

Effect of Dietary Cotton Stalk Proportion on Growth Performance and Digestive Performance in Sheep: Postprint

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Abstract

This experiment aimed to investigate the effects of different proportions of cotton stalk in diets on growth performance and nutrient apparent digestibility in sheep, as well as the digestion and metabolism parameters of nutrients from cotton stalk in sheep. The experiment adopted a single-factor completely randomized design, in which 50 experimental sheep with similar body weight were randomly divided into 5 groups with 10 sheep per group; the control group (CK group) was fed a complete pellet basal diet, while the experimental groups were fed basal diets with cotton stalk replacing 10% (group A), 20% (group B), 30% (group C), and 40% (group D), respectively. The total experimental period was 68 days, including a 7-day preliminary period, a 53-day feeding trial, and an 8-day digestion and metabolism trial. The results showed: The results showed: 1) ADG decreased with increasing replacement proportion of cotton stalk, with groups C and D being extremely significantly lower than the CK group ($P < 0.01$) and significantly lower than group A ($P < 0.05$); there was no significant difference among the CK, A, and B groups ($P > 0.05$). Dry matter intake showed no significant change ($P > 0.05$). 2) The apparent digestibility of dietary nutrients decreased sequentially with increasing replacement proportion of cotton stalk, wherein the apparent digestibility of dry matter (DM), organic matter (OM), crude protein (CP), crude fiber (EE), neutral detergent fiber (NDF), and acid detergent fiber (ADF) in group D was 17.17% ($P < 0.01$), 18.22% ($P < 0.01$), 12.14% ($P < 0.01$), 36.36% ($P < 0.01$), 26.26% ($P < 0.01$), and 36.24% ($P < 0.05$) lower than that in the CK group, respectively. 3) The apparent digestibility of nutrients in cotton stalk showed varied responses with increasing replacement proportion. When the cotton stalk replacement proportion was 30%, the apparent digestibility of nutrients in cotton stalk was all at relatively high levels. The apparent digestibility of DM and OM in groups C and D was extremely significantly higher than that in groups A and B ($P <$

0.01); the apparent digestibility of CP and NDF in group A was extremely significantly lower than that in groups B, C, and D ($P < 0.01$). Under the conditions of this experiment, cotton stalk can be used as a roughage for fattening sheep production, with a replacement proportion of 30% being appropriate.

Full Text

Effects of Cotton Stalk Ratio in Diets on Growth and Digestive Performance of Sheep

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Abstract

This experiment was conducted to investigate the effects of different dietary cotton stalk ratios on growth performance, nutrient apparent digestibility in sheep, and the digestive metabolism parameters of nutrients from cotton stalk itself. A single-factor completely randomized design was employed, in which fifty sheep with similar body weight were randomly assigned to five groups (n=10 per group). The control group (CK) received a basal complete pellet diet, while treatment groups received diets where cotton stalk replaced 10% (Group A), 20% (Group B), 30% (Group C), and 40% (Group D) of the basal diet, respectively. The entire experimental period lasted 68 days, comprising a 7-day preliminary period, a 53-day feeding trial, and an 8-day digestion-metabolism trial. The results showed that: (1) Average daily gain (ADG) decreased with increasing cotton stalk replacement ratio, with Groups C and D being extremely significantly lower than Group CK ($P < 0.01$) and significantly lower than Group A ($P < 0.05$); no significant differences were observed among Groups CK, A, and B ($P > 0.05$). Dry matter intake (DMI) remained unchanged across treatments ($P > 0.05$). (2) Dietary nutrient apparent digestibility decreased sequentially with increasing cotton stalk replacement ratio. Compared with Group CK, Group D exhibited reductions of 17.17% ($P < 0.01$), 18.22% ($P < 0.01$), 12.14% ($P < 0.01$), 36.36% ($P < 0.01$), 26.26% ($P < 0.01$), and 36.24% ($P < 0.05$) in apparent digestibility of dry matter (DM), organic matter (OM), crude protein (CP), ether extract (EE), neutral detergent fiber (NDF), and acid detergent fiber (ADF), respectively. (3) The apparent digestibility of nutrients within cotton stalk itself showed variable patterns with increasing replacement ratio. When cotton stalk replacement reached 30%, the apparent digestibility of all nutrients in cotton stalk remained at relatively high levels. Groups C and D showed extremely significantly higher DM and OM digestibility than Groups A and B ($P < 0.01$), while Group A exhibited extremely significantly lower CP and NDF digestibility than Groups B, C, and D ($P < 0.01$). Under the conditions of this experiment, cotton stalk can be utilized as a roughage in fattening sheep production, with an optimal replacement ratio of 30%.

Keywords: cotton stalk; sheep; nutrient; growth performance; apparent digestibility

Since 2011, the national cotton planting area in China has shown a year-by-year declining trend, decreasing by approximately 36% by 2017 [1]. According to data published by the National Bureau of Statistics [1], cotton stalk production in 2017 reached about 8.85 million tons, indicating substantial output. The current situation of cotton stalk utilization is characterized by abundant resources, low utilization efficiency, and excessive proportions used for combustion or returned to fields [2]. Enhancing cotton stalk utilization could alleviate regional shortages of roughage supply while reducing environmental pollution. Cotton stalk offers advantages of large resource availability and convenient centralized collection, providing favorable conditions for its feed utilization. Researchers have conducted studies on nutritional value evaluation [3-4], feeding effects [5-6], screening of microorganisms for efficient cellulose degradation [7-8], and quality improvement [9-10]. These studies indicate that cotton stalk is a roughage with certain crude protein content but relatively low rumen degradability. Replacing portions of corn stalk, wheat straw, or reed with cotton stalk for cattle and sheep feeding shows no negative effects, while microorganisms significantly promote crude fiber degradation, and pelleting or microwave treatment can improve cotton stalk feed quality. However, few reports exist on digestion and utilization parameters of cotton stalk in animals. Wei Min et al. [11] investigated digestive metabolism parameters of cotton stalk nutrients in sheep using a restricted-feeding group as control, but physiological functions may differ between starved and normal states [12]. Therefore, this experiment, based on satiated animals, examined the effects of replacing different proportions of basal diet with cotton stalk on growth performance, nutrient apparent digestibility, and changes in digestive metabolism parameters of cotton stalk nutrients in sheep, providing a theoretical basis for scientific utilization of cotton stalk in production practice.

1.1 Diet Preparation

The cotton stalk used in this experiment was harvested in Bachu County, Kashgar Prefecture, Xinjiang, during the current year. Cotton stalk and other roughages were ground through a 1-cm screen, mixed thoroughly with other ingredients, and processed into complete pelleted diets with a diameter of 6 mm.

1.2 Experimental Design

Fifty Small-tailed Han sheep with similar body weight [(35.23±5.83) kg] and good body condition were randomly allocated to five groups (n=10). The control group (CK) received a complete pelleted basal diet formulated according to Chinese Feeding Standard of Meat-Producing Sheep (NY/T 816–2004) [13]. Treatment groups received diets where cotton stalk replaced 10% (Group A),

20% (Group B), 30% (Group C), and 40% (Group D) of the basal diet. Diet composition and nutrient levels are presented in Table 1. Experimental animals were housed individually in pens equipped with drinking bowls and exercise yards. Feed troughs were cleaned before morning feeding, and pens and exercise yards were disinfected every 10 days. Animals were fed twice daily at 10:00 and 19:00 with ad libitum access to feed and water. The total experimental period lasted 68 days, including a 7-day preliminary period, a 53-day feeding trial, and an 8-day digestion-metabolism trial.

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

Items	Groups
Ingredients	
Corn	
Wheat bran	
Soybean meal	
Premix ¹	
NaH PO	
NaCl	
Cotton stalk	
Corn stalk	
Alfalfa hay	
Total	
Nutrient levels²	
ME/(MJ/kg)	
OM	
CP	
EE	
NDF	
ADF	

¹The premix provided the following per kg of diets: VA 300 IU, VD 420 IU, VE 4 IU, biotin 0.16 mg, pantothenic acid 4.2 mg, nicotinic acid 3.6 mg, Cu 2 mg, Fe 22 mg, Mn 20 mg, Zn 16 mg, I 0.4 mg, Se 0.13 mg, Co 0.13 mg.

²ME was a calculated value, while others were measured values.

1.3.1 Growth Performance Measurements

All experimental sheep were weighed before morning feeding at the beginning and end of the trial to calculate average daily gain (ADG). Daily feed offered and refusals were recorded accurately to determine dry matter intake (DMI).

1.3.2 Sample Collection

At the end of the feeding trial, six sheep were randomly selected from each group for the digestion-metabolism trial, which lasted 8 days. At the start, homemade

fecal collection bags were attached to the animals. A 4-day adaptation period was designed to allow sheep to acclimate to the bags. From day 5 onwards, all feces in the collection bags were collected for four consecutive days before morning feeding, recorded as the previous day's feces, weighed, and 10% was sampled. The 4-day fecal samples were mixed after air-drying and stored in sealed bags. During the collection period, 200 g of feed samples were collected daily for four consecutive days. Nutrient contents including dry matter (DM), crude protein (CP), ether extract (EE), neutral detergent fiber (NDF), acid detergent fiber (ADF), lignin (ADL), crude ash, calcium (Ca), and phosphorus (P) were determined according to Zhang Liying [14]. Gross energy (GE) in cotton stalk was measured following He Jianhua [15].

1.3.3 Digestibility Calculation

Apparent digestibility of dietary nutrients was calculated using the method of Adeola [16]:

$$A\% = [(B - C)/B] \times 100$$

where A is the apparent digestibility of a nutrient in the diet; B is the mass of the nutrient intake; and C is the mass of the nutrient in feces.

Apparent digestibility of nutrients in cotton stalk was calculated using the method of Yang Feng [17]:

$$D\% = [(A - B)/F \times 100] + B$$

where D is the apparent digestibility of a nutrient in cotton stalk; A is the apparent digestibility of the nutrient in the replacement diet; B is the apparent digestibility of the nutrient in the basal diet; and F is the proportion of the nutrient from cotton stalk relative to the total nutrient in the replacement diet.

1.4 Data Processing

Experimental data were organized using Excel 2010 and analyzed using the MIXED procedure of SAS 9.0 statistical software.

2.1 Nutritional Level of Cotton Stalk

As shown in Table 2, the cotton stalk used in this experiment contained 6.37% CP, 62.92% NDF, 48.53% ADF, and 18.55% ADL.

Table 2 Nutrient contents of cotton stalk (DM basis)

Item	Content
GE/(MJ/kg)	

2.2 Effects of Different Cotton Stalk Ratios on Growth Performance of Sheep

Table 3 shows that initial body weight did not differ significantly among groups ($P>0.05$), while final body weight decreased sequentially with increasing cotton stalk replacement ratio. Group CK was significantly higher than Groups C and D ($P<0.05$), with no significant differences among other groups ($P>0.05$). Cotton stalk replacement ratio had an extremely significant effect on ADG ($P<0.01$), which decreased with increasing replacement ratio. Specifically, ADG in Group CK was 37.92% and 53.28% higher than in Groups C and D, respectively ($P<0.01$), while ADG in Group A was 23.81% and 37.68% higher than in Groups C and D, respectively ($P<0.05$). No significant differences were observed among Groups CK, A, and B ($P>0.05$). DMI decreased with increasing cotton stalk replacement ratio, with Group CK being 2.65% higher than Group D, though differences among groups were not significant ($P>0.05$).

Table 3 Effects of different ratios of cotton straw in diets on growth performance of sheep

Items	Groups					P-value
Initial weight/kg						
Final weight/kg	51.73 ^a	50.63 ^a	48.93 ^a	47.32	46.59	<0.05
ADG/g	311.98 ^a	280.08 ^a	238.54	226.21	203.54	<0.01
DMI/(kg/d)						

In the same row, values with no letter or the same letter superscripts mean no significant difference ($P>0.05$), while different small letter superscripts mean significant difference ($P<0.05$), and different capital letter superscripts mean extremely significant difference ($P<0.01$). The same as below.

2.3 Effects of Different Cotton Stalk Ratios on Nutrient Apparent Digestibility of Sheep

As shown in Table 4, increasing cotton stalk replacement ratio generally resulted in higher fecal excretion and lower nutrient apparent digestibility. Fecal excretion in Group D was extremely significantly higher by 16.36% compared with Groups CK and A ($P<0.01$), while Groups B and C were significantly higher by 14.55% compared with Group CK and by 12.73% compared with Group A ($P<0.05$). No significant differences were found between Groups CK and A or among the other three groups ($P>0.05$). Dietary nutrient apparent digestibility decreased sequentially with increasing cotton stalk replacement ratio, with effects reaching extremely significant levels for all nutrients except ADF, which showed significant effects ($P<0.05$). Compared with Group CK, Group D exhibited reductions of 17.17% ($P<0.01$), 18.22% ($P<0.01$), 12.14% ($P<0.01$), 36.36%

($P < 0.01$), 26.26% ($P < 0.01$), and 36.24% ($P < 0.05$) in apparent digestibility of DM, OM, CP, EE, NDF, and ADF, respectively.

Table 4 Effects of different ratios of cotton straw in diets on nutrient apparent digestibility of sheep (DM basis) %

Items	Groups					P-value
Excrement/(kg/d)	0.55	0.55	0.63 ^a	0.62 ^a	0.64 ^a	<0.01
DM	72.06 ^a	69.50 ^a	64.00	64.05	61.50	<0.01
OM	73.52 ^a	71.10 ^a	65.71	64.76	62.19	<0.01
CP	69.83 ^a	64.24 ^a	60.71 ^a	54.56	51.21	<0.01
EE	87.97 ^a	86.09 ^a	84.59 ^a	83.97 ^a	78.45	<0.01
NDF	64.24 ^a	62.65 ^a	55.54	54.25	50.88	<0.01
ADF	55.38 ^a	50.00 ^a	49.44 ^a	46.36 ^a	40.65	<0.05

2.4 Apparent Digestibility of Nutrients in Cotton Stalk

Table 5 reveals that apparent digestibility of nutrients in cotton stalk varied with replacement ratio. Groups C and D showed extremely significantly higher DM and OM digestibility than Groups A and B ($P < 0.01$), stabilizing after 30% replacement with maximum values of 44.67% and 43.56%, respectively. CP and NDF digestibility changed little after 20% replacement, with Group A being extremely significantly lower than Groups B, C, and D ($P < 0.01$), reaching maximum values of 39.74% and 35.51%, respectively. ADF digestibility showed no significant differences among groups at replacement ratios below 30% ($P > 0.05$), but decreased extremely significantly when the ratio increased to 40% ($P < 0.01$). The highest ADF digestibility (34.43%) was observed in Group A.

Table 5 Apparent digestibility of nutrients in cotton stalks (DM basis) %

Items	Groups					P-value
DM	26.29	29.46	44.24 ^a	44.67 ^a	30.19	<0.01
OM	29.96	41.83 ^a	43.56 ^a	30.19		<0.01
CP	26.20	38.71 ^a	39.74 ^a	36.35 ^a		<0.01
NDF	23.32	33.86 ^a	32.09 ^a	35.51 ^a		<0.01
ADF	34.43 ^a	33.71 ^a	33.90 ^a	24.15		<0.01

3.1 Nutritional Level of Cotton Stalk

The nutrient content of cotton stalk varies among reports due to multiple factors including soil, water, climate, variety, harvest time, and fertilization conditions. Wei Min et al. [3] and Fang Lei et al. [18] reported that whole cotton stalk contained 6.5% and 5.67% CP, 44.0% and 46.05% cellulose, 10.7% and 6.36% hemicellulose, 15.3% and 17.18% ADL, 0.63% and 1.19% Ca, and 0.09% and

0.11% P, respectively. Consequently, cotton stalk is considered a roughage containing certain amounts of crude protein but with high fiber content.

3.2.1 Effects of Different Cotton Stalk Ratios on Body Weight Gain in Sheep

Previous studies have shown that when dietary nutrient levels are consistent, replacing corn stalk (10%, 20%, and 30%) [5] or wheat straw (25% and 50%) [19] with cotton stalk at different ratios exerts no significant effect on sheep ADG. However, ADG differs when dietary nutrient levels are inconsistent. Hou Pengxia et al. [20] observed that dietary nutrient levels decreased with reducing concentrate-to-forage ratio in Tan sheep, and higher nutrient levels resulted in greater daily weight gain. In this experiment, the reduction in ADG with increasing cotton stalk replacement ratio likely resulted from differences in dietary nutrient levels among groups.

3.2.2 Effects of Different Cotton Stalk Ratios on Feed Intake in Sheep

Adequate DMI is an important prerequisite for animals to express their growth performance. Studies have demonstrated that adding 10% to 30% cotton stalk to diets has little effect on sheep DMI [5], consistent with our results. Reports indicate that diets with appropriate concentrate-to-forage ratios can improve DMI in ruminants [20-21], but similar results were not observed in this experiment, possibly because animals consume more pelleted diets [22]. Zhang Litao et al. [23] reported that sheep DMI increased to some extent with increasing roughage proportion in complete pelleted diets. Theoretically, due to limited rumen space and the bulky nature of roughage, DMI should decrease with increasing roughage proportion [24]. However, the pelleting process compresses the physical space among ingredients, resulting in similar relative density across diets in this experiment, which may have eliminated the effect of roughage volume on intake. Additionally, since pelleted diets have higher rumen disappearance rates [25], gastrointestinal passage rates, and nutrient apparent digestibility [26] than meal diets, the accelerated emptying speed of digesta in the gastrointestinal tract enabled animals to consume more roughage.

3.3.1 Effects of Different Cotton Stalk Ratios on Apparent Digestibility of DM and OM in Sheep

Halidai Rehemujiang et al. [19] found no significant differences in DM apparent digestibility among sheep fed diets containing 0%, 25%, and 50% cotton stalk, which contradicts our findings. In this experiment, besides varying cotton stalk proportions, the concentrate-to-forage ratio also differed among groups. When dietary roughage proportion increased, NDF content rose accordingly, and high fiber levels reduced rumen retention time and accelerated gastrointestinal passage rate, leading to decreased digestibility of OM, non-fibrous carbohydrates, CP, EE, and other nutrients in the whole digestive tract [27]. Zhang Litao et

al. [23] reported that increasing dietary NDF content from 33.35% to 48.35% significantly decreased DM and OM apparent digestibility. In this experiment, increasing cotton stalk replacement ratio elevated dietary NDF content, resulting in significantly reduced DM and OM apparent digestibility, which corresponds to the observation of unchanged DMI but significantly increased fecal excretion among groups.

3.3.2 Effects of Different Cotton Stalk Ratios on Apparent Digestibility of CP and EE in Sheep

Studies have shown that adding different levels of cotton stalk to diets has no significant effect on rumen ammonia nitrogen concentration [5] or nitrogen utilization [19], suggesting no obvious impact on CP utilization. Rumen microbial protein (MCP) is the main source of absorbable protein for ruminants in the small intestine [28] and serves as an important indicator of CP utilization. MCP synthesis is primarily affected by available energy and nitrogen for rumen microorganisms [29-30]. When diets are mainly composed of roughage, MCP synthesis efficiency decreases due to insufficient energy, while increasing concentrate levels can enhance MCP production and promote CP utilization [31-32]. Sinclair et al. [29] suggested that higher synchronization of degradable energy and nitrogen in the rumen leads to greater MCP synthesis efficiency. Zhang Litao et al. [23] demonstrated that CP and EE apparent digestibility were highest when dietary NDF content was 33.35%, and increasing or decreasing NDF level reduced dietary digestibility. In this experiment, Group CK had a concentrate-to-forage ratio of 49:51 and NDF level of 40.86%. With increasing replacement ratio, the concentrate-to-forage ratio decreased and NDF level increased sequentially, resulting in gradually reduced synchronization of available energy and nitrogen in the rumen and consequently decreased CP apparent digestibility.

3.3.3 Effects of Different Cotton Stalk Ratios on Apparent Digestibility of NDF and ADF in Sheep

Both dietary fiber content and concentrate-to-forage ratio affect NDF and ADF apparent digestibility. Halidai Rehemjiang et al. [19] replaced wheat straw with 0%, 25%, and 50% cotton stalk at the same concentrate-to-forage ratio, resulting in dietary ADF contents of 24.04%, 27.70%, and 28.25%, respectively, and found that dietary NDF and ADF apparent digestibility decreased significantly compared with the control, but with no significant differences between the 25% and 50% groups. Ruminant diets have an optimal concentrate-to-forage ratio [33-34]; NDF and ADF apparent digestibility are highest at concentrate-to-forage ratios of 66.35:33.35 (NDF level 33.35) [23] or 55:45 [24], and decrease when the concentrate-to-forage ratio is reduced (or NDF level increased). In this experiment, increasing replacement ratio elevated dietary NDF and ADF contents and reduced concentrate-to-forage ratio, leading to decreased NDF and ADF apparent digestibility. Moreover, as cotton stalk intake increased with

replacement ratio, NDF and ADF intake also increased. Since the effective degradation rate of nutrients from cotton stalk in animals is low [3] and animal degradation capacity is limited, this may also reduce NDF and ADF apparent digestibility, which was confirmed by the results of NDF and ADF digestibility in cotton stalk in this study.

3.4 Apparent Digestibility of Nutrients in Cotton Stalk

High ADL content is a major characteristic of cotton stalk. Due to its stable nature, ADL protects cellulose and hemicellulose [34]; thus, traditional nutrition considers ADL in feed to be unavailable to animals. However, recent studies have found that rumen microorganisms can degrade a very small portion of ADL [35]. Sun Yunzhang et al. [36] demonstrated that dietary ADL content negatively correlates with DM and crude fiber digestibility. The ADL content in cotton stalk (15.3%) is 2-3 times that in wheat straw (7.9%), corn stalk (4.6%), and rice straw (5.2%), yet the rumen effective degradation rate of DM in cotton stalk (33.28%) is lower, being 88.25% of wheat straw, 54.14% of corn stalk, and 67.71% of rice straw [3]. Other studies reported that the effective degradation rates of DM, NDF, and ADF from cotton stalk in sheep rumen were 26.90%, 27.89%, and 26.21%, respectively [4]. Our results also indicate that apparent digestibility of all nutrients in cotton stalk is relatively low, with DM, OM, CP, and NDF digestibility reaching higher levels at 20% and 30% replacement ratios. When cotton stalk replacement ratio reached 30%, ADF digestibility was at a critical state, and further increasing the ratio caused ADF digestibility to decline sharply. Therefore, the comprehensive utilization efficiency of nutrients in cotton stalk may be highest at the 30% replacement ratio.

4 Conclusion

1. Cotton stalk is nutritionally rich but has low nutrient digestibility and utilization efficiency, making it a relatively poor-quality roughage.
2. Under the conditions of this experiment, when cotton stalk replaced 30% of the basal diet, the digestibility of nutrients from cotton stalk in sheep remained at relatively high levels.
3. Cotton stalk can be used as a roughage in fattening sheep production, with an appropriate addition ratio of 30%.

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