Effects of Partial Deletion of Essential Amino Acids from Starter Feed on Slaughter Performance and Amino Acid Content in Different Parts of Weaned Hu Sheep Lambs (Postprint)

Authors: Li Xueling, Zhang Naifeng, Ma Tao, Dayong Tao, Chai Jianmin, Wang Yurong, Zhang Fan, Diao Qiyu

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Abstract

This experiment aimed to investigate the effects of partial deduction of essential amino acids (lysine, methionine, threonine, and tryptophan) in starter feed on slaughter performance and amino acid content in different body parts of weaned Hu sheep lambs. One hundred 50-day-old weaned male Hu sheep lambs were randomly allocated into 5 groups with 4 replicates per group and 5 lambs per replicate. The control (PC) group was fed an amino acid-balanced starter feed, while the four experimental groups were fed starter feeds with 30% deduction of Lys, Met, Thr, and Trp, respectively, based on the PC group, designated as PD-Lys, PD-Met, PD-Thr, and PD-Trp groups, with the remaining amino acid contents kept consistent. The pre-trial period was 11 d, and the formal trial period was 60 d. At 120 days of age, 6 lambs were randomly selected from each group for slaughter. The results showed: 1) Compared with the PC group, the PD-Lys and PD-Met groups exhibited significantly reduced empty body weight, skin and wool weight, carcass weight, and hoof weight ($P<0.05$); 2) The carcass crude protein content in the PD-Met group was significantly lower than that in the PC and PD-Trp groups ($P<0.05$), the skin and wool crude fat content in the PC, PD-Lys, and PD-Met groups was significantly lower than that in the PD-Thr and PD-Trp groups ($P<0.05$), the carcass crude fat content in the PC group was significantly lower than that in all other groups ($P<0.05$), and the head and hoof moisture content in the PD-Met group was significantly lower than that in the PC and PD-Lys groups ($P<0.05$); 3) The essential and non-essential amino acid contents in head and hoof, skin and wool, and the essential amino acid content in carcass in the PD-Met group were significantly lower than those in the PC group ($P<0.05$). Based on the above results, the ideal pattern of the four essential amino acids (lysine, methionine, threonine, and tryptophan) for

weaned Hu sheep from 61 to 120 days of age was determined as follows: carcass 100:35:44:13, skin and wool 100:21:129:11, head and hoof 100:34:70:7.

Full Text

Effects of Partial Deduction of Essential Amino Acids in Starter Feed on Slaughter Performance and Amino Acid Contents in Different Body Parts of Weaned Hu Lambs

LI Xueling[1,2], ZHANG Naifeng[1], MA Tao[1], TAO Dayong[2], CHAI Jianmin[1], WANG Yurong[2], ZHANG Fan[1], DIAO Qiyu[1,*]

[1]Key Laboratory of Feed Biotechnology, Ministry of Agriculture, Feed Research Institute, Chinese Academy of Agricultural Sciences, Beijing 100081, China
[2]College of Animal Science, Tarim University, Alar 843300, China

Abstract

This study investigated the effects of partially deducting essential amino acids (lysine, methionine, threonine, and tryptophan) from starter feed on the slaughter performance and amino acid contents in different body parts of weaned Hu lambs. One hundred male Hu lambs weaned at 50 days of age were randomly allocated into five groups, with four replicates per group and five lambs per replicate. The positive control (PC) group received a starter feed with balanced amino acids, while four experimental groups received starter feeds with 30% deductions of lysine (PD-Lys), methionine (PD-Met), threonine (PD-Thr), and tryptophan (PD-Trp), respectively, with other amino acids remaining consistent. The pre-trial period lasted 11 days, followed by a 60-day formal experimental period. At 120 days of age, six lambs from each group were randomly selected for slaughter. The results showed: (1) Empty body weight, skin and wool weight, carcass weight, and foot weight in the PD-Lys and PD-Met groups were significantly lower than those in the PC group ($P<0.05$). (2) Carcass crude protein content in the PD-Met group was significantly lower than in the PC and PD-Trp groups ($P<0.05$). The crude fat content in skin and wool of the PC, PD-Lys, and PD-Met groups was significantly lower than in the PD-Thr and PD-Trp groups ($P<0.05$), while the PC group had significantly lower carcass crude fat content compared to all other groups ($P<0.05$). The moisture content of head and feet in the PD-Met group was significantly lower than in the PC and PD-Lys groups ($P<0.05$). (3) Essential and non-essential amino acid contents in head and feet, as well as essential amino acid content in carcass and skin/wool, were significantly lower in the PD-Met group compared to the PC group ($P<0.05$). Based on these results, the ideal essential amino acid patterns for 61-120 day-old weaned Hu lambs are: carcass 100:35:44:13, skin and wool 100:21:129:11, and head and feet 100:34:70:7 for Lys:Met:Thr:Trp.

Keywords: Hu lamb; essential amino acids; carcass; model

Introduction

Hu lamb meat is renowned for its excellent quality and rich amino acid nutritional value, while lamb skin is celebrated as "China' s soft gemstone" both domestically and internationally for its pure white color and wave-like patterns [1]. Dietary amino acids serve as crucial precursors for amino acid conversion and synthesis in the body. The composition and content of amino acids in feed strongly correlate with muscle protein synthesis, meat yield, and amino acid content in the final product [2]. Supplementation with rumen-protected lysine (RP-Lys) and rumen-protected methionine (RP-Met) can promote small intestinal amino acid balance, reduce excess nitrogen metabolism caused by amino acid imbalance, and alleviate liver and kidney burden, thereby contributing positively to environmental protection. As research has progressed, our research group has demonstrated that RP-Met supplementation in starter feed can improve lamb performance, particularly in daily weight gain and feed conversion efficiency [3]. Studies by Chai [4] and Pérez et al. [5] found that the composition and content of essential amino acids in lamb muscle are also significantly related to early weaning and environmental conditions, with lamb muscle essential amino acid content closely matching dietary amino acid patterns. Dvalishvili [6] and Cho et al. [7] investigated changes in amino acid content in wool and longissimus dorsi muscle at different ages. Amino acid content and composition in starter feed vary across different lamb tissues, influencing not only meat flavor directly but also generating aromatic compounds through Maillard reactions between flavor amino acids and reducing sugars [8]. However, whether dietary amino acid content and composition affect the conventional nutrient composition of lamb meat remains unreported.

This study utilized rumen-protected Lys, Met, threonine (RP-Thr), and tryptophan (RP-Trp) in starter feed, applying the amino acid partial deduction method to investigate changes in slaughter performance and amino acid content in different body parts of Hu lambs under four essential amino acid deduction models. By comparing these with dietary amino acid content, this research provides a theoretical basis for further investigation into amino acid metabolism mechanisms and improvement of mutton quality in meat sheep.

1. Materials and Methods

1.1 Experimental Materials RP-Met was provided by Evonik Degussa Technology Co., Ltd., RP-Lys by CJ Feed Co., Ltd., and RP-Thr and RP-Trp by Jiangsu Kangdequan Technology Co., Ltd. Each product contained approximately 65% methionine hydrochloride, lysine hydrochloride, threonine hydrochloride, and tryptophan hydrochloride, respectively, with a rumen bypass rate of 80%.

1.2 Experimental Design A single-factor completely randomized design was employed. One hundred male Hu lambs weaned at 50 days of age (approximately 11 kg body weight) were divided into five groups according to similar body weight and age, with four replicates per group and five lambs per replicate. Based on the partial deduction method, dietary treatments were: amino acid balanced diet (PC group), 30% lysine deduction (PD-Lys group), 30% methionine deduction (PD-Met group), 30% threonine deduction (PD-Thr group), and 30% tryptophan deduction (PD-Trp group).

1.3 Starter Feed Composition The composition and nutrient levels of the starter feeds are presented in Table 1 .

1.4 Experimental Period and Location The experiment was conducted from September to December 2015 at Hailun Sheep Industry Co., Ltd. in Dalun Town, Jiangsu Province. The pre-trial period lasted 11 days, followed by a 60-day formal experimental period.

1.5 Feeding Management The sheep house was thoroughly disinfected every 15 days (rotating between 0.2% chloroisocyanuric acid, 2.0% caustic soda, and 0.5% povidone-iodine). All experimental lambs followed normal vaccination protocols. Lambs were trained to consume starter feed beginning at 50 days of age. From 61 to 120 days of age, starter feed was provided at 4% of body weight daily, fed twice daily at 08:00 and 16:00, with free access to water.

1.6 Analytical Methods 1.6.1 Calculation of Essential Amino Acid Intake per Unit Metabolic Body Weight

Amino acid intake per unit metabolic weight [mg/(kg W · · d)] = [dry matter intake (kg/d) × amino acid content in starter feed (mg/kg)] / metabolic body weight (kg).

1.6.2 Determination of Conventional Nutrient Composition and Amino Acid Content

At 120 days of age, six lambs from each group were accurately weighed to obtain live weight before slaughter. After slaughter, head and feet, carcass, and viscera were separately minced in a grinder, and skin and wool samples were sheared. From each body part, 100 g of tissue sample was collected, placed in clean sealed bags, and stored at -20°C for subsequent analysis.

Conventional nutrient composition was determined as follows: crude protein content was measured using a KDY-9830 automatic Kjeldahl nitrogen analyzer; moisture, crude fat, crude ash, calcium, and phosphorus contents were determined according to Zhang Liying [9]. Amino acid content was analyzed using an amino acid analyzer (S-433D, Sykam, Germany). Samples were first hydrolyzed with acid (6 mol/L HCl at 110°C; 5 mol/L NaOH for Trp determination). After preparing standard samples, both standards and treated samples were analyzed using the amino acid analyzer.

1.7 Data Processing and Analysis Raw data were initially processed using Excel 2013, followed by one-way ANOVA using SAS 9.2 statistical software. Differences were considered significant at $P<0.05$.

2. Results

2.1 Effects of Amino Acid Partial Deduction on Slaughter Performance Dry matter intake and amino acid intake during the formal experimental period are shown in Table 2 . As shown in Table 3 , empty body weight of lambs in the PD-Met group was significantly lower than in the PC, PD-Thr, and PD-Trp groups ($P<0.05$). Carcass weight in the PD-Lys, PD-Met, and PD-Trp groups was significantly lower than in the PC group ($P<0.05$). Both foot weight and skin/wool weight in the PD-Met group were significantly lower than in the PC group ($P<0.05$). No significant differences were observed in dressing percentage between amino acid deduction groups and the PC group ($P>0.05$).

2.2 Effects of Amino Acid Partial Deduction on Conventional Nutrient Composition As shown in Table 4 , the moisture content of head and feet in the PC and PD-Lys groups was significantly higher than in the PD-Met group ($P<0.05$), but did not differ significantly from the PD-Thr and PD-Trp groups ($P>0.05$). Carcass crude fat content in the PD-Lys, PD-Met, PD-Thr, and PD-Trp groups was significantly higher than in the PC group ($P<0.05$). Skin and wool crude fat content in the PD-Thr and PD-Trp groups was significantly higher than in the PC group ($P<0.05$). Carcass crude protein content in the PD-Met group was significantly lower than in the PC and PD-Trp groups ($P<0.05$), but did not differ significantly from the PD-Lys and PD-Thr groups ($P>0.05$). No significant differences were observed in crude ash, calcium, or phosphorus contents in head and feet, carcass, or skin and wool among all groups ($P>0.05$).

2.3 Effects of Amino Acid Partial Deduction on Amino Acid Content in Head and Feet As shown in Table 5 , Lys content in head and feet of the PD-Lys group was significantly lower than in the PC group ($P<0.05$), but did not differ significantly from the PD-Met, PD-Thr, and PD-Trp groups ($P>0.05$). Trp content in head and feet of the PD-Trp group was significantly lower than in the PC and PD-Thr groups ($P<0.05$), but did not differ significantly from the PD-Lys and PD-Met groups ($P>0.05$). Phenylalanine content in head and feet of the PD-Met group was significantly lower than in the PC, PD-Trp, and PD-Thr groups ($P<0.05$), but did not differ significantly from the PD-Lys group ($P>0.05$). Alanine content in head and feet of the PD-Met group was significantly lower than in the PC and PD-Trp groups ($P<0.05$), but did not differ significantly from the PD-Lys and PD-Thr groups ($P>0.05$). Essential and non-essential amino acid contents in head and feet of the PD-Met group were significantly lower than in the PC group ($P<0.05$), but did not differ significantly from the PD-Lys, PD-Thr, and PD-Trp groups ($P>0.05$). No significant differences were observed in other amino acid contents in head and feet among all groups ($P>0.05$).

2.4 Effects of Amino Acid Partial Deduction on Amino Acid Content in Carcass As shown in Table 6 , Lys content in carcass of the PD-Lys group was significantly lower than in the PC group (P<0.05), but did not differ significantly from the PD-Met, PD-Thr, and PD-Trp groups (P>0.05). Essential amino acid content in carcass of the PD-Lys and PD-Met groups was significantly lower than in the PC group (P<0.05). Non-essential amino acid content in carcass of the PD-Lys and PD-Trp groups was significantly lower than in the PD-Thr group (P<0.05), but did not differ significantly from the PC and PD-Met groups (P>0.05). No significant differences were observed in other amino acid contents in carcass among all groups (P>0.05).

2.5 Effects of Amino Acid Partial Deduction on Amino Acid Content in Skin and Wool As shown in Table 7 , Lys content in skin and wool of the PD-Lys group was significantly lower than in the PC group (P<0.05), but did not differ significantly from the PD-Met, PD-Thr, and PD-Trp groups (P>0.05). Thr content in skin and wool of the PD-Thr group was significantly lower than in the PC group (P<0.05), but did not differ significantly from the PD-Lys, PD-Met, and PD-Trp groups (P>0.05). Aspartic acid content in skin and wool of the PD-Thr group was significantly lower than in the PC and PD-Met groups (P<0.05). Serine content in skin and wool of the PD-Lys group was significantly lower than in the PC group (P<0.05). Glutamic acid content in skin and wool of the PD-Thr group was significantly lower than in the PC group (P<0.05). Alanine content in skin and wool of the PD-Lys group was significantly lower than in the PC group (P<0.05). Cysteine content in skin and wool of the PD-Met group was significantly lower than in the PC group (P<0.05). Essential amino acid content in skin and wool of the PD-Met group was significantly lower than in the PC and PD-Trp groups (P<0.05). Non-essential amino acid content in skin and wool of the PD-Lys and PD-Met groups was significantly lower than in the PC group (P<0.05). No significant differences were observed in other amino acid contents in skin and wool among all groups (P>0.05).

3. Discussion

3.1 Effects on Slaughter Performance Slaughter performance evaluation facilitates assessment of lamb growth and development at different stages and is crucial for improving mutton quality. This study found that, except for dressing percentage, all other slaughter performance indicators in amino acid deduction groups were lower than in the PC group. Ferreira et al. [10] reported that feeding Merino sheep of 30-45 kg with diets containing different essential amino acid compositions did not significantly affect dressing percentage during growth, consistent with our findings. Partial deduction of Lys and Met in this study did not significantly affect dressing percentage but significantly impacted carcass weight, head weight, foot weight, and skin/wool weight. This may be because Met is the first limiting amino acid for wool keratin protein synthesis, and dietary Met supplementation promotes wool growth and consequently affects skin and wool quality. Our study found that Trp was the first limiting amino acid for achieving maximum dressing percentage in lambs, which differs from the amino acid sequence for maximum daily weight gain and feed conversion ratio identified by our research group [3]. Previous studies have not investigated this aspect, possibly because nitrogen balance trials were not employed for in-depth exploration, leading to inaccurate assessment of amino acid limitation. Therefore, reducing dietary protein while adding rumen-protected amino acids to achieve balanced supplementation and utilization ratios not only promotes carcass weight and skin/wool growth but also accelerates the time for Hu lambs to reach slaughter weight. However, the effects on slaughter performance of weaned lambs require further investigation through combined nitrogen balance trials.

3.2 Effects on Conventional Nutrient Composition Muscle moisture content is closely related to meat juiciness [11]. Muscle fat content significantly influences meat quality and palatability, affecting flavor, juiciness, and tenderness. Approximately 50% of fatty acids in lamb meat are unsaturated, which can prevent obesity, arteriosclerosis, elevated blood lipids, and thrombosis [12]. Muscle protein content is a primary indicator of meat nutritional quality, and amino acids are essential components determining protein deposition. Balanced amino acid patterns are crucial for improving meat quality and nutrient content [12]. Crude ash content in muscle is closely related to mineral content, with higher ash content indicating relatively higher mineral elements such as calcium and phosphorus. Additionally, peptide hormones synthesized from amino acids, such as calcitonin, participate in calcium and phosphorus metabolism, thereby affecting mineral distribution in tissues [13].

Nie Furong et al. [14] reported that muscle moisture, crude protein, crude fat, and crude ash contents in 3-month-old Small-tailed Han sheep were 73.63%, 62.82%, 15.98%, and 5.98%, respectively. In Dorper × Small-tailed Han crossbred lambs, these values were 73.26%, 63.06%, 11.34%, and 6.24%, respectively, with calcium and phosphorus contents ranging from 0.20% to 0.70%. Xi et al. [15] found that supplementing Met in low-protein diets for 60-day-old yellow-feathered broilers resulted in muscle moisture, crude protein, and crude fat contents of 61.37%, 51.86%, and 30.80%, respectively, which were 0.30%-0.50% higher than in high-protein diets without Met supplementation. The conventional nutrient contents measured in 120-day-old Hu lambs in this study were lower than those reported by Nie Furong et al. [14] and Xi et al. [15], but the differences were minor. Nutrient contents in amino acid deduction groups were generally lower than in the control group, indicating that balanced dietary amino acids play an important role in improving lamb meat quality, flavor, tenderness, and juiciness.

3.3 Effects on Amino Acid Content in Head and Feet The amino acid composition and content in sheep head and feet are important indicators for evaluating carcass nutritional value, particularly in sheep brain which is rich in protein containing abundant Lys, glutamic acid, leucine, and aspartic acid. The two acidic amino acids, glutamic acid and aspartic acid, are strongly related to antioxidant capacity [16]. Chang Fei et al. [16] found through defatting analysis that glutamic acid content was highest in sheep brain, followed by aspartic acid at 9.13% and 5.47%, respectively. Zhang Xi et al. [17] reported that glutamic acid and aspartic acid contents were 7-12 times higher than Met content, and that glutamic acid, aspartic acid, leucine, and Lys are primary components of brain polypeptides that play important roles in regulating neurological function. Our study found that glutamic acid content was highest in head and feet across different amino acid deduction treatments, but the PD-Met group had the lowest glutamic acid content relative to the PC group, consistent with previous findings. This indicates that Met deduction significantly affects acidic amino acids such as glutamic acid and aspartic acid, consequently influencing antioxidant capacity. The high content of these two acidic amino acids provides theoretical support for research findings on high antioxidant capacity.

In this study, Lys, Met, Thr, and Trp contents in head and feet of the PC group were 11.60%, 3.96%, 8.16%, and 0.89%, respectively (amino acid ratio of 100:34:70:7), which were higher than the values of 7.03%, 2.08%, and 3.79% (ratio of 100:30:54) reported by Ferreira et al. [10] through rumen amino acid infusion. This demonstrates that rumen-protected amino acid supplementation can effectively increase amino acid content in weaned lamb tissues, with ratios consistent with our group' s previous findings of Lys:Met:Thr:Trp ratios of 100:44:44:8 and 100:34:38:8 for maximum daily weight gain and dressing percentage [3], except for higher Trp content in head and feet. In the PD-Met group, essential amino acid contents, particularly Lys, phenylalanine, and valine, were lower than in the PC group, indicating that essential amino acid deficiency severely affects synthesis of other essential and non-essential amino acids in lamb head and feet, thereby disrupting amino acid balance patterns [17]. Overall, head and feet are one of the factors influencing appropriate amino acid ratios and contents in lamb carcass, providing important scientific evidence for breaking traditional "amino acid black box" theories [18].

3.4 Effects on Amino Acid Content in Carcass Lamb carcass amino acids are high-quality proteins whose types and proportions closely match human essential amino acid requirements, being easily digestible and absorbable [19]. Lamb carcass is rich in umami amino acids, and amino acid content directly relates to mutton flavor. The carcass amino acid pattern can serve as a research model for ideal amino acids in lambs, providing a reference pattern for dietary amino acid balance [20]. Van et al. [21] reported that Lys, Met, Thr, and Trp contents in carcass of 28 kg Dorper $\times$ Merino crossbred lambs were 9.09%, 1.40%, 4.56%, and 1.67%, respectively. Sánchez-Mendoza [22] and Boisen et al. [23] found that dietary Met supplementation significantly affected carcass weight and crude protein content, both reaching maximum values at 1.20 mg/d Met supplementation, but neither study further explored carcass amino acid content or modeling.

Our study employed the amino acid partial deduction method to analyze amino acid content in different tissues. We found that essential amino acid supplementation resulted in carcass Lys, Met, Thr, and Trp contents of 12.20%, 3.64%, 1.40%, and 4.58%, respectively, with an ideal amino acid pattern of 100:35:44:13. Carcass amino acid content showed an upward trend compared to Van et al. [21], and the pattern was similar to our group' s previously identified ratio of 100:(37-41):(39-45):12 for maximum nitrogen deposition [3]. Both essential and non-essential amino acid contents in carcass of the PD-Met group showed decreasing trends compared to the PC group, consistent with findings from Sánchez-Mendoza [22] and Boisen et al. [23]. In conclusion, Lys and Met are essential limiting amino acids for lamb muscle and bone growth [24]. Although the carcass amino acid pattern differs from that of head and feet, it more closely approximates the amino acid balance pattern for the growth stage. Ideal amino acid patterns vary among different breeds, lines, and growth stages, and research on ideal amino acid patterns for Hu lambs requires further exploration at genetic and protein levels.

3.5 Effects on Amino Acid Content in Skin and Wool Wool growth requires substantial protein. Wool is composed of cysteine- and Met-rich proteins, necessitating large amounts of Met and cysteine from the body amino acid pool, with relatively lower requirements for other amino acids [25]. Yang Hua et al. [26] analyzed selective absorption of Met and cysteine by wool in 10-month-old Merino lambs, causing amino acid imbalance in other tissues. In other words, amino acids provided by diet and rumen microorganisms cannot meet the specific demands of wool growth for Met and cysteine, resulting in much lower amino acid utilization efficiency for wool growth compared to other body tissues [27].

Our results showed that amino acid imbalance significantly affected Lys and Thr contents in skin and wool, with significant changes also observed in aspartic acid, serine, glutamic acid, alanine, and cysteine contents. Met deduction significantly reduced both essential and non-essential amino acid contents in skin and wool. The allocation ratio of amino acids between wool growth and body weight gain correlates with sheep growth rate. Met deficiency reduces synthesis of low-sulfur proteins that compose wool, while deficiencies in essential amino acids Lys and Thr also affect non-essential amino acids such as aspartic acid and serine that influence wool fiber helical structure and fiber diameter [28].

4. Conclusions

1. Deficiency of the four essential amino acids (Lys, Met, Thr, and Trp) in starter feed affects slaughter performance of 61-120 day-old weaned Hu lambs, with Met deficiency particularly causing significant reductions in empty body weight, carcass weight, skin/wool weight, and foot weight.

2. Essential amino acid deficiency directly affects carcass crude protein content, crude fat content in carcass and skin/wool, and moisture content in

head and feet, but does not affect calcium and phosphorus contents.

3. The ideal patterns of the four essential amino acids (Lys:Met:Thr:Trp) differ among tissues: carcass 100:35:44:13, skin and wool 100:21:129:11, and head and feet 100:34:70:7.

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