

## Effects of *Eucommia ulmoides* Leaves on Nutrient Digestion and Utilization, Growth Performance, and Slaughter Performance in Sheep (Postprint)

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### Abstract

*Eucommia* leaves are high-quality roughage containing bioactive compounds. The present study aimed to investigate the effects of *Eucommia* leaves on nutrient digestion and utilization, growth performance, and slaughter performance in sheep. Thirty healthy Hu sheep with similar age and body weight were selected and randomly divided into three groups (n=10): a control group fed basal diet without *Eucommia* leaves (CTL group), a low-level *Eucommia* leaf group fed diet containing 10% *Eucommia* leaves (EUL1 group), and a high-level *Eucommia* leaf group fed diet containing 20% *Eucommia* leaves (EUL2 group). Feeding trial and digestion-metabolism trial were conducted. The results showed that dietary supplementation with different levels of *Eucommia* leaves had significant effects ( $P < 0.05$ ) on final weight, weight gain, feed intake, and daily weight gain, as well as on the digestibility and retention rate of energy and nitrogen, but had no significant effects ( $P > 0.05$ ) on the digestibility and retention rate of calcium and phosphorus. Additionally, *Eucommia* leaves significantly affected ( $P < 0.05$ ) dressing percentage and carcass lean meat percentage, while no significant effects ( $P > 0.05$ ) were observed on carcass weight, lean meat weight, bone weight, or meat-to-bone ratio. It can be concluded that *Eucommia* leaves exert significant effects on nutrient digestibility, utilization efficiency, growth performance, and slaughter performance in sheep, and the magnitude of these effects is dose-dependent.

## Full Text

### Effects of *Eucommia Ulmoides* Leaves on Nutrient Digestion and Utilization, Growth Performance, and Slaughter Performance of Sheep

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#### Abstract

*Eucommia ulmoides* leaves are a high-quality roughage with medicinal active substances. This experiment was conducted to investigate the effects of *Eucommia ulmoides* leaves on nutrient digestion and utilization, growth performance, and slaughter performance of sheep. Thirty healthy Hu sheep with similar age and body weight were randomly divided into three groups (n=10): a control group fed a basal diet without *Eucommia ulmoides* leaves (CTL group), a low-level group fed a diet containing 10% *Eucommia ulmoides* leaves (EUL1 group), and a high-level group fed a diet containing 20% *Eucommia ulmoides* leaves (EUL2 group). A feeding trial and digestion-metabolism experiment were conducted. The results showed that dietary supplementation with different levels of *Eucommia ulmoides* leaves significantly affected final weight, weight gain, feed intake, and daily gain ( $P<0.05$ ), significantly affected the digestibility and retention rate of energy and nitrogen ( $P<0.05$ ), but had no significant effect on the digestibility and retention rate of calcium and phosphorus ( $P>0.05$ ). Additionally, *Eucommia ulmoides* leaves significantly affected dressing percentage and carcass meat percentage ( $P<0.05$ ), but had no significant effect on carcass weight, meat weight, bone weight, or meat-to-bone ratio ( $P>0.05$ ). In conclusion, *Eucommia ulmoides* leaves significantly affect nutrient digestibility, utilization, growth performance, and slaughter performance in sheep, with the degree of influence being related to the supplementation level.

**Key words:** *Eucommia ulmoides* leaves; energy; nitrogen; digestibility; utiliza-

tion rate; growth performance; slaughter performance

## Introduction

*Eucommia ulmoides* is a valuable medicinal tree species, with its bark used in traditional medicine. It has a sweet taste and warm properties, and is known to tonify the liver and kidneys, strengthen muscles and bones, and provide various therapeutic effects. Modern research has discovered that *Eucommia* contains more than 70 chemical components. In addition to common nutrients (amino acids, organic acids, polysaccharides, phospholipids, vitamins, and trace elements), it also contains many special functional components (such as lignans, iridoids, phenols, sterols, flavonoids, polysaccharides, etc.), which have multiple functions [1]. It has been reported that *Eucommia* can stimulate the central nervous system, enhance cellular metabolism, prevent muscle and bone aging, degrade cholesterol, reduce body fat, balance blood pressure, eliminate metabolic waste, restore vascular elasticity, clear heat and promote diuresis, provide broad-spectrum antimicrobial activity, and enhance immunity [2-3]. *Eucommia* leaves have similar chemical compositions and pharmacological effects as *Eucommia* bark, and they are abundant, low-cost, and easy to harvest, making them suitable as animal feed [4-5]. *Eucommia* leaves can not only improve feed palatability and enhance animal immunity and health status, but their special medicinal components can also regulate metabolism, affecting animal growth, production performance, and product quality, which is significant for developing feed resources and improving breeding efficiency. Numerous studies have reported that adding *Eucommia* leaf meal or additives to animal diets can promote growth, increase daily weight gain, and reduce feed-to-gain ratio in various animals (cattle, sheep, pigs, chickens, fish, etc.), while also altering muscle composition by reducing fat content and increasing amino acid and protein levels, thereby improving meat flavor and quality [6-10]. Additionally, *Eucommia* leaves can enhance animal health by increasing immune organ indices, T-lymphocyte proportions, and serum immunoglobulin levels, and reducing the incidence of mastitis in dairy cows [10-12]. However, few reports have addressed its effects on feed utilization and production performance in sheep. This study investigated the effects of *Eucommia* leaves on nutrient digestibility, utilization, growth performance, and slaughter performance in sheep to elucidate the functional value of *Eucommia* leaves and provide a scientific basis for further development of *Eucommia* leaf feed resources.

## Materials and Methods

### 1.1 Source of *Eucommia Ulmoides* Leaves

*Eucommia* leaves were sourced from a *Eucommia* planting base in Ruyang County, Henan Province. They were collected in autumn, sun-dried, packed, and stored for later use.

## 1.2 Animal Selection and Experimental Design

Thirty healthy Hu sheep aged 5 months with body weights of 28–34 kg were selected and randomly allocated to three groups using a single-factor completely randomized design (with diet as the experimental factor). The groups were: a control group fed a conventional diet without *Eucommia* leaves (CTL group), a low-level group fed a diet containing 10% *Eucommia* leaves (EUL1 group), and a high-level group fed a diet containing 20% *Eucommia* leaves (EUL2 group), with 10 sheep per group.

## 1.3 Feeding Management

Before the experiment, the sheep pens were thoroughly disinfected. Experimental sheep were dewormed and vaccinated, then housed in separate pens. The trial consisted of a 15-day pre-trial period followed by a 90-day formal experimental period. Diet formulations were designed according to NRC (2007) [13] standards for sheep (Table 1). Various feed ingredients were processed into total mixed rations (TMR) using a mixer. Diets were provided at 3.5% of sheep body weight (with leftover feed controlled within 10%). Feed was offered at 07:00 and 16:30 daily, with ad libitum access to feed, water, and movement. Before each feeding, feed troughs were cleaned, and leftover feed was collected, weighed, and recorded. Pens were cleaned twice daily (morning and afternoon), and environmental disinfection with 0.5% peracetic acid was performed 1–2 times per week to maintain pen hygiene.

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

Items	Ingredients	CTL group	EUL1 group	EUL2 group
	Corn silage			
	Peanut seedling			
	<i>Eucommia ulmoides</i> leaves			
	Corn			
	Soybean meal			
	Wheat bran			
	Premix <sup>1</sup>			
	NaCl			
	Sodium bicarbonate			
	CaHPO <sub>4</sub>			
	<b>Total</b>			
<b>Nutrient levels<sup>2</sup></b>	Digestive energy (kJ/kg)			
	Crude protein			
	Ether extract			
	Neutral detergent fiber			
	Acid detergent fiber			
	Calcium			

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Items	Ingredients	CTL group	EUL1 group	EUL2 group
	Total phosphorus			

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<sup>1</sup> The premix provided the following per kg of diets: Cu 16.0 mg, Fe 60.0 mg, Mn 40.0 mg, Zn 60.0 mg, I 0.80 mg, Se 0.30 mg, Co 0.30 mg, VA 200,000 IU, VD<sub>3</sub> 250,000 IU, VE 750 mg.

<sup>2</sup> Digestive energy was a calculated value, while the others were measured values.

#### 1.4 Determination of Dietary Nutrient Digestibility

A digestion-metabolism trial (total collection of feces and urine method) was conducted during the feeding trial. After weighing, five sheep with similar body weights were selected from each group and placed in custom-made digestion-metabolism cages (Patent No. 2009203148043). The diets and water were supplied through feed troughs and water troughs, respectively. Dietary supply was based on the average feed intake from the previous period, with water added as needed to ensure ad libitum access. Daily observations were made regarding feed intake, activity, and stress status. Before each feeding, leftover feed was collected, weighed, and recorded. Sheep showing abnormal signs were promptly replaced. After adaptation to cage housing (6-7 days), feces and urine were collected according to standard procedures using specially designed feces collection trays and urine collection troughs to collect all excretions. Fecal and urine samples were collected once daily in the morning and afternoon. For fecal sampling, all feces in the collection tray were weighed, and a 10% (g/g) subsample was placed in a plastic bag, sealed, and stored at -20 °C. For urine sampling, the total urine volume in the collection bag was measured with a graduated cylinder, mixed thoroughly, and a 10% (mL/mL) subsample was placed in a clean plastic bottle and frozen at -20 °C. After 7 days of collection, the digestion-metabolism trial ended, and sheep were reweighed and returned to pen housing. The leftover feed and fecal samples collected over 7 days were reduced to approximately 1000 g using the quartering method and brought to the laboratory for analysis. Frozen urine samples were thawed, mixed thoroughly, and approximately 500 mL was taken to the laboratory for analysis.

**1.4.1 Sample Processing and Detection** Approximately 100 g of feed, leftover feed, and fecal samples were placed in trays and dried in a 65 °C oven for 48 hours, then removed and equilibrated for 24 hours before weighing to determine initial moisture content and calculate air-dry basis content. Samples were then ground using a micro plant grinder (FZ102, Shanghai Jinpeng Analytical Instrument Co., Ltd.), passed through a 40-mesh sieve, and stored in self-sealing bags. Urine samples were thawed, mixed thoroughly, and appropriate amounts were taken for analysis. The following indices were measured:

**Gross energy:** Determined by oxygen bomb calorimetry [14] using an oxygen bomb calorimeter (Model TYHWW-2000, Hebi Tianyu Instrument and Meter

Manufacturing Co., Ltd.). 1) For feed, leftover feed, and fecal samples: Approximately 1.0000 g of sample was weighed into a crucible and combusted in the calorimeter according to the manufacturer's instructions. 2) For urine samples: A quarter of a  $\Phi 15$  cm quantitative filter paper was weighed and placed in a crucible to determine the heat value of the filter paper (repeated 6 times) and calculate the average. Another quarter of filter paper was weighed, placed in a crucible, and 1.0000 g of urine sample was precisely weighed and absorbed onto the filter paper. The crucible with filter paper was dried in a 60 °C oven before combustion in the calorimeter.

**Nitrogen content:** Determined by the Kjeldahl method [15] using an automatic Kjeldahl nitrogen analyzer (SKD-2000, Shanghai Peiou Analytical Instrument Co., Ltd.).

**Calcium content:** Determined by atomic absorption spectrophotometry [15] using an atomic absorption spectrophotometer (WFX-120B, Beijing Ruili Analytical Instrument Co., Ltd.).

**Phosphorus content:** Determined by molybdenum yellow colorimetry [15] using a UV-Vis spectrophotometer (UV-1600, Beijing Ruili Analytical Instrument Co., Ltd.).

#### 1.4.2 Calculation of Nutrient Digestibility and Retention Rates

**Energy digestibility and retention rate:** Digestible energy (kJ/d) = Energy intake - Fecal energy;

Energy digestibility (%) = (Digestible energy / Energy intake)  $\times$  100;

Retained energy (kJ/d) = Energy intake - Fecal energy - Urinary energy;

Energy retention rate (%) = (Retained energy / Energy intake)  $\times$  100.

**Nitrogen digestibility and retention rate:** Digestible nitrogen (g/d) = Nitrogen intake - Fecal nitrogen;

Nitrogen digestibility (%) = (Digestible nitrogen / Nitrogen intake)  $\times$  100;

Retained nitrogen (g) = Nitrogen intake - Fecal nitrogen - Urinary nitrogen;

Nitrogen retention rate (%) = (Retained nitrogen / Nitrogen intake)  $\times$  100.

**Calcium digestibility and retention rate:** Digestible calcium (g/d) = Calcium intake - Fecal calcium;

Calcium digestibility (%) = (Digestible calcium / Calcium intake)  $\times$  100;

Retained calcium (g/d) = Calcium intake - Fecal calcium - Urinary calcium;

Calcium retention rate (%) = (Retained calcium / Calcium intake)  $\times$  100.

**Phosphorus digestibility and retention rate:** Digestible phosphorus (g/d) = Phosphorus intake - Fecal phosphorus;

Phosphorus digestibility (%) = (Digestible phosphorus / Phosphorus intake)  $\times$  100;

Retained phosphorus (g/d) = Phosphorus intake - Fecal phosphorus - Urinary phosphorus;

Phosphorus retention rate (%) = (Retained phosphorus / Phosphorus intake)

× 100.

### 1.5 Growth Performance Measurement

After the pre-trial period, selected experimental sheep were weighed for three consecutive days before morning feeding (07:00) after overnight fasting, and the average was used as the initial body weight to commence the formal trial. Daily feed provision and leftover amounts were recorded for each group to calculate feed intake. Body weight was measured every 15 days until the trial ended. Feed intake, daily weight gain, and feed-to-gain ratio were calculated using the following formulas:

Feed intake (g/d) = [Feed provision (g) - Leftover feed (g)] / Trial days (d);

Daily weight gain (g/d) = Total weight gain (g) / Trial days (d);

Feed-to-gain ratio = Feed intake (g/d) / Daily weight gain (g/d).

### 1.6 Slaughter Performance Measurement

After the feeding trial, five sheep were randomly selected from each group, fasted for 24 hours with water withheld for 12 hours, weighed, and then slaughtered. The following indices were recorded and calculated:

**Live weight before slaughter:** Body weight prior to slaughter.

**Carcass weight:** After slaughter, bleeding, skinning, head removal, and removal of all internal organs (except kidneys and surrounding fat), and removal of parts below the knee and hock joints, the carcass was left to stand for 30 minutes before weighing.

**Meat weight:** The weight of lean meat after careful deboning of the warm carcass (meat remaining on bones and meat scraps lost not exceeding 300 g).

**Meat-to-bone ratio:** The ratio of bone weight to lean meat weight in the carcass.

**Dressing percentage (%)** = (Carcass weight / Live weight before slaughter) × 100.

**Meat percentage (%)** = (Meat weight / Live weight before slaughter) × 100.

**Carcass meat percentage (%)** = (Meat weight / Carcass weight) × 100.

### 1.7 Statistical Analysis

Measured data were initially organized using Excel and statistically analyzed using GraphPad Prism 5.0 software. One-way ANOVA was used for intergroup difference analysis. When significant differences were detected ( $P < 0.05$ ), Turkey's test was used for multiple comparisons.  $P < 0.05$  was considered statistically significant, and  $0.05 \leq P < 0.10$  was considered a trend toward significance. Data are presented as means ± standard deviation.

## Results

### 2.2 Effects of *Eucommia Ulmoides* Leaves on Dietary Nutrient Digestion and Utilization in Sheep

As shown in Table 2, compared with the CTL group, energy intake was significantly increased in both EUL1 and EUL2 groups ( $P < 0.05$ ), with the ranking  $EUL1 > EUL2 > CTL$ . Fecal energy followed the pattern  $EUL2 > EUL1 > CTL$ , with EUL2 being significantly higher than EUL1 and CTL ( $P < 0.05$ ), while no significant difference was observed between EUL1 and CTL ( $P > 0.05$ ). Digestible energy ranked  $EUL1 > EUL2 > CTL$ , but differences among groups were not significant ( $P > 0.05$ ). Energy digestibility in EUL2 was significantly lower than in CTL and EUL1 ( $P < 0.05$ ), with no significant difference between EUL1 and CTL ( $P > 0.05$ ). Urinary energy in EUL2 was significantly higher than in CTL ( $P < 0.05$ ), while EUL1 did not differ significantly from either CTL or EUL2 ( $P > 0.05$ ). Energy deposition in EUL1 was significantly higher than in both CTL and EUL2 ( $P < 0.05$ ), with no significant difference between EUL2 and CTL ( $P > 0.05$ ). Energy retention rate was significantly higher in EUL1 and CTL compared with EUL2 ( $P < 0.05$ ), with no significant difference between EUL1 and CTL ( $P > 0.05$ ).

Nitrogen intake in EUL1 and EUL2 was significantly higher than in CTL ( $P < 0.05$ ), with no significant difference between EUL1 and EUL2 ( $P > 0.05$ ). Fecal nitrogen in EUL1 and EUL2 was significantly higher than in CTL ( $P < 0.05$ ), and EUL2 was significantly higher than EUL1 ( $P < 0.05$ ). Digestible nitrogen in EUL1 was significantly higher than in CTL ( $P < 0.05$ ), while CTL was significantly higher than EUL2 ( $P < 0.05$ ). Nitrogen digestibility in CTL and EUL1 was significantly higher than in EUL2 ( $P < 0.05$ ), with no significant difference between CTL and EUL1 ( $P > 0.05$ ). No significant differences were observed among the three groups for urinary nitrogen ( $P > 0.05$ ). Nitrogen retention in EUL1 was significantly higher than in CTL ( $P < 0.05$ ), and CTL was significantly higher than EUL2 ( $P < 0.05$ ). Nitrogen retention rate in CTL and EUL1 was significantly higher than in EUL2 ( $P < 0.05$ ), with no significant difference between CTL and EUL1 ( $P > 0.05$ ).

Compared with the CTL group, EUL1 and EUL2 showed an increasing trend in calcium and phosphorus intake, retention amount, and retention rate ( $0.05 \leq P < 0.10$ ).

**Table 2 Effects of *Eucommia ulmoides* leaves on feed nutrients digestion and utilization of sheep**

Items	CTL group	EUL1 group	EUL2 group	P-value
<b>Energy</b>				

Items	CTL group	EUL1 group	EUL2 group	P-value
Energy intake [kJ/(head·d)]	17.05±0.35 <sup>a</sup>	20.91±1.03 <sup>b</sup>	19.89±0.82 <sup>b</sup>	
<i>Fecalenergy</i> [kJ/(head·d)]	8.44±0.48 <sup>a</sup>	9.45±0.75 <sup>a</sup>	11.14±0.33 <sup>b</sup>	
<i>Digestibleenergy</i> [kJ/(head·d)]	8.62±1.21	11.48±1.95	8.73±1.74	
<i>Energydigestibility</i> (±2.52 <sup>a</sup> )	54.89±2.13 <sup>a</sup>	43.88±0.65 <sup>b</sup>		
<i>Urinaryenergydeposition</i> [kJ/(head·d)]	0.23±0.02 <sup>a</sup>	0.30±0.05 <sup>ab</sup>	0.47±0.12 <sup>b</sup>	
<i>Energydepositionrate</i> (±2.57 <sup>a</sup> )	53.47±2.12 <sup>ab</sup>	41.54±0.25 <sup>b</sup>		
<i>*Nitrogen*</i>				
<i>Nitrogenintake</i> [g/(head·d)]	21.22±0.48 <sup>a</sup>	25.89±1.14 <sup>b</sup>	24.92±0.94 <sup>b</sup>	
<i>Fecalnitrogen</i> [g/(head·d)]	9.38±0.47 <sup>a</sup>	11.44±0.50 <sup>b</sup>	14.55±0.29 <sup>c</sup>	
<i>Digestiblenitrogen</i> [g/(head·d)]	11.84±0.50 <sup>a</sup>	14.45±0.75 <sup>b</sup>	10.37±0.68 <sup>c</sup>	
<i>Nitrogendigestibility</i> (±1.94 <sup>a</sup> )	55.77±0.94 <sup>a</sup>	41.46±1.14 <sup>b</sup>		
<i>Nitrogendeposition</i> [g/(head·d)]	4.71±0.73	5.79±1.10	5.03±1.16	
<i>Nitrogenretentionrate</i> (±2.63 <sup>a</sup> )	33.62±4.31 <sup>a</sup>	21.67±3.53 <sup>b</sup>		
<i>*Calcium*</i>				
<i>Calciumintake</i> [g/(head·d)]	6.12±0.28	8.44±1.11	7.77±0.99	
<i>Fecalcalcium</i> [g/(head·d)]	3.93±0.25	5.70±0.88	4.53±0.57	
<i>Digestiblecalcium</i> [g/(head·d)]	2.18±0.24	2.72±0.94	3.25±0.78	
<i>Calciumdigestibility</i> (±2.21)	32.44±4.11	39.35±6.50		
<i>Urinarycalciumdeposits</i> [g/(head·d)]	0.16±0.03	0.17±0.03	0.19±0.07	
<i>Calciumdepositionrate</i> (±1.79)	30.13±4.08	36.86±6.49		
<i>*Phosphorus*</i>				
<i>Phosphorusintake</i> [g/(head·d)]	0.53±0.03	0.50±0.02	0.67±0.11	
<i>Fecalphosphorus</i> [g/(head·d)]	0.27±0.02	0.24±0.01	0.35±0.07	
<i>Digestiblephosphorus</i> [g/(head·d)]	0.25±0.02	0.27±0.01	0.32±0.09	
<i>Phosphorusdigestibility</i> (±2.13)	52.03±2.08	49.90±3.60		
<i>Urinaryphosphorusdeposition</i> [g/(head·d)]	0.06±0.01	0.05±0.01	0.07±0.01	
<i>Phosphorusdepositionrate</i> (±1.63)	41.08±2.28	39.36±3.70		

In the same row, values with different small letter superscripts mean significant difference ( $P < 0.05$ ), while with the same or no letter superscripts mean no significant difference ( $P > 0.05$ ).

### 2.3 Effects of *Eucommia Ulmoides* Leaves on Growth Performance of Sheep

As shown in Table 3, initial body weights were similar across groups. After three months of feeding diets containing *Eucommia* leaves, weight gain in EUL1 and EUL2 groups was significantly higher than in the CTL group ( $P < 0.05$ ), increasing by 36.58% and 20.86%, respectively, with no significant difference between EUL1 and EUL2 ( $P > 0.05$ ). Daily weight gain in EUL1 and EUL2 was significantly higher than in CTL ( $P < 0.05$ ), while EUL2 did not differ significantly from EUL1 ( $P > 0.05$ ). Feed intake in EUL1 was significantly higher than in EUL2 ( $P < 0.05$ ), and EUL2 was significantly higher than CTL ( $P < 0.05$ ), indicating that *Eucommia* leaves improved feed intake in sheep. The feed-to-gain ratio in EUL1 and EUL2 showed a decreasing trend compared with

CTL ( $0.05 \leq P < 0.10$ ), with no significant difference between EUL1 and EUL2 ( $P > 0.05$ ), suggesting that appropriate levels of *Eucommia* leaves improved feed conversion efficiency in sheep.

**Table 3 Effects of *Eucommia ulmoides* leaves on growth performance of sheep**

Items	CTL group	EUL1 group	EUL2 group	P-value
Initial weight (kg)	28.42 $\pm$ 1.35	28.92 $\pm$ 1.39	28.49 $\pm$ 1.66	<i>Finalweight(kg)</i>  39.10 $\pm$ 1.58 <sup>a</sup>  43.50 $\pm$ 1.48 <sup>b</sup>  41.40 $\pm$ 1.98 <sup>b</sup>     <i>Boo</i>

#### 2.4 Effects of *Eucommia Ulmoides* Leaves on Slaughter Performance of Sheep

As shown in Table 4, compared with the CTL group, live weight before slaughter was significantly increased in EUL1 ( $P < 0.05$ ), while no significant difference was observed between EUL2 and CTL ( $P > 0.05$ ). Dressing percentage was significantly reduced in both EUL1 and EUL2 ( $P < 0.05$ ), while bone weight and meat-to-bone ratio showed an increasing trend ( $0.05 \leq P < 0.10$ ). No significant differences were found among groups for carcass weight or meat weight ( $P > 0.05$ ). Carcass meat percentage was increased in EUL1 compared with CTL ( $P > 0.05$ ) but significantly decreased in EUL2 compared with CTL ( $P < 0.05$ ).

**Table 4 Effects of *Eucommia ulmoides* leaves on slaughtering performance of sheep**

Items	CTL group	EUL1 group	EUL2 group	P-value
Live weight before slaughter (kg)	38.51 $\pm$ 1.48 <sup>a</sup>	42.62 $\pm$ 1.73 <sup>b</sup>	40.65 $\pm$ 2.58 <sup>a</sup>	<i>Carcassweight(kg)</i>  19.67 $\pm$ 0.63 19.43 $\pm$ 0.54 19.35 $\pm$ 1.66

## Discussion

### 3.1 Effects of *Eucommia Ulmoides* Leaves on Dietary Energy Digestion and Utilization

The primary energy sources for ruminants are glucose and volatile fatty acids (VFAs) such as acetate, propionate, and butyrate, with VFAs providing 70–80% of digestible energy [16]. VFAs are mainly produced through fermentation of dietary fiber, hemicellulose, starch, and other soluble carbohydrates, and their production and composition are closely related to feed type and composition.

When dietary neutral detergent fiber (NDF) levels are high, the acetate-to-propionate ratio is high and energy utilization efficiency is low, and vice versa [17]. In this experiment, as *Eucommia* leaf supplementation increased, dietary NDF levels gradually decreased in EUL1 and EUL2 groups, suggesting a reduced acetate-to-propionate ratio and increased energy digestibility. However, a considerable portion of soluble carbohydrates in *Eucommia* leaves consists of special medicinal components (such as lignans, phenylpropanoids, iridoids, polysaccharides, etc.) [2], which affect energy digestion and utilization. This may be one reason for the reduced energy digestibility and retention rate in the EUL2 group.

Fecal energy excretion represents the largest loss of dietary energy, accounting for approximately one-third of total energy intake [18], and is closely related to feed composition and characteristics. When consuming low-quality roughage, fecal energy can account for up to 60% of total energy [19]. Xu et al. [20] reported that increased energy intake leads to corresponding increases in fecal energy excretion. In this experiment, *Eucommia* leaf supplementation increased energy intake and fecal energy excretion, with EUL2 being significantly higher than EUL1 and CTL, indicating that appropriate levels of medicinal components can improve energy utilization, while excessive levels reduce energy digestion and utilization.

Certain medicinal components in *Eucommia* leaves (such as aucubin) not only affect energy digestion and utilization but also have diuretic effects. Urinary energy primarily originates from nitrogen-containing organic compounds in urine, such as urea and uric acid, and is related to dietary structure, metabolic status, particularly dietary protein levels, and amino acid balance [21]. In this experiment, urinary energy excretion increased with *Eucommia* leaf supplementation (EUL2 > EUL1 > CTL), indicating that medicinal components in *Eucommia* leaves enhanced nitrogen metabolism and increased urinary nitrogen and energy excretion.

Considering energy intake, fecal energy, and urinary energy, energy deposition in EUL1 was significantly higher than in EUL2 and CTL, with the highest energy digestibility and retention rate. However, energy retention rate in EUL2 was significantly reduced, even lower than in CTL, indicating that high-level *Eucommia* leaves and excessive medicinal components enhanced energy catabolism and reduced energy deposition. The specific mechanisms require further investigation.

### **3.2 Effects of *Eucommia Ulmoides* Leaves on Dietary Nitrogen Digestion and Utilization**

Nitrogen is an essential component of body proteins, and its digestion and metabolism are related to health status, dietary protein levels, and amino acid composition and balance. Dietary nitrogen intake significantly affects nitrogen metabolism; low nitrogen intake results in high utilization efficiency, whereas

high intake reduces utilization efficiency. Wang et al. [21] reported that when nitrogen intake exceeds normal physiological requirements, excess nitrogen is excreted as fecal nitrogen, urinary nitrogen, and milk nitrogen. Undigested and unabsorbed dietary nitrogen is excreted as fecal nitrogen, which also contains considerable endogenous nitrogen [22]. Increased urinary nitrogen excretion occurs for two reasons: first, insufficient supply of limiting amino acids affects the utilization of other amino acids, causing unused nitrogen to be excreted in urine; second, dietary amino acids exceeding requirements are converted through gluconeogenesis or energy metabolism [21]. In this experiment, as nitrogen intake increased in EUL1 and EUL2 groups, fecal nitrogen, urinary nitrogen, and digestible nitrogen also increased, and nitrogen metabolism remained in positive balance. However, nitrogen digestibility and retention rate in EUL2 were significantly lower than in EUL1 (though still higher than CTL), indicating that *Eucommia* leaf supplementation level affected nitrogen metabolism and that an optimal proportion exists for crude feed supplementation. Beyond this proportion, effective protein digestion and absorption decrease, increasing fecal nitrogen excretion. Special medicinal components in *Eucommia* leaves (lignans, iridoids, etc.) can promote the turnover and metabolism of nitrogen-containing substances (proteins and amino acids) in tissue cells, increasing urinary nitrogen excretion and thereby reducing nitrogen deposition. The optimal *Eucommia* leaf supplementation level is related to animal feed intake, population, and individual differences, and the specific reasons require further investigation.

### 3.3 Effects of *Eucommia Ulmoides* Leaves on Growth and Slaughter Performance of Sheep

*Eucommia* leaves are rich in nutrients, containing various minerals, trace elements, amino acids, and numerous medicinal components and bioactive substances with special functions. They can supplement nutrients and improve health status. Studies have shown that various feed ingredients interact in mixed diets, producing different associative effects that affect animal growth performance to varying degrees [23]. Dietary nutrient digestibility reflects associative effects from interactions among ingredients in mixed diets rather than the digestibility of single components [24]. Positive associative effects can improve overall diet utilization and feed intake, enhancing animal growth performance, while negative effects reduce overall digestibility and feed intake, decreasing growth performance. In this experiment, feed intake in EUL1 and EUL2 increased by 15.16% and 7.26%, respectively, compared with the control, and daily weight gain increased by 31.84% and 20.89%, respectively. Energy and nitrogen digestibility and retention rate increased in EUL1 but decreased in EUL2, indicating that as *Eucommia* leaf supplementation increased and dietary composition changed, the positive associative effects among components affecting nitrogen utilization gradually diminished. Additionally, this may be related to the inhibition of fat synthesis by unsaturated fatty acids (linoleic acid, linolenic acid) and flavonoids in *Eucommia* leaves [25].

The results indicate that appropriate levels of *Eucommia* leaves can improve feed intake in sheep. EUL1 had significantly higher feed intake than CTL and EUL2, suggesting that 10% *Eucommia* leaf supplementation is optimal, improving diet palatability, daily weight gain, and reducing feed-to-gain ratio, thereby increasing growth rate. The effects of *Eucommia* leaves vary among animal species. Ma et al. [26] found that increasing *Eucommia* leaf supplementation levels significantly reduced feed intake and daily weight gain in pigs. Wang et al. [27] reported no significant changes in daily feed intake or daily weight gain in chickens fed *Eucommia* leaves, suggesting that *Eucommia* leaves are more suitable for herbivores such as sheep.

Many factors affect sheep slaughter performance, including feeding methods, age, live weight before slaughter, and body condition. Increased age and live weight before slaughter significantly affect dressing percentage [28]. Growth rate during the growth stage affects live weight before slaughter, thereby influencing dressing percentage and meat percentage. Internal organ weight is another factor affecting dressing percentage [29-30]; heavier internal organs result in relatively lower dressing percentage. In this experiment, EUL1 sheep with higher live weight before slaughter had lower dressing percentage than the other two groups, partly because 10% *Eucommia* leaf supplementation increased feed intake and gastrointestinal content, and partly due to reduced abdominal fat [32]. Ou et al. [32] reported that *Eucommia* leaf meal significantly reduced abdominal fat percentage in broilers. Zheng et al. [33] found that *Eucommia* leaf powder reduced blood triglyceride levels, upregulated hepatic fatty acid synthase (FAS) expression, downregulated fat oxidation-related enzymes such as carnitine acyltransferase (CAT) and acyl-CoA oxidase (ACO), and reduced intra-abdominal fat content in mice. Additionally, meat-to-bone ratio affects dressing percentage. Hopkins et al. [34] suggested that sheep development significantly affects meat-to-bone ratio, and Santos-Silva et al. [35] reported that carcass weight positively correlates with meat-to-bone ratio. Dressing percentage, meat-to-bone ratio, and carcass meat percentage are key indicators of slaughter performance. In this experiment, dressing percentage was significantly reduced in EUL1 and EUL2, while meat-to-bone ratio showed an increasing trend, which may be related to the bone growth-promoting function of iridoid compounds in *Eucommia* leaves [31]. The effect of *Eucommia* leaves on dressing percentage varies among animal species. Adding 0.5%-2.0% *Eucommia* leaf powder to broiler diets improved carcass quality without significantly affecting dressing percentage [32]. In this experiment, the effect of *Eucommia* leaves on carcass meat percentage was dose-dependent: carcass meat percentage increased in EUL1 but significantly decreased in EUL2. The relationship between slaughter performance and *Eucommia* leaf supplementation level requires further investigation. Although dressing percentage decreased in *Eucommia* leaf groups, net meat weight did not differ significantly among groups due to higher live weight before slaughter.

## Conclusions

1. The effects of *Eucommia ulmoides* leaves on dietary nutrient digestion and utilization are dose-dependent. Low-level supplementation (10%) improved energy and nitrogen utilization, while high-level supplementation (20%) reduced energy and nitrogen utilization, but had minimal effect on calcium and phosphorus utilization.
2. *Eucommia ulmoides* leaves increased feed intake, daily weight gain, and live weight before slaughter in sheep to a certain extent.
3. *Eucommia ulmoides* leaves had varying effects on slaughter performance, reducing dressing percentage and showing dose-dependent effects on carcass meat percentage.

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