BCAAs) which recorded lower values of all growth performance parameters and higher feed conversion ratio.

Regarding to the interaction between two different levels of dietary protein under three levels of BCAAs supplementations, rabbits fed recommended dietary protein (18% CP) + 2g (BCAAs) (3:1:2) achieved significantly the highest final LBW, total gain, and daily gain values, followed them in the values the group fed recommended dietary protein (18% CP) + 2g (BCAAs) (2:1:1) and low dietary protein (17% CP) + 2g (BCAAs) (3:1:2) , which did not show any significant differences between them in the final body weight of rabbits, Also, there were no significant differences in final body weight and daily gain between the groups fed recommended protein (18% CP) + zero level (BCAAs) and Low protein (17% CP) + 2g (BCAAs) (2:1:1). While, the lowest value of final LBW, total gain, and daily gain values was for the group fed low protein (17% CP) + zero BCAAs. However, group fed recommended protein (18% CP) + 2g (BCAAs) (3:1:2) recorded the best feed conversion ratio compared to the other groups. The reasons for the increasing and improvement in growth performance indicators may be due to the increase in the amount of leucine added to the tested diets.

The BCAAs, particularly leucine can increase muscle protein synthesis and reduce muscle protein breakdown by stimulating the initiation of enzymes controlling protein synthesis. This involves phosphorylation of the mammalian target of rapamycin (mTOR) and sequential activation of 70-kD S6 protein kinase (p70 S6 kinase) and the eukaryotic initiation factor 4E-binding protein 1 (Yoshizawa, 2004). Isoleucine has significantly lower effect than leucine on protein synthesis or enzyme phosphorylation in skeletal muscle of rats and Valine has almost no effect (Kimball and Jefferson, 2004). *In vivo* and *in vitro* studies have shown a significant increase (25–50%) of muscle protein synthesis and significant decrease (30%) in protein degradation by oral and intravenously administration of BCAAs. The mixture of other AA has shown no effect on protein turnover (Freund and Hanani, 2002). And on the contrary, a research was conducted by Negro *et al.*, (2008) to investigate the effects of BCAAs supplementation on performance, muscle recovery, and the immune system. While there was no apparent improvement in performance, supplementing with BCAA improved muscle repair and immunological function identifying potential advantages.

Timmler and Rodehutscord (2003) conducted a graded level up to 1.27% valine supplemental intake research in 0 to 21 day White Pekin ducks given a baseline diet containing (valine 0.68%, CP 18%, and 2,990 kcal ME/kg), and no impact was detected. However, the scientists discovered that 0.7% valine was best for achieving 95% proteins growth. Hanafy and Attia (2018) conducted a BCAA research on Japanese quail breeder and discovered that valine 0.2% and CP 18%was ideal for the quail's egg yield and growth performance. with a research with turkey by Kop- Bozbay and Ocak (2020), a BCAA mixture consisting of leucine, isoleucine, and valine in a ratio of 3:1:2 was given to 1 week old turkeys that were both fed directly or delayed fed after 48 or 72 hours. The BCAA combination increased body weight gain in all groups and improved breast growth of muscles in delay fed birds.

Effect of dietary protein levels, levels of BCAAs supplementations and their interaction on carcass characteristics of growing rabbits:

Table (5a,b) shows the effects of level of crude protein under two levels of BCAAs supplementations on carcass characteristics of growing rabbits. Concerning protein levels, rabbits fed recommended dietary protein (18% CP) recorded significantly ($P<0.05$) higher Kidney, heart, liver, round, shoulder, lung and trachea, rack, loin, hind up, digestive tract, leg weight, hot carcass weight, belt weight and final weight.

Table (5a): Effect of dietary protein levels, levels of BCAAs supplementations and their interaction on carcass characteristics of growing rabbits

	Carcass characteristics						
Items	**Kidneys**	**Liver**	**Heart**	**Digestive tract**	**Hind up.**	**Shoulder**	**Rack**
Main factors							
Protein levels (P)							
Recommended protein (18% CP)	18.72^{a}	75.97^{a}	10.10^{a}	284.89^{a}	142.70^{a}	491.56^{a}	184.44^{a}
Low protein (17% CP)	16.07^{b}	64.80^{b}	8.24^{b}	211.89^{b}	121.67^{b}	367.11^{b}	167.22^{b}
±S.E	±1.56	±4.24	±0.83	±1.61	±4.70	±2.42	±3.49
Sig.	**	**	***	**	**	**	**
Levels of amino acids (A)							
Zero level 0g (BCAA)(0)	13.96^{b}	60.22^{c}	7.86^{c}	217.83^{c}	117.17^{b}	339.67^{c}	167.50^{b}
2g (BCAA) (2:1:1)	19.08^{a}	77.33^{a}	8.73^{b}	250.83^{b}	138.11^{a}	458.50^{b}	174.17^{ab}
2g (BCAA) (3:1:2)	19.15^{a}	73.63^{b}	10.93^{a}	276.50^{a}	141.26^{a}	489.83^{a}	185.83^{a}
±S.E	±1.90	±5.19	±1.01	±1.97	±5.75	±2.97	±4.28
Sig.	*	*	***	**	*	*	*
The interaction between P×A							
Recommended protein (18% CP) + zero level	14.40^{d}	69.13^{c}	8.51^{c}	245.67^{b}	122.68^{c}	380.33^{c}	171.67^{b}
Recommended protein (18% CP) + low level	21.65^{a}	83.99^{a}	9.22^{b}	251.00^{b}	150.56^{b}	505.00^{b}	180.00^{b}
Recommended protein (18% CP) + high level	20.12^{a}	74.79^{b}	12.58^{a}	358.00^{a}	154.86^{a}	589.33^{a}	201.67^{a}
Low protein (17% CP) + zero level	13.51^{d}	51.30^{d}	7.20^{c}	190.00^{c}	111.67^{d}	299.00^{d}	163.33^{c}
Low protein (17% CP) + 2g BCAA (2:1:1)	16.51^{c}	70.66^{b}	8.24^{ab}	250.67^{b}	125.67^{c}	412.00^{c}	168.33^{c}
Low protein (17% CP) + 2g BCAA (3:1:2)	18.18^{b}	72.46^{b}	9.27^{b}	195.00^{c}	127.67^{c}	390.33^{c}	170.00^{b}
±S.E	±2.69	±7.34	±1.43	±2.79	±8.14	±4.20	±6.05
Sig.	***	*	*	**	**	***	***

a,b,c,…… different superscript are significantly (P<0.05) differ between means in the same row

Regarding to the levels of BCAAs supplementations, at level 2g (BCAAs) (3:1:2), rabbits show significant (P<0.05) effect on kidney, heart, liver, round, shoulder, rack, loin , hind up, digestive tract, leg, hot carcass weight, belt and final weight, followed by group fed 2g (BCAA) (2:1:1), comparing to group fed zero level 0g (BCAA) which recorded lower values of all carcass characteristics.

Regarding to the interaction between different levels of crude protein under two levels of BCAAs supplementations, rabbits fed recommended dietary protein (18% CP) + 2g (BCAAs) (3:1:2) achieved the highest significantly (P<0.05) carcass weight values, followed them in the values the group fed recommended dietary protein (18% CP) + 2g (BCAAs) (2:1:1) and low dietary protein (17% CP) + 2g (BCAAs) (3:1:2), Also, there were no significant differences in most carcass characteristics between the groups fed recommended dietary protein (18% CP) + zero level (BCAAs) and Low dietary protein (17% CP) + 2g (BCAAs) (2:1:1). While, the lowest value of carcass characteristics was for the group fed low dietary protein (17% CP) + zero level. However, group fed recommended protein (18% CP) + 2g (BCAAs) (3:1:2) recorded the best carcass characteristics compared to the other groups. The improvement in the carcass characteristics is due to the tested groups added with BCAAs, because most of the BCAAs are used by the body for energy production, and when their percentage is increased in the animal's feed, the increase in the BCAAs is directed to the formation of the body's muscles. Where the muscles in the body of rabbits contain approximately 35% BCAAs, and when added to the diet, it leads to an improvement in the performance of growth and weight gain, which is reflected in the characteristics of the carcass.

Table (5b): Effect of dietary protein levels, levels of BCAAs supplementations and their interaction on carcass characteristics of growing rabbits

	Carcass characteristics						
Items	**Loin**	**Round**	**Hot carcass**	**Lung and Trachea**	**Leg**	**Belt**	**final weight**
Main factors							
Protein levels (P)							
Recommended protein (18% CP)	269.44^{a}	471.89^{a}	1432.11^{a}	15.94^{a}	70.30^{a}	339.44^{a}	2486.11^{a}
Low protein (17% CP)	163.22^{b}	349.50^{b}	965.11^{b}	11.35^{b}	67.22^{b}	254.33^{b}	1836.67^{b}
±S.E	±1.59	±2.00	±7.11	±0.95	±8.94	±1.94	±1.03.
Sig.	***	**	***	**	*	**	***
Levels of amino acids (A)							
Zero level 0g (BCAA)(0)	178.67^{c}	342.50^{b}	953.50^{c}	12.94	60.62^{c}	266.17^{b}	1855.00^{c}
2g (BCAA) (2:1:1)	223.83^{b}	447.42^{a}	1285.00^{b}	14.61	71.00^{b}	307.67^{a}	2241.67^{b}
2g (BCAA) (3:1:2)	246.50^{a}	442.17^{a}	1357.33^{a}	13.4	74.67^{a}	316.83^{a}	2387.50^{a}
±S.E	±1.95	±2.45	±8.70	±1.16	±1.09	±2.38	±1.26
Sig.	*	*	**	NS	**	*	*
The interaction between P×A							
Recommended protein (18% CP) + zero level	229.33^{c}	399.00^{bc}	1190.33^{c}	15.63^{ab}	91..72^{ab}	309.67^{ab}	2143.33^{c}
Recommended protein (18% CP) + low level	263.67^{b}	487.33^{ab}	1451.33^{b}	16.64^{a}	77.00^{a}	364.00^{a}	2473.33^{b}
*Recommended protein (18% CP) + high level	315.33^{a}	529.33^{a}	1654.67^{a}	15.56^{ab}	78.00^{a}	344.67^{a}	2841.67^{a}
Low protein (17% CP) + zero level	128.00^{e}	286.00^{d}	716.67^{d}	10.25^{d}	65.33^{c}	222.67^{d}	1566.67^{e}
Low protein (17% CP) + 2g BCAA (2:1:1)	184.00^{d}	407.50^{c}	1118.67^{c}	12.57^{c}	65.00^{c}	251.33^{c}	2010.00^{c}
Low protein (17% CP) + 2g BCAA (3:1:2)	177.67^{d}	355.00^{cd}	1060.00^{c}	11.24^{c}	71.33^{b}	289.00^{b}	1933.33^{d}
±S.E	±2.76	±3.47	±1.23	±1.64	±1.54	±3.37	±1.79.
Sig.	***	***	***	*	**	*	**

a,b,c,…… different superscript are significantly ($P<0.05$) differ between means in the same row

The BCAAs are one of the nine essential amino acids and make up 40% of the AA needed by mammals and 35% of the essential amino acids in muscle proteins, which are an excellent source of energy due to their carbon skeleton. Leucine is ketogenic and can be immediately degraded into acetyl CoA, which is the source of ketone bodies, whereas iso leucine is both ketogenic and the glucogenic as a result of the post-absorptive metabolism. valine is a glucogenic AA that can be turned into glucose by gluconeogenesis in the liver. The plasma concentration of BCAAs is directly influenced by dietary intake since they are not catabolized in the liver (Yoshizawa, 2004).

Effect of different level of dietary protein under two levels of BCAAs supplementations on meat's amino acids profile of growing rabbits:

The amino acids profile as affected by two different level of dietary protein under three levels of BCAAs supplementations is summarized in Table (6a,b).

Table (6a): Effect of dietary protein levels, levels of BCAAs supplementations and their interaction on meat's amino acids profile of growing rabbits.

Items	Essential Amino acids profile									
	Arginin	**Histidine**	**Isoleucine**	**Leucine**	**lysine**	**methionine**	**phenylalanine**	**threonine**	**tryptophan**	**Valine**
Main factors protein levels (P)										
Recommended protein (18% CP)	4.89^{a}	2.64^{a}	3.52^{a}	6.07^{a}	6.59^{a}	1.66	3.04^{a}	2.84^{a}	0.37^{a}	3.46^{a}
Low protein (17% CP)	4.57^{b}	2.11^{b}	3.20^{b}	5.74^{b}	6.37^{b}	1.57	2.80^{b}	2.62^{b}	0.26^{b}	3.17^{b}
±S.E	±0.05	±0.05	±0.05	±0.06	±0.06	±0.04	±0.06	±0.06	±0.02	±0.06
Sig.	*	*	**	**	*	NS	*	*	*	**
Levels of amino acids (A)										
Zero level 0g (BCAA)(0)	4.45^{c}	2.15^{b}	3.10^{b}	5.73^{b}	6.32^{b}	1.58	2.63^{c}	2.45^{b}	0.22^{b}	3.15^{b}
2g (BCAA) (2:1:1)	4.75^{b}	2.25^{b}	3.38^{a}	5.90^{ab}	6.47^{ab}	1.68	2.95^{b}	2.85^{a}	0.35^{a}	3.33^{ab}
2g (BCAA) (3:1:2)	4.98^{a}	2.73^{a}	3.60^{a}	6.08^{a}	6.65^{a}	1.57	3.18^{a}	2.90^{a}	0.37^{a}	3.45^{a}
±S.E	± 0.07	± 0.06	±0.07	± 0.07	±0.08	±0.04	±0.07	±0.07	±0.03	±0.07
Sig.	***	*	*	*	*	NS	***	*	**	*
The interaction between P×A										
Recommended protein (18% CP) + zero level	4.57^{bc}	2.33^{bc}	3.37^{ab}	5.93^{ab}	6.50^{ab}	1.77^{a}	2.67^{c}	2.63^{b}	0.27^{bc}	3.27^{ab}
Recommended protein (18% CP) + 2g (BCAA) (2:1:1)	4.97^{a}	2.43^{b}	3.53^{ab}	6.03^{ab}	6.73^{a}	1.73^{a}	3.07^{b}	2.93^{ab}	0.43^{a}	3.50^{ab}
Recommended protein (18% CP) + 2g (BCAA) (3:1:2)	5.13^{a}	3.17^{a}	3.67^{a}	6.23^{a}	6.53^{ab}	1.47^{bc}	3.40^{a}	2.97^{a}	0.40^{a}	3.60^{a}
Low protein (17% CP) + zero level	4.33^{c}	1.97^{d}	2.83^{c}	5.53^{c}	6.13^{c}	1.40^{c}	2.60^{c}	2.27^{c}	0.17^{c}	3.03^{ab}
Low protein (17% CP) + 2g (BCAA) (2:1:1)	4.53^{bc}	2.07^{cd}	3.23^{b}	5.77^{bc}	6.20^{bc}	1.63^{ab}	2.83^{bc}	2.77^{ab}	0.27^{bc}	3.17^{b}
Low protein (17% CP) + 2g (BCAA) (3:1:2)	4.83^{ab}	2.30^{bc}	3.53^{ab}	5.93^{ab}	6.77^{a}	1.67^{a}	2.97^{bc}	2.83^{ab}	0.33^{ab}	3.30^{a}
±S.E	±0.09	±0.08	±0.10	±0.10	±0.11	±0.06	±0.10	±0.10	±0.04	±0.11
Sig.	*	**	*	*	*	*	**	**	*	*

a,b,c,…… different superscript are significantly (P<0.05) differ between means in the same row

Table (6b): Effect of dietary protein levels, levels of BCAAs supplementations and their interaction on meat's amino acids profile of growing rabbits.

Items	Non- Essential Amino acids profile							
	alanine	aspartic acid	cysteine	glutamic acid	glycine	proline	serine	tyrosine
Main factors								
protein levels (P)								
Recommended protein (18% CP)	4.08[b]	5.20[b]	0.53	9.44[b]	1.56[b]	4.2	3.01[b]	1.76[b]
Low protein (17% CP)	4.43[a]	5.61[a]	0.58	9.98[a]	2.01[a]	4.09	3.19[a]	2.10[a]
±S.E	±0.06	±0.05	±0.04	±0.09	±0.06	±0.06	±0.04	±0.05
Sig.	**	*	NS	**	**	NS	*	**
Levels of amino acids (A)								
Zero level 0g (BCAA)(0)	4.77[a]	5.90[a]	0.58	10.08[a]	1.87	4.40[a]	2.95[b]	2
2g (BCAA) (2:1:1)	4.30[b]	5.38[b]	0.6	9.55[b]	1.7	3.98[b]	3.10[ab]	1.85
2g (BCAA) (3:1:2)	3.72[c]	4.93[c]	0.48	9.50[b]	1.78	4.05[b]	3.25[a]	1.93
±S.E	±0.07	±0.06	±0.04	±0.11	±0.07	±0.07	±0.06	±0.07
Sig.	**	***	NS	*	NS	*	*	NS
The interaction between P×A								
Recommended protein (18% CP) + zero level	4.47[b]	5.53[b]	0.67[a]	9.47[bc]	1.27[c]	4.63[a]	2.83[c]	1.57[c]
Recommended protein (18% CP) + 2g (BCAA) (2:1:1)	4.13[c]	5.23[c]	0.53[ab]	9.63[bc]	1.63[b]	3.93[b]	3.03[bc]	1.77[bc]
Recommended protein (18% CP) + 2g (BCAA) (3:1:2)	3.67[d]	4.83[d]	0.40[b]	9.23[c]	1.77[b]	4.03[b]	3.17[ab]	1.93[b]
Low protein (17% CP) + zero level	5.07[a]	6.27[a]	0.50[ab]	10.70a	2.47[a]	4.17[b]	3.07[bc]	2.43[a]
Low protein (17% CP) + 2g (BCAA) (2:1:1)	4.47[b]	5.53[b]	0.67[a]	9.47[bc]	1.77[b]	4.03[b]	3.17[ab]	1.93[b]
Low protein (17% CP) + 2g (BCAA) (3:1:2)	3.77[d]	5.03[cd]	0.57[ab]	9.77[b]	1.80[b]	4.07[b]	3.33[a]	1.93[b]
±S.E	±0.10	±0.09	±0.06	±0.16	±0.10	±0.10	±0.08	±0.09
Sig.	**	*	**	**	***	*	**	*

a,b,c,…… different superscript are significantly (P<0.05) differ between means in the same row

Rabbits fed recommended dietary protein (18% CP) recorded significantly (P<0.05) higher essential amino acids Arginine, Histidine, Isoleucine, Leucine, lysine, phenylalanine, threonine, tryptophan and Valine. And rabbits fed Low dietary protein (17% CP) recorded significantly (P<0.05) higher in non-essential amino acids Alanine, aspartic acid, glutamic acid, glycine and serine. Also, there are no significant differences between the two different level of crude protein in methionine, cysteine and proline.

Regarding to the levels of BCAAs supplementations, at level 2g (BCAA) (3:1:2), rabbits showed significant (P<0.05) effect on Arginine, Histidine, Isoleucine, Leucine, lysine, phenylalanine, threonine, tryptophan and Valine, followed by group fed 2g (BCAA) (2:1:1), comparing to group fed 0g (BCAA) which recorded lower values. And rabbits fed 0g (BCAA) recorded significantly (P<0.05) higher in non-essential amino acids Alanine, aspartic acid, glutamic acid, and serine. Also, there are no significant differences between the different level of BCAA in methionine, cysteine and proline, Glycine and tyrosine.

Regarding to the interaction between two different levels of crude protein under three levels of BCAAs supplementations, rabbits fed recommended dietary protein (18% CP) + 2g (BCAAs) (3:1:2) achieved the highest significantly (P<0.05) Arginine, Histidine, Leucine, Isoleucine, threonine, phenylalanine, Valine and tryptophan values, followed them in the values the group fed recommended protein (18% CP) + 2g (BCAA) (2:1:1) and Low protein (17% CP) + 2g (BCAA) (3:1:2),

It is clear to note that all experimental groups added with BCAAs had higher in contents of Isoleucine, Leucine and Valine values. Also, there were no significant differences in Isoleucine, Leucine and Valine between the groups fed recommended protein (18% CP) + (0 g (BCAA), 2g (BCAA) (2:1:1) and 2g (BCAA) (3:1:2)) and Low protein (17% CP) + (2g (BCAA) (2:1:1) and 2g (BCAA) (3:1:2)). While, the lowest value of meat's Isoleucine, Leucine and Valine values were for the group fed Low protein (17% CP) + zero level of BCAA.

In piglets, BCAAs-transaminase is primarily found in skeletal muscle, but it is widely distributed throughout the body's tissues in both the cytosol and the mitochondria. As a result, increased BCAAs intake raises levels of 3 AA (Isoleucine, Leucine, and Valine) in plasma and then in muscles (Wiltafsky *et al.,* 2010).

BCAAs (leucine, isoleucine, and valine) are necessary amino acids that play an important role in the production of muscle proteins and metabolism. The effect of feeding BCAAs on muscle levels of amino acids has been extensively studied and many different authors have contributed significant insights. There are several studies on the impact of the addition of BCAAs on muscle amino acid levels. Blomstrand *et al*. (2006) studied the effects of BCAAs supplementation on muscle protein synthesis and found that BCAAs supplementation enhanced the phosphorylation of important enzymes responsible for protein synthesis, reflecting improved anabolic responses in the muscle tissue and increased the essential amino acid in muscles tissue.

Shimomura *et al.,* (2010) investigated the effect of BCAAs supplementation on muscular pain. Their findings revealed that BCAA decreased the damage to muscles and delayed onset muscle pain, maybe due to the muscles protein and levels of amino acids being preserved.

Effect of different level of dietary protein under two levels BCAAs Supplementations on meat's meat pH and meat quality of growing rabbits

Table (7) shows the effects of two levels of dietary protein under three levels of BCAAs supplementations on meat pH and meat quality of growing rabbits. No statistically significant differences were observed between the tested groups in terms of dietary protein and also between the levels of addition of BCAAs and the interaction between them on the meat pH.

Concerning dietary protein levels, rabbits fed low dietary protein diet (17% CP)) recorded significantly (P<0.05) higher TVN. Also, there was no significant difference in TBA between the groups fed dietary recommended protein (18% CP) and Low dietary protein (17% CP).

Regarding to the levels of BCAAs supplementations, at 0g (BCAA), rabbits show significant (P<0.05) values of TVN and TBA, comparing to group fed 2g (BCAA) (2:1:1) and 2g (BCAA) (3:1:2) which recorded lower values of TVN and TBA.

Regarding to the interaction between two different levels of dietary protein under three levels of BCAAs supplementations, rabbits fed recommended dietary protein (18% CP) + zero (BCAA) and low protein (17% CP) + zero (BCAAs) achieved the highest significantly (P<0.05) TVN and TBA values, followed them decreasing in the values of the all group fed BCAAs. BCAAs are primarily associated with muscle protein synthesis, their direct influence on meat quality in livestock or the impact of BCAA supplementation on the quality of meat products consumed by animal is not well-documented in scientific literature. Most studies investigating BCAAs supplementation focus on its effects on muscle protein synthesis, performance, and muscle recovery, rather than meat quality. Further research in this area continues to explore the specific mechanisms and optimal strategies for BCAAs supplementation in various contexts.

Table (7): Effect of dietary protein levels, levels of BCAAs supplementations and their interaction on meat pH and meat quality of growing rabbits.

Items	Meat quality		
	pH	TVN	TBA
Main factors			
Protein levels (P)			
Recommended dietary protein (18% CP)	5.83	3.36^{b}	0.24
Low protein (17% CP)	5.72	3.68^{a}	0.26
±S.E	±0.07	±0.08	± 0.01
Sig.	NS	*	NS
Levels of amino acids (A)			
0g (BCAAs)	5.70	3.94^{a}	0.27^{a}
2g (BCAAs) (2:1:1)	5.76	3.40^{b}	0.25^{ab}
2g (BCAAs) (3:1:2)	5.86	3.22^{b}	0.23^{b}
±S.E	±0.09	±0.10	±0.01
Sig.	NS	*	*
The interaction between P×A			
Recommended dietary protein (18% CP) + zero level	5.74	3.79^{ab}	0.27^{a}
Recommended dietary protein (18% CP) + 2g (BCAA) (2:1:1)	5.80	3.25^{bc}	0.23^{ab}
Recommended dietary protein (18% CP) + 2g (BCAA) (3:1:2)	5.95	3.04^{c}	0.22^{b}
Low dietary protein (17% CP) + zero level	5.67	4.09^{a}	0.28^{a}
Low dietary protein (17% CP) + 2g (BCAA) (2:1:1)	5.71	3.55^{ab}	0.26^{ab}
Low dietary protein (17% CP) + 2g (BCAA) (3:1:2)	5.77	3.41^{b}	0.25^{ab}
±S.E	±0.13	±0.14	±0.01
Sig.	NS	**	*

a,b,c,…… different superscript are significantly (P<0.05) differ between means in the same row

G1: Rabbits fed control diet contain recommended dietary protein (18% CP) without any supplementation.

G2: Rabbits fed control diet contain recommended dietary protein (18% CP) supplemented with 2 g BCAAs/kg diet 2:1:1 (luecine: Iso luecine: Valine)

G3: Rabbits fed control diet contain recommended dietary protein (18% CP) supplemented with 2 g BCAAs/kg diet 3:1:2 (luecine:Iso luecine: Valine)

G4: Rabbits fed control diet contain low dietary protein (17% CP) without any supplementation

G5: Rabbits fed control diet contain low dietary protein (17% CP) supplemented with 2 g BCAAs/kg diet BCAAs/kg diet 2:1: (luecine: Iso luecine: Valine)

G6: Rabbits fed control diet contain low dietary protein (17% CP) supplemented with 2 g BCAAs/kg diet 3:1:2 (luecine:Iso luecine: Valine)

Effect of different level of dietary protein under two levels of BCAAs Supplementations on meat's meat antioxidant activity of growing rabbits

Results in Table 8. Indicated that the rabbits fed recommended dietary protein (18% CP) recorded significantly (P<0.05) higher in antioxidant activity presented in GPx, SOD and CAT (U/mg protein). Compared with the group fed 17% CP. And rabbits fed low dietary protein (17% CP) recorded significantly (P<0.05) higher in MDA. Regarding to the levels of BCAAs supplementations, at 2g (BCAA) (3:1:2), rabbits show significant (P<0.05) effect on GPx, SOD and CAT (U/mg protein), followed by group fed low level 2g (BCAAs) (2:1:1), comparing to group fed 0g (BCAAs) which recorded lower values. And rabbits fed 0g (BCAAs) recorded significantly (P<0.05) higher in MDA. Regarding to the interaction between two different levels of dietary protein under three levels of BCAAs supplementations, rabbits fed recommended dietary protein (18% CP) + 2g (BCAA) (3:1:2) achieved The highest significantly (P<0.05) antioxidant activity presented in GPx, SOD and CAT (U/mg protein) values, followed them in the values of the group fed recommended protein (18% CP) + 2g (BCAA) (2:1:1) and Low protein (17% CP) + 2g (BCAAs) (3:1:2), While the lowest values were significantly recorded for the 18% and 17% groups at 0g BCAAs level for oxidative activity, while the highest values were significantly in MDA compared to the rest of the tested groups to which BCAAs was added.

Table (8): Effect of dietary protein levels, levels of BCAAs supplementations and their interaction on meat antioxidant activity (U/ mg protein). of growing rabbits.

Items	**Antioxidant activity (U/ mg protein)**			
	GPx	**SOD**	**CAT**	**MDA**
Main factors				
Protein levels (P)				
Recommended protein (18% CP)	24.59^{a}	128.10^{a}	14.41^{a}	0.65^{b}
Low protein (17% CP)	20.81^{b}	119.80^{b}	11.79^{b}	0.81^{a}
±S.E	±0.60	±1.21	±0.52	±0.02
Sig.	***	***	***	***
Levels of amino acids (A)				
Zero level (0)	20.10^{b}	118.13^{c}	11.24^{b}	0.85^{a}
2g (BCAA) (2:1:1)	22.92^{a}	123.78^{b}	13.43^{a}	0.72^{b}
2g (BCAA) (3:1:2)	25.08^{a}	129.93^{a}	14.62^{a}	0.63^{b}
±S.E	±0.73	±1.48	±0.64	± 0.03
Sig.	***	***	**	**
The interaction between P×A				
Recommended protein (18% CP) + zero level	20.97^{c}	121.73^{bc}	11.46^{c}	0.78^{b}
Recommended protein (18% CP) + 2g (BCAA) (2:1:1)	25.37^{ab}	127.70^{b}	15.60^{ab}	0.63^{c}
Recommended protein (18% CP) + 2g (BCAA) (3:1:2)	27.43^{a}	134.87^{a}	16.18^{a}	0.56^{d}
Low protein (17% CP) + zero level	19.23^{d}	114.53^{d}	11.02^{c}	0.93^{a}
Low protein (17% CP) + 2g (BCAA) (2:1:1)	20.47^{c}	119.87^{c}	11.27^{c}	0.81^{ab}
Low protein (17% CP) + 2g (BCAA) (3:1:2)	22.73^{b}	125.00^{bc}	13.07^{b}	0.70^{b}
±S.E	±1.03	±2.10	±0.91	±0.04
Sig.	***	***	***	***

a,b,c,…… different superscript are significantly (P<0.05) differ between means in the same row

G1: Rabbits fed control diet contain recommended dietary protein (18% CP) without any supplementation.

G2: Rabbits fed control diet contain recommended dietary protein (18% CP) supplemented with 2 g BCAAs/kg diet 2:1:1 (luecine: Iso luecine: Valine)

G3: Rabbits fed control diet contain recommended dietary protein (18% CP) supplemented with 2 g BCAAs/kg diet 3:1:2 (luecine:Iso luecine: Valine)

G4: Rabbits fed control diet contain low dietary protein (17% CP) without any supplementation

G5: Rabbits fed control diet contain low dietary protein (17% CP) supplemented with 2 g BCAAs/kg diet BCAAs/kg diet 2:1: (luecine: Iso luecine: Valine)

G6: Rabbits fed control diet contain low dietary protein (17% CP) supplemented with 2 g BCAAs/kg diet 3:1:2 (luecine:Iso luecine: Valine)

These results were agreed with, Emily *et al*., (2023) reported that branch-chain amino acids as an antioxidant supplement could decrease oxidative stress without affecting muscle protein synthesis.

Effect of different level of dietary protein under two levels of BCAAs supplementations on blood constituents of growing rabbits:

Results of blood constituents are shown in Table 9. Statistical analysis revealed that rabbits fed

Table (9): Effect of dietary protein levels, levels of BCAAs supplementations and their interaction on blood constituents of growing rabbits.

Items	Protein fraction(g/dl)			Kidney enzymes		Liver enzymes		Immunity	
	T.P	**Albumin**	**Globulin**	**Urea (mg/l)**	**Creatinine (mg/dl)**	**AST u/l**	**ALT u/l**	**IgG**	**IgM**
Main factors									
Protein levels (P)									
Recommended protein (18% CP)	6.27^{a}	4.23	2.04	27.00^{a}	0.81^{a}	32.64^{a}	22.08^{a}	40.34^{a}	55.46^{a}
Low protein (17% CP)	5.55^{b}	4.01	1.54	25.08^{b}	0.74^{b}	26.38^{b}	18.44^{b}	35.33^{b}	51.10^{b}
±S.E	±0.15	±0.08	±0.18	±0.50	±0.02	±0.94	±0.37	±0.92	±1.24
Sig.	***	NS	NS	**	*	***	***	***	*
Levels of amino acids (A)									
Zero level	5.41^{b}	3.91^{b}	1.50	25.43	0.71^{b}	25.65^{b}	17.78^{c}	34.47^{b}	50.35^{b}
2g (BCAA) (2:1:1)	5.83^{b}	4.13^{ab}	1.71	25.55	0.77^{ab}	29.10^{b}	20.58^{b}	38.10^{a}	53.32^{ab}
2g (BCAA) (3:1:2)	6.48^{a}	4.32^{a}	2.17	27.13	0.85^{a}	33.78^{a}	22.42^{a}	40.95^{a}	56.17^{a}
±S.E	±0.19	±0.09	±0.22	±0.61	±0.03	±0.15	±0.46	±1.13	±1.53
Sig.	***	*	NS	NS	**	***	***	**	*
The interaction between P ×A									
Recommended protein (18% CP) + 0g BCAAs	5.67^{b}	3.97^{b}	1.69^{ab}	25.90^{b}	0.73^{b}	27.90^{bc}	19.43^{bc}	36.73^{b}	52.37^{bc}
Recommended protein (18% CP) + 2g (BCAA) (2:1:1)	6.33^{ab}	4.33^{ab}	2.00^{ab}	27.10^{ab}	0.83^{ab}	33.07^{ab}	22.87^{ab}	41.00^{ab}	55.63ab
Recommended protein (18% CP) + 2g (BCAA) (3:1:2)	6.80^{a}	4.38^{a}	2.42^{a}	28.00^{a}	0.88^{a}	36.97^{a}	23.93^{a}	43.30^{a}	58.37^{a}
Low protein (17% CP) + zero level	5.15^{d}	3.84^{c}	1.31^{b}	24.97^{c}	0.69^{c}	23.40^{c}	16.13^{d}	32.20^{c}	48.33^{c}
Low protein (17% CP) + 2g (BCAA) (2:1:1)	5.34^{c}	3.93^{c}	1.41^{ab}	24.01^{bc}	0.71^{bc}	25.13^{c}	18.30^{c}	35.19^{bc}	51.00^{bc}
Low protein (17% CP) + 2g (BCAA) (3:1:2)	6.17^{ab}	4.26^{ab}	1.91^{ab}	26.27^{ab}	0.81^{ab}	30.60^{b}	20.90^{b}	38.60^{ab}	53.97^{b}
±S.E	±0.27	±0.13	±0.31	±0.86	±0.04	±1.62	±0.64	±1.60	±1.16
Sig.	**	*	*	*	**	***	***	**	*

a,b,c,…… different superscript are significantly (P<0.05) differ between means in the same row

recommended dietary protein (18% CP) recorded significantly (P<0.05) higher in total protein (T.P), urea, creatinine, AST and ALT, Also, immunity values in term of IgG and IgM found to be (P<0.05) higher in favor of recommended dietary protein (18% CP) compared with the rabbits fed low protein (17% CP). No significant differences were found among the two levels of dietary protein in globulin and albumin values. Regarding to the levels of BCAAs supplementations, at 2g (BCAAs) (3:1:2), rabbits show significant (P<0.05) effect on T.P, creatinine, AST, ALT, IgG and IgM, followed by group fed low level 2g (BCAAs) (2:1:1), comparing to group fed 0g (BCAAs) which recorded lower values. And there were no significant differences were found between different levels in the term of urea and globulin.

Regarding to the interaction between two different levels of dietary protein under three levels of BCAAs supplementations, rabbits fed recommended protein (18% CP) + 2g (BCAAs) (3:1:2) achieved the highest significantly (P<0.05) T.P, creatinine, urea, globulin, albumin, AST and ALT, Also, immunity values in term of IgG and IgM., Followed them the group fed recommended protein (18% CP) + 2g (BCAAs) (2:1:1) and followed by Low protein (17% CP) + 2g (BCAAs) (3:1:2), While the lowest values were significantly recorded for the group fed 18% at zero BCAA then group fed (17% CP) + 2g (BCAAs) (2:1:1) and then 17% at 0g BCAAs level. All blood measurements in all tested groups were within the normal limits for rabbit blood measurements, and an increase in immunity was observed. Researchers have recently concentrated on how BCAAs affect immune system processes. According to Zhao *et al.*, (2014), immune cells have the ability to oxidize BCAAs, express branched-chain alpha keto acid dehydrogenase and decarboxylase activities, and integrate BCAAs into proteins.

Lymphocytes have the highest levels of iso leucine, followed by eosinophils and neutrophils, and Leucine can accelerate its own breakdown by raising the activity of lymphocyte branched-chain keto acid dehydrogenase (Calder, 2006).

BCAAs are vital in maintaining immune cell activity because they provide nitrogen and carbon skeletons for the production of other amino acids such as glutamine (De Simone *et al*., 2013). A deficiency of BCAAs in the diet inhibits innate immune function by reducing the number of lymphocytes and white blood cells, making the body highly at risk for infections (Ma *et al*., 2018).

Effect of BCAAs on economic feed efficiency:

Results in Table 10. of the economic study showed that (G3 and G6) groups were the highest daily feed cost followed with (G2, G2 and G5, respectively) while the lowest daily feed cost was observed for rabbits fed (G4). The highest relative economic efficiency recorded by (G6 and G3) being 141.66 and 129.63%, respectively when compared with the group (G1) (100%). The better economic efficiency as a result of supplementation of BCAAs could be regarding to the recorded increased in the daily gain g/h/day productive performance of this study.

Table (10): Effect of BCAAs on economic efficiency of growing rabbits.

Item	**Experimental ration**					
	G1	**G2**	**G3**	**G4**	**G5**	**G6**
Average feed intake(g)	105	105	105	105	105	105
daily gain g/h/day	17.73	18.77	21.14	14.60	17.56	18.41
Daily feed cost (LE)	1.15	1.28	1.27	1.05	1.18	1.07
Av. Revenue of daily gain	1.59	1.68	1.90	1.31	1.58	1.65
Net feed revenue (LE)	0.44	0.40	0.63	0.26	0.40	0.58
Economic feed efficiency %	38.26	31.25	49.60	24.76	33.89	54.20
Relative Economic efficiency	100	81.67	129.63	64.71	88.57	141.66

Market price at the time of experimentation for 1 ton 18% cp CFM WAS 11000 LE/ ton, 1 ton 17% cp CFM WAS 10000 LE/ ton, 1 KG lucine WAS 600LE, valine 500 LE , Iso lucine 800 LE, the price of 1kg live rabbits was 90 LE.

CONCLUSION

BCAAs may be identified as a promising supplementing material for boosting body weight gain, the conversion of feed ratio, antioxidant activities, blood immunoglobulin levels, , and the production of meat high in total percentage of essential amino acids. Overall, these findings may support the suggestion of supplementing rabbit diets with BCAAs diets at recommended dietary protein (18% CP) + 2g (BCAA) (3:1:2) and low dietary protein (17% CP) + 2g (BCAA) (3:1:2), as well as raising awareness of the need of adding BCAAs to dietary protein for growing rabbits.

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تأثير إضافة الأحماض الأمينية المتفرعة السلسلة على الأداء الإنتاجي للأرنب الجبلي النامية

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كان الهدف من هذه الدراسة هو قياس الأداء الإنتاجي للأرانب النامية متأثراً بالمستويين المختلفين من البروتين الغذائي تحت ثلاثة مستويات من مكملات الأحماض الأمينية المتفرعة السلسلة (BCAAs). تم إجراء تجربة تغذية لمدة 90 يومًا. تم وزن 72 أرنباً بعمر 8 أسابيع عند وصول الأرانب إلى المزرعة ووزعت عشوائياً على ست مجموعات تجريبية. (G1): تحتوي الأرانب التي تم تغذيتها على نظام غذائي كنترول على مستوى البروتين الموصى به (18% CP) دون أي مكملات. (G2 وG3): يحتوي نظام غذائي كنترول يحتوي على البروتين الموصى به (18% CP) مكملًا بـ 2 جم من BCAAs/كجم من النظام الغذائي 2:1:1 ومع 2 جم من BCAA/كجم من النظام الغذائي 3:1:2 (اللوسين: الأيزوليوسين: فالين). (G4): الأرانب التي تم تغذيتها على نظام غذائي كنترول تحتوي على مستوى بروتين منخفض (17% CP) بدون أي مكملات. (G5 وG6): تحتوي الأرانب التي تم تغذيتها على نظام غذائي كنترول يحتوي على نسبة منخفضة من البروتين (17% CP) مكملة بـ 2 جم من BCAAs/كجم من النظام الغذائي 2:1:1 و2 جم من BCAAs/كجم من النظام الغذائي 3:1:2 (اللوسين: الأيزوليوسين :الفالين). حققت مجموعة الأرانب المغذاة (G3) أعلى معنويا (P<0.05) في معاملات الهضم DM، OM، CP، EE وNFE. و أيضا القيمة الغذائية من حيث DCP و TDN، تليها المحموعه (G2)، تليها ((G6، G1)) ثم (G5). حققت مجموعة الأرانب المغذاة (G3) أعلى وزن نهائي ومكتسب يومي معنويا، تلتها في قيم المجموعة المغذاة بالبروتين الغذائي الموصى به (G2) و(G6)، والتي لم تظهر أي فروق معنوية بينهما في وزن الجسم النهائي للأرانب سجلت المجموعة المغذاة (G3) أفضل نسبة تحويل غذائي مقارنة بالمجموعات الأخرى. حققت الأرانب المغذاة بالبروتين الموصى به (G3) أعلى قيم وزن الذبيحة معنويا (P<0.05)، تليها قيم المجموعة المغذاة بالبروتين الموصى به (G2) و (G6)، حققت الأرانب المغذية (G6) أعلى قيم معنوية (P<0.05) للأرجينين، الهستيدين، الأيزوليوسين، الليوسين، الفنيل ألانين، الثريونين، التربتوفان والفالين، تلتها في قيم المجموعة المغذية (G2) و (G6). حققت (G1) و (G4) أعلى قيمة معنوية (P<0.05) لـ TVN وTBA، كما حققت الأرانب التي تم تغذيتها (G3) أعلى معنوية (P<0.05) لنشاط مضادات الأكسدة في GPx وSOD وCAT (بروتين U/mg). تلتها القيم التي غذتها المجموعة (G2) والمنخفضة البروتين (G6)، في حين سجلت أقل القيم معنوية لمجموعتي 18% و17% عند مستوى 0 جرام BCAA للنشاط التأكسدي. حققت الأرانب المغذية (G3) أعلى معنوي (P<0.05) في قيم المناعة في الدم والألبومين والجلوبيولين واليوريا والكرياتينين وAST وALT، وكذلك قيم المناعة بالنسبة لـ IgG وIgM. وأعلى كفاءة اقتصادية نسبية سجلتها مجموعتي (G6 وG3). وبشكل عام، سجلت المجموعة الثالثة أفضل النتائج التي تم الحصول عليها، في حين سجلت المجموعة الثالثة والسادسة أفضل النتائج في حسابات الكفاءة الاقتصادية.