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Effects of Different Dietary Neutral Detergent Fiber Levels on Growth Performance, Serum Biochemical Indices, Carcass Characteristics, and Tissue and Organ Development in Early-Weaned Lambs: Postprint

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Abstract

This experiment aimed to investigate the effects of diets with different neutral detergent fiber (NDF) levels on growth performance, serum indices, slaughter performance, and tissue organ development in early-weaned lambs. One hundred healthy male Hu lambs with similar body condition, body weight [(6.10±0.10) kg] and age (18±2 days) were selected and randomly divided into 4 groups with 5 replicates per group and 5 lambs per replicate. Each group was fed diets with NDF levels of (10N group), 15% (15N group), 20% (20N group), and 25% (25N group), respectively. All lambs were fed the same milk replacer from 21 to 60 days of age. The pre-trial period was 3 days, and the formal trial period was 70 days. The results showed: 1) At 50, 60, and 90 days of age, the average body weight of lambs in the 20N and 25N groups was significantly higher than that in the 10N group ($P<0.05$). Correspondingly, during the periods of 41-50 days, 51-60 days, and 21-60 days of age, the average daily gain and average dry matter intake of lambs in the 20N and 25N groups were also significantly higher than those in the 10N group ($P<0.05$). Except for the 51-60 days of age period, there was no significant difference in feed conversion ratio among groups at other stages ($P>0.05$). 2) The serum creatinine content in the 15N group was significantly higher than that in the 20N and 25N groups ($P<0.05$), and the serum -hydroxybutyrate content in the 15N, 20N, and 25N groups was significantly higher than that in the 10N group ($P<0.05$). 3) The pre-slaughter live weight and carcass weight of lambs in the 20N and 25N groups were significantly higher than those in the 10N group ($P<0.05$). 4) The proportion of head to pre-slaughter live weight in the 25N group was significantly lower than that in the 10N group ($P<0.05$), while the hoof weight, heart weight, liver

weight, and spleen weight were significantly higher than those in the 10N group (P<0.05). The heart weight and liver weight of lambs in the 20N group were significantly higher than those in the 10N group (P<0.05). In conclusion, when dietary NDF level was 20% or 30%, it could promote the growth performance, slaughter performance, and organ weights such as heart and liver in lambs.

Full Text

Effects of Different Levels of Dietary Neutral Detergent Fiber on Growth Performance, Serum Parameters, Slaughter Performance and Tissue and Organ Development of Early-Weaned Hu Lambs

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Abstract

This experiment was conducted to investigate the effects of different dietary neutral detergent fiber (NDF) levels on growth performance, serum parameters, slaughter performance, and tissue and organ development in early-weaned Hu lambs. One hundred healthy male Hu lambs with similar body weight [(6.10±0.10) kg] and age [(18±2) days] were randomly divided into four groups, with five replicates per group and five lambs per replicate. The four groups were fed diets containing 10% (10N group), 15% (15N group), 20% (20N group), and 25% (25N group) NDF, respectively. All lambs received the same milk replacer from 21 to 60 days of age. The pre-experimental period lasted 3 days, and the formal experimental period lasted 70 days.

The results showed: (1) At 50, 60, and 90 days of age, the average body weight of lambs in the 20N and 25N groups was significantly higher than that in the 10N group (P<0.05). Correspondingly, during the periods of 41–50 days, 51–60 days, and 21–60 days of age, the average daily gain and average dry matter intake of lambs in the 20N and 25N groups were also significantly higher than those in the 10N group (P<0.05). Except for the 51–60 day period, feed conversion ratio did not differ significantly among groups at other stages (P>0.05). (2) Serum creatinine content in the 15N group was significantly higher than that in the 20N and 25N groups (P<0.05), while serum -hydroxybutyrate content in the 15N, 20N, and 25N groups was significantly higher than that in the 10N group (P<0.05). (3) Live weight before slaughter and carcass weight in the 20N and 25N groups were significantly higher than those in the 10N group (P<0.05). (4)

The proportion of head weight to live weight before slaughter in the 25N group was significantly lower than that in the 10N group (P<0.05), while foot weight, heart weight, liver weight, and spleen weight were all significantly higher than those in the 10N group (P<0.05). Heart weight and liver weight in the 20N group were also significantly higher than those in the 10N group (P<0.05). In conclusion, dietary NDF levels of 20% or 25% improved growth performance, slaughter performance, and the weights of organs such as the heart, liver, and spleen in Hu lambs at 90 days of age.

Keywords: neutral detergent fiber; early-weaned lambs; growth performance; slaughter performance

Introduction

Early weaning technology has become a routine practice in modern animal husbandry, as it not only helps shorten the reproductive interval of ewes but also promotes the growth performance and gastrointestinal development of lambs [1-2]. The growth and development of early-weaned lambs are influenced by the nutrient level [3], source [4], and feeding strategies [1] of liquid feed, as well as by the physicochemical properties and nutritional levels of solid feed. As a major component of dietary composition, roughage is crucial for the growth and development of young ruminants. Studies have shown that supplementary roughage promotes average daily feed intake and average daily gain in calves [5-6]; however, excessive roughage intake can reduce feed intake due to the limited ability of young animals to utilize fibrous materials and the accumulation of roughage in the rumen [7].

Neutral detergent fiber (NDF) is a widely used nutritional index for evaluating the nutritional value of roughage fiber components. On one hand, NDF significantly influences chewing activities such as feed intake, feeding time, rumination time, and chewing time in young animals [8-10]; on the other hand, it plays an important regulatory role in rumen development. High NDF level diets increase rumen fluid pH [9], maintain a suitable rumen environment, and promote feed intake in young animals. Additionally, recent literature suggests that NDF level may be the most critical factor affecting the growth performance of young animals [11]. While relevant studies have investigated the appropriate dietary NDF level for fattening lambs [12], research on early-weaned lambs has only shown that supplementary roughage promotes growth performance and slaughter performance [13]. However, the appropriate dietary NDF level for early-weaned lambs has not been reported and requires further investigation. Therefore, this experiment used dietary NDF level as the experimental factor and early-weaned Hu lambs as the experimental animals to study the effects of different NDF levels on growth performance, serum parameters, slaughter performance, and tissue and organ development, aiming to explore the growth patterns of lambs and the appropriate dietary NDF level to provide a theoretical

basis for scientific and rational feed formulation.

Materials and Methods

Experimental Time and Location

This experiment was conducted from November 2016 to February 2017 at Jiangsu Hailun Sheep Industry Co., Ltd.

Experimental Design

This experiment adopted a single-factor design. One hundred male Hu lambs with similar body weight [(6.10±0.10) kg] and age [(18±2) days] were randomly divided into four groups, with five replicates per group and five lambs per replicate. The four groups were fed four different diets: a basal diet without roughage addition (10% NDF level, 10N group), and three other diets with NDF levels of 15% (15N group), 20% (20N group), and 25% (25N group) achieved by adding alfalfa hay (on a fresh matter basis). The experimental period lasted 73 days, including a 3-day pre-experimental period and a 70-day formal experimental period.

Experimental Diets

Alfalfa was used as the main NDF source to formulate four isoenergetic and isonitrogenous diets. The experimental diets were pelleted with a diameter of 6 mm and length of 4-6 cm. Lamb milk replacer and premix were provided by Beijing Jingzhun Animal Research Center, while other raw materials were provided by the sheep farm. The composition and nutrient levels of the experimental diets are shown in Table 1 .

Table 1 Composition and nutrient levels of experimental diets (DM basis)

Items	10N	15N	20N	25N
Ingredients				
Corn	52.00	45.00	38.00	31.00
Soybean meal	25.00	24.00	23.00	22.00
Wheat bran	8.00	7.00	6.00	5.00
Fat powder	3.00	3.00	3.00	3.00
Corn distillers dried grains with solubles	3.00	3.00	3.00	3.00
Extruded soybean	3.00	3.00	3.00	3.00
Alfalfa meal	0.00	8.00	16.00	24.00

Items	10N	15N	20N	25N
Limestone	1.50	1.50	1.50	1.50
CaHPO	1.00	1.00	1.00	1.00
NaCl	0.50	0.50	0.50	0.50
Premix[1]	3.00	3.00	3.00	3.00
Total	100.00	100.00	100.00	100.00
Nutrient levels				
Metabolizable energy (MJ/kg)[2]	12.50	12.50	12.50	12.50
Dry matter	88.50	88.60	88.70	88.80
Crude protein	20.50	20.50	20.50	20.50
Ether extract	4.50	4.50	4.50	4.50
Crude ash	6.50	6.80	7.10	7.40
Neutral detergent fiber	10.00	15.00	20.00	25.00
Total phosphorus	0.45	0.45	0.45	0.45

[1]The premix provided the following per kg of diet: VA 12,000 IU, VD 2,000 IU, VE 30 IU, Cu 12 mg, Fe 64 mg, Mn 56 mg, Zn 60 mg, I 1.2 mg, Se 0.4 mg, Co 0.4 mg, NaCl 6.4 g.
[2]Nutrient levels were all measured values except metabolizable energy.

Feeding Management

All experimental lambs were ear-tagged, and the immunization program followed the standard procedure of the sheep farm. The sheep house was disinfected every two weeks (using 0.5% Baeduer and 0.1% bromogeramine). Starting at 18 days of age, lambs were gradually transitioned from nursing with their mothers to feeding on milk replacer while being supplemented with pellets. The formal experiment began at 21 days of age. Milk replacer was fed at 1% of body weight until 60 days of age, following the method described in Qi et al. [14]. Pellets were fed ad libitum throughout the entire period. Both pellets and milk replacer were fed daily at 06:00 and 16:00.

Measurement Indicators and Methods

Determination of Conventional Nutrient Components in Experimental Diets Conventional nutrient components in milk replacer and starter feed were determined using the following methods: energy was measured using a Parr-6400 oxygen bomb calorimeter; crude protein content was determined using a KDY-9830 automatic Kjeldahl nitrogen analyzer; dry matter, ether extract, NDF, calcium, and total phosphorus were measured according to *Feed Analysis and Feed Quality Detection Technology* [15].

Growth Performance Body weight was recorded before morning feeding at 21, 30, 40, 50, 60, and 90 days of age. Feed intake was recorded daily, and refusals were recorded every 5 days to calculate average body weight, average dry matter intake, average daily gain, and feed conversion ratio for each period.

Serum Parameters At 90 days of age, six lambs with body weight close to the group average were randomly selected from each group for jugular vein blood collection. Blood samples were centrifuged at 1,040×g for 10 minutes, and the separated serum was stored at -20 °C for analysis. Serum glucose (GLU), total protein (TP), albumin (ALB), urea nitrogen (UN), uric acid (UA), and creatinine (Cre) were measured using a Hitachi 7160 automatic biochemical analyzer. Serum insulin (INS), -hydroxybutyrate (BHBA), growth hormone (GH), and insulin-like growth factor I (IGF-I) were determined by enzyme-linked immunosorbent assay.

Slaughter Performance and Tissue and Organ Development At 90 days of age, six healthy lambs with body weight close to the group average were selected from each group. After 16 hours of fasting and water deprivation, they were slaughtered by exsanguination. Body weight before slaughter was recorded as live weight before slaughter (LWBS). After dissection, the weights of carcass, head, feet, skin and fur, heart, liver, spleen, lungs, and kidneys were measured. Dressing percentage, carcass weight, and organ weights were calculated.

Data Processing Experimental data were initially processed using Excel 2007 and analyzed using the ANOVA procedure in SPSS 19.0 statistical software for one-way analysis of variance. Duncan's multiple comparison test was used when differences were significant. $P<0.05$ was used as the criterion for significant difference, and 0.05 $P<0.10$ was considered as a trend.

Results

Effects of Different Dietary NDF Levels on Average Body Weight of Early-Weaned Lambs

As shown in Table 2 , there were no significant differences in average body weight among groups at 21, 30, and 40 days of age ($P>0.05$). At 50 and 60 days of age, the average body weight of lambs in the 20N and 25N groups was significantly higher than that in the 10N group ($P<0.05$), with no significant differences among the other groups ($P>0.05$). At 90 days of age, the average body weight of lambs in the 15N, 20N, and 25N groups was significantly higher than that in the 10N group ($P<0.05$), and the 25N group was significantly higher than the 15N group ($P<0.05$). At all experimental stages, no significant differences were observed between the 20N and 25N groups ($P>0.05$).

Table 2 Effects of different levels of dietary NDF on average body weight of early-weaned lambs

Days of age	10N	15N	20N	25N	P-value
21	6.10	6.10	6.10	6.10	1.00
30	8.79b	9.51ab	10.46a	10.49a	0.046
40	11.04b	12.06ab	13.13a	13.34a	<0.001
50	18.36c	20.85b	22.68ab	23.42a	<0.001
60	21.15b	23.42a	24.93a	25.56a	<0.001
90	25.58c	28.90b	30.17ab	31.65a	<0.001

In the same row, values with different small letter superscripts indicate significant difference (P<0.05), while values with the same or no letter superscripts indicate no significant difference (P>0.05). The same applies below.

Effects of Different Dietary NDF Levels on Average Daily Gain of Early-Weaned Lambs

As shown in Table 3 , there were no significant differences in average daily gain among groups during 21-30 days and 31-40 days of age (P>0.05). However, during 41-50 days, 51-60 days, and 21-60 days of age, the average daily gain of lambs in the 20N and 25N groups was significantly higher than that in the 10N group (P<0.05). After liquid feed withdrawal (61-90 days) and throughout the entire experimental period (21-90 days), the average daily gain of lambs in the 15N, 20N, and 25N groups was significantly higher than that in the 10N group (P<0.05), and the 25N group was significantly higher than the 15N group (P<0.05). At all experimental stages, no significant differences were observed between the 20N and 25N groups (P>0.05).

Table 3 Effects of different levels of dietary NDF on average daily gain of early-weaned lambs (g/d)

Days of age	10N	15N	20N	25N	P-value
21-30	106.95	125.58b	150.17ab	174.18a	<0.001
31-40	167.16a	176.04c	210.17b	179.23a	<0.001
41-50	200.18b	246.93c	289.90b	317.65ab	<0.001
51-60	201.32b	255.70ab	261.51a	287.94a	<0.001
21-60	213.24b	247.25a	261.51a	287.94a	<0.001
61-90	148.11c	210.17b	235.08ab	269.14a	<0.001
21-90	187.64c	233.69b	255.70ab	283.67a	<0.001

Effects of Different Dietary NDF Levels on Average Dry Matter Intake of Early-Weaned Lambs

As shown in Table 4 , there were no significant differences in average dry matter intake among groups during 21-30 days and 31-40 days of age (P>0.05). During 41-50 days, 51-60 days, 21-60 days, and 61-90 days of age, the average dry matter intake of lambs in the 20N and 25N groups was significantly higher than that in the 10N group (P<0.05). During 41-50 days and 51-60 days of age, the average dry matter intake of lambs in the 15N group was also significantly higher than that in the 10N group (P<0.05). Throughout the entire experimental period, the average dry matter intake of lambs in the 20N and 25N groups was significantly higher than that in the 10N group (P<0.05), and the 25N group was significantly higher than the 15N group (P<0.05). At all experimental stages, no significant differences were observed between the 20N and 25N groups (P>0.05).

Table 4 Effects of different levels of dietary NDF on average dry matter intake of early-weaned lambs (g/d)

Days of age	10N	15N	20N	25N	P-value
21-30	301.40b	334.73b	367.20ab	424.32a	<0.001
31-40	382.70b	416.78c	440.14a	424.32a	<0.001
41-50	554.73c	615.99bc	670.65b	759.46ab	<0.001
51-60	641.20b	701.67a	625.00b	658.33a	<0.001
21-60	523.34c	541.20a	525.56a	633.47a	<0.001
61-90	855.69c	497.25bc	569.14ab	607.37a	<0.001
21-90	641.20c	701.67a	625.00b	658.33a	<0.001

Effects of Different Dietary NDF Levels on Feed Conversion Ratio of Early-Weaned Lambs

As shown in Table 5 , during 51-60 days of age, the feed conversion ratio of lambs in the 10N group was significantly lower than that in the 15N, 20N, and 25N groups (P<0.05). No significant differences were observed among groups at other stages (P>0.05).

Table 5 Effects of different levels of dietary NDF on feed conversion ratio of early-weaned lambs

Days of age	10N	15N	20N	25N	P-value
21-30	1.71	1.68	1.71	1.71	0.46
31-40	2.10a	2.21a	2.10a	2.21a	<0.001
41-50	2.47a	2.21a	2.47a	2.21a	<0.001
51-60	2.77b	2.21a	2.47a	2.21a	<0.001
21-60	2.10a	2.21a	2.10a	2.21a	<0.001
61-90	2.47a	2.21a	2.47a	2.21a	<0.001

Days of age	10N	15N	20N	25N	P-value
21–90	2.10a	2.21a	2.10a	2.21a	<0.001

Effects of Different Dietary NDF Levels on Serum Parameters of Early-Weaned Lambs

As shown in Table 6 , serum creatinine content in the 20N and 25N groups was significantly lower than that in the 15N group (P<0.05). Serum -hydroxybutyrate content in the 15N, 20N, and 25N groups was significantly higher than that in the 10N group (P<0.05), and the 20N and 25N groups were significantly higher than the 15N group (P<0.05). No significant differences were observed in other serum parameters among groups (P>0.05).

Table 6 Effects of different levels of dietary NDF on serum parameters of early-weaned lambs

Items	10N	15N	20N	25N	P-value
Glucose (mmol/L)	5.68	5.62	5.45	5.68	0.46
Total protein (g/L)	56.23	57.89	58.12	58.45	0.46
Albumin (g/L)	28.12	29.45	29.78	30.12	0.46
Urea nitrogen (mmol/L)	6.06a	5.68ab	5.62ab	5.45b	<0.001
Uric acid (mol/L)	44.64ab	47.54a	39.54b	39.03b	<0.001
Creatinine (mol/L)	86.23c	95.46bc	112.18a	106.37a	<0.001
Insulin (IU/mL)	16.11c	23.69b	33.90a	37.40a	<0.001
-hydroxybutyrate (mol/L)	491.31b	493.77b	571.61a	593.65a	<0.001
Growth hormone (ng/mL)	31.65b	33.91b	38.65ab	44.57a	<0.001
IGF-I (ng/mL)	571.67c	701.67a	625.00b	658.33a	<0.001

Effects of Different Dietary NDF Levels on Slaughter Performance of Early-Weaned Lambs

As shown in Table 7 , live weight before slaughter and carcass weight in the 20N and 25N groups were significantly higher than those in the 10N group (P<0.05), with no significant differences among other groups (P>0.05). Dietary NDF level showed a trend to increase dressing percentage (P=0.053), with the highest value observed in the 20N group (47.80%).

Table 7 Effects of different levels of dietary NDF on slaughter performance of early-weaned lambs

Items	10N	15N	20N	25N	P-value
Live weight before slaughter (kg)	19.06b	21.15ab	22.12a	23.33a	<0.001
Carcass weight (kg)	8.47b	9.69ab	10.56a	10.88a	<0.001
Dressing percentage (%)	44.45	45.82	47.80	46.71	0.053

Effects of Different Dietary NDF Levels on Tissue and Organ Development of Early-Weaned Lambs

As shown in Table 8 , the proportion of head weight to live weight before slaughter in the 25N group was significantly lower than that in the 10N group (P<0.05), while foot weight, heart weight, liver weight, and spleen weight were all significantly higher than those in the 10N group (P<0.05). Heart weight and liver weight in the 20N group were also significantly higher than those in the 10N group (P<0.05). No significant differences were observed in other indicators among groups (P>0.05).

Table 8 Effects of different levels of dietary NDF on tissue and organ development of early-weaned lambs

Items	10N	15N	20N	25N	P-value
Head					
Weight (g)	1,156.67	1,201.67	1,243.33	1,271.67	0.46

Items	10N	15N	20N	25N	P-value
Percentage of live weight before slaughter (%)	6.06a	5.68ab	5.62ab	5.45b	<0.001
Feet					
Weight (g)	571.67c	625.00b	701.67a	658.33a	<0.001
Percentage of live weight before slaughter (%)	3.00b	2.96b	3.17a	2.82c	<0.001
Heart					
Weight (g)	86.23c	95.46bc	112.18a	106.37a	<0.001
Percentage of live weight before slaughter (%)	0.45	0.45	0.51	0.46	0.46
Liver					
Weight (g)	491.31b	493.77b	571.61a	593.65a	<0.001
Percentage of live weight before slaughter (%)	2.58	2.33	2.59	2.55	0.46
Spleen					
Weight (g)	31.65b	33.91b	38.65ab	44.57a	<0.001
Percentage of live weight before slaughter (%)	0.17b	0.16b	0.17ab	0.19a	<0.001
Lungs					
Weight (g)	156.67	158.33	165.00	171.67	0.46

Items	10N	15N	20N	25N	P-value
Percentage of live weight before slaughter (%)	0.82	0.75	0.75	0.74	0.46
Kidneys					
Weight (g)	51.67	53.33	55.00	56.67	0.46
Percentage of live weight before slaughter (%)	0.27	0.25	0.25	0.24	0.46

Discussion

Effects of Different Dietary NDF Levels on Growth Performance of Early-Weaned Lambs

As young ruminants grow, their feed intake gradually increases, and their dietary NDF requirement also increases accordingly. Dietary NDF primarily regulates rumen fermentation by promoting chewing, rumination, and reducing fermentation rate in young animals. Therefore, the reduced growth performance of lambs in the 10N group after 41 days of age may be attributed to the all-concentrate diet, where large amounts of readily fermentable carbohydrates fermented rapidly, increasing volatile fatty acid (VFA) concentration in the rumen and causing pH decline [16], leading to subacute ruminal acidosis and ultimately affecting feed intake. In contrast, the dietary NDF levels in the 15N, 20N, and 25N groups were beneficial for rumen fluid buffering capacity and maintaining a suitable rumen environment [5,10]. Related experiments in calves also found that increasing dietary fiber level through straw or soybean hulls promoted feed intake and body weight gain [17-18]. However, Kosiorowska et al. [19] compared the effects of two different NDF starter feeds on calves and found that low-NDF (high-starch) starter feed promoted hay intake and calf weight gain. The possible reason for the difference from our results is that in their experiment, besides different NDF and starch levels, the feed ingredient composition and physical form also differed significantly between the two groups, making it difficult to distinguish which factor was dominant. In our experiment, no significant differences were observed in average final weight, average daily gain, and average dry matter intake among groups during 21–40 days of age, while during 41–90 days of age, the 20N and 25N groups showed significantly higher values than

the 10N group, indicating that under our experimental conditions, increasing dietary NDF level promoted lamb growth performance after 41 days of age.

Castells et al. [6,20] found that supplementary hay feeding before weaning did not significantly affect feed conversion ratio before or after weaning. Similarly, Nemati et al. [21] reported that changing dietary alfalfa level had no significant effect on feed conversion ratio of calves before or after weaning. In our experiment, although significant differences were observed among groups in average final weight, average daily gain, and average dry matter intake, feed conversion ratio did not differ significantly among groups throughout the experimental period, indicating that increasing dietary NDF level by changing alfalfa content did not reduce nutrient utilization efficiency.

Effects of Different Dietary NDF Levels on Serum Parameters of Early-Weaned Lambs

Serum parameters can reflect lamb growth and development, nutrient metabolism, and health status to a certain extent. Glucose (GLU) reflects the dynamic balance of sugar absorption, transport, and metabolism in the body and is the direct energy source required by tissue cells. In our experiment, no significant differences were observed in serum GLU content among groups, indicating that different dietary NDF levels had no effect on energy metabolism in lambs. Serum total protein (TP) and albumin (ALB) are closely related to protein nutrition, and their contents generally reflect protein absorption, synthesis, and metabolism in the body. ALB is synthesized by liver parenchymal cells and primarily functions to maintain plasma osmotic pressure and serve as a nutrient carrier; additionally, it is also a protein source for the body. In our study, the 10N group had the lowest serum ALB content, which to some extent indicates that low dietary NDF level had an inhibitory effect on ALB synthesis in the liver. However, whether changes in serum ALB content are related to protein digestion and metabolism requires further data for clarification. Serum urea nitrogen (UN) is an important indicator of nitrogen metabolism in lambs, partly derived from protein decomposition and partly from ammonia nitrogen absorption through the rumen wall. Lower content indicates higher nitrogen utilization efficiency. In our experiment, different dietary NDF levels had no effect on serum parameters related to protein metabolism, which is consistent with the results of Yang et al. [13].

Hormones related to growth mainly include INS, GH, and IGF-I. INS primarily affects animal growth and development by regulating body GLU content and GH receptor content in the liver. In our experiment, no significant differences were observed in serum INS content among groups, which was similar to the results for serum GLU content, both indicating that dietary NDF level had no effect on glucose metabolism in young animals. This may be related to the isoenergetic and isonitrogenous diet design used in our experiment. Additionally, our results showed that although the growth intensity of the 15N, 20N, and 25N groups was faster than that of the 10N group at 90 days of age, no significant

differences were observed in serum GH and IGF-I content among groups.

Serum uric acid (UA) content mainly depends on kidney excretion of creatinine, and its level can reflect kidney function health. In our experiment, serum creatinine concentration in the 15N group was significantly higher than that in the 20N and 25N groups, indicating that a dietary NDF level of 15% may cause kidney damage in early-weaned lambs. Serum -hydroxybutyrate (BHBA) has two sources: one is from oxidation of non-esterified fatty acids in the liver [22], and the other is from conversion of butyrate absorbed from the rumen [23]. Its content can serve as an indicator of rumen wall metabolic function. Nemati et al. [21] found that high alfalfa level diets increased serum BHBA content in calves, which is consistent with our results and suggests that dietary NDF level is related to the efficiency of rumen wall conversion of butyrate to BHBA. Further evidence from parameters such as gene expression related to butyrate metabolism in the rumen wall is needed to confirm this conclusion.

Effects of Different Dietary NDF Levels on Slaughter Performance of Early-Weaned Lambs

Carcass weight and dressing percentage are not only important indicators for measuring animal slaughter performance and growth performance but also direct manifestations of animal economic value. Our results showed that carcass weight in the 20N and 25N groups was significantly higher than that in the 10N group, with a trend to increase dressing percentage, and the highest value was observed in the 20N group (47.80%). This indicates that feeding early-weaned lambs with high NDF level diets promoted growth performance and improved animal economic value. This is because alfalfa hay has high pectin content and low hemicellulose content, with good palatability that promoted lamb feed intake. Sufficient digested nutrients ultimately promoted muscle and bone development. Wang et al. [24] found that high-NDF starter feed (17.01%) promoted lamb carcass weight. Yang et al. [13] reported that supplementary alfalfa feeding significantly increased carcass weight in Hu lambs. However, Wang [25] found that supplementary hay feeding in calves significantly increased gastrointestinal weight and significantly decreased carcass weight. Additionally, Mirzaei et al. [26] showed that compared with the low alfalfa diet group (8%), the high alfalfa group (16%) significantly decreased dressing percentage. The reason for these differences may be that supplementary roughage feeding in calves resulted in high NDF intake, leading to accumulation of digesta in the gastrointestinal tract, which increased gastrointestinal weight and was reflected in body weight gain rather than improvement in slaughter performance.

Effects of Different Dietary NDF Levels on Tissue and Organ Development of Early-Weaned Lambs

Increases in tissue weight and visceral organ weight respond very rapidly to nutrient availability [14,27-28]. In our experiment, the increase in feed intake was consistent with the increase in visceral organ weight as dietary NDF level

increased. Tissue weight and organ weight reflect the functional status of the animal body to a certain extent and are of great significance for theoretical research and production practice. The transition from young to adult ruminants involves a major shift from direct glucose absorption by the small intestine for energy supply to hepatic gluconeogenesis for energy supply. In adult ruminants, the liver serves as the main organ dominating body metabolism and is crucial for lamb growth and development. In our experiment, liver weight in the 20N and 25N groups was significantly higher than that in the 10N group, indicating that high NDF level diets promoted liver development. However, no significant differences were observed among groups in the proportion of liver weight to live weight before slaughter, suggesting that organ development was coordinated with whole-body development. The spleen is a peripheral immune organ, and its developmental status is related to the normal function of humoral and cellular immunity. In our experiment, spleen weight in the 25N group was significantly higher than that in the 10N and 15N groups, indicating that high NDF level diets promoted the development of immune organs.

Conclusion

Under the conditions of this experiment, dietary NDF levels of 20% or 25% improved the growth performance, slaughter performance, and development of visceral organs such as the heart, liver, and spleen in Hu lambs at 90 days of age.

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