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Research Article

Growth Performance and Meat Quality in Tibetan Sheep Fed Diets Differing in Type of Forage

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Abstract

The Qinghai-Tibetan Plateau is a large and elevated plateau (mean elevation 4500 m) in northwestern China, where with a harsh environment for animal survival. Tibetan sheep is an important dominant livestock that inhabit this harsh environment. The objective of this trial was to preliminarily explore and compare the effects of indigenous barley straw (BS) and artificial cultivated oat hay (OH) on growth performance, visceral organ mass and meat quality of Tibetan sheep. Twenty-four Tibetan sheep with initial weights of 15.9±1.92 kg were randomly assigned to two mixed diets containing the same concentrate mixed with BS or OH, and the experiment was carried out in a completely randomized design. The weight of lungs and thymus for OH was greater (P≤0.05) than that of BS, while the weight of other viscera (heart, liver, kidney, epinephros and spleen) had no significant difference (P>0.05) between the two. The weight of the rumen, reticulum and abomasum for OH was 10.31%, 31.22% and 33.44% (P≤0.01) higher than that of BS. The length of the colon in sheep fed OH diet was longer (P≤0.01) than the sheep fed BS diet. The content of Histidine in longissimus dorsi muscle of OH was greater (P≤0.05) than that of BS, while there were no significant (P>0.05) differences between the two for the other individual amino acids (AA), umami AA, essential AA and total AA. It is concluded that the two types of roughage did not affect the growth and slaughter performance, meat quality, but OH is beneficial for the gastrointestinal development for Tibetan sheep.

Keywords: *Tibetan sheep, Growth performance, Meat quality, Forage*

Farklı Yemlerle Beslenen Tibet Koyunlarında Büyüme Performansı ve Et Kalitesi

Öz

Qinghai-Tibet Platosu Çin'in kuzeybatısında yer alan geniş ve yüksek (ortalama rakım 4500 m) bir plato olup hayvancılık için çetin çevre şartlarına sahiptir. Tibet koyunu bu çetin coğrafyada yaşayan en önemli besi hayvanıdır. Bu çalışmanın amacı, yerli arpa samanı (AS) ve yapay ekili yulaf samanının (YS) Tibet koyununda büyüme performansı, viseral organ ağırlığı ve et kalitesi üzerine etkilerinin ön değerlendirmesini yapmaktır. Başlangıç ağırlıkları 15.9±1.92 kg olan yirmi dört Tibet koyunu iki gruba ayrılarak AS veya YS içeren iki karışık diyetle tamamen rastgele dizayn düzeneğinde beslendi. YS ile beslenenlerde akciğerlerin ve timusun ağırlığı AS ile beslenenlere oranla daha fazlayken (P≤0.05) diğer viseral organlarda (kalp, karaciğer, böbrek, adren ve dalak) iki besleme arasında anlamlı fark gözlemlenmedi (P>0.05). YS ile beslenenlerde rumen, retikulum ve abomazum ağırlıkları AS ile beslenenlere oranla sırasıyla %10.31, %31.22 ve %33.44 daha fazlaydı (P≤0.01). YS ile beslenen koyunlarda kolon, AS ile beslenenlere oranla daha uzundu (P≤0.01). YS ile beslenen koyunların longissimus dorsi kasında histidin miktarı AS ile beslenenlere oranla daha fazla iken (P≤0.05) diğer bireysel amino asitler (AA), umami AA, esansiyel AA ve total AA her iki uygulama arasında fark göstermedi (P>0.05). Tibet koyununda yem tipinin büyüme ve kesim performansı ile et kalitesini etkilemediği fakat YS uygulamanın gastrointestinal gelişim için daha faydalı olduğu sonucuna varıldı.

Anahtar sözcükler: *Tibet koyunu, Büyüme performansı, Et kalitesi, Yem*

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INTRODUCTION

The Qinghai-Tibetan Plateau is known as the "third pole" of the world because it is characterized by high altitude, severe cold, low oxygen level, strong UV radiation, a short growing season, and deficiencies in feed supply [1,2]. Tibetan sheep is the major indigenous ruminant that inhabit this harsh environment living at an altitude of 3.000 to 5.000 m, it is the main resource of meat and milk in those areas, and the major source of income for most nomadic and seminomadic people in these regions. The traditional feeding system for Tibetan sheep is free range husbandry, however the harsh environment cause shortage of feedstuffs and nutritional impairment [3]. In order to improve the production efficiency for Tibetan sheep, it is particularly important to conduct scientific supplementary feeding scheme using local resources.

Highland barley is the main crop in Tibet, and the total cultivated area was about 117.900 ha that makes up more than 69.7% of the total area of grain in Tibet. As an important source of roughage for local animals, highland barley straw (BS) can offset the shortage of feedstuffs to some extent, especially during the cold season [4]. Oat is also widely planted in Tibet, although it is not as extensive as highland barley, it is a cereal grain of the family *Gramineae (Poaceae)*. Along with green mass, oat hay (OH) is a valuable feed for agricultural animals [5].

Some studies about OH and BS feed on sheep have been published. The dry matter (DM) and crude protein (CP) intakes were significantly increased with and the average daily gain was higher when OH was replaced by rosemary distillation residues in lamb diets, but carcass composition and gut weights were similar among groups [6]. When feeding with OH, DM, organic matter (OM) and neutral detergent fiber (NDF) digestibilities were higher in Tibetan than fine-wool sheep [7]. Replacement of OH by BS promotes PUFA deposition in the muscle and long-chain FAs in the adipose fat of Tibetan sheep [8]. It is possible to fatten light lambs on a TMR pellet including ground BS by increasing average daily gain and reducing the fattening period, without any negative impact on carcass and meat characteristics [9]. Previously study had shown the difference of nutritional composition between OH and BS, the OM and nitrogen content of OH seemed to higher than that of BS, and the acid detergent fiber content of BS was higher than OH [2]. But there few research comparing the OH and BS on growth performance and meat quality of Tibetan sheep, and how to make full use of the resource in local is meaningful for improving production efficiency. The goal of this study was to evaluate the effect of forage type on growth performance and meat quality of Tibetan sheep.

MATERIAL and METHODS

Animal and Management: The experiment was conducted according to the animal care and use guidelines of the Animal Care Committee, Institute of Animal Husbandry and Veterinary, Tibet Academy of Agriculture and Animal Husbandry. The experimental was conducted at the research farm of Institute of Animal Husbandry and Veterinary, Tibet Academy of Agriculture and Animal Husbandry, Lhasa City, China. The formal experiment commenced on 25 June and ended on 25 July 2018. The average daily temperatures ranged from a minimum of 11ºC to a maximum of 26ºC. Twenty-four Tibetan sheep with an average body weight (BW) of 15.9±1.92 kg were used in this experiment, all the sheep have the same age and equal number of ram and ewe. The sheep were randomly divided into six pens (four sheep/pen), the animal represented the experimental unit. All the sheep were provided with free access to fresh water.

Experimental Diets and Design: The experiment was carried out in a completely randomized design. Sheep were randomly and equally assigned to two experimental treatments, the sources of roughage for the two dietary treatments consisted of BS or OH, BS (Zangqing 311, a popular local barley breed) was assigned to three pens and OH (Tianyan 1, a popular oat breed large-scale cultivated in Tibet) was assigned to the other three pens. Sheep in both treatments received the same concentrate, and the ingredients of the concentrate were (DM basis): 45 g/kg soybean meal, 470 g/kg corn, 424 g/kg wheat bran, 7 g/kg calcium carbonate, 9 g/kg palm oil, 9 g/kg sodium chloride, 36 g/kg minerals, and vitamins premix. The ratio of concentrate to roughage was 50:50. Diets were prepared to provide 1.3 times the level required for the maintenance of metabolizable energy (ME) according to the Zhang and Zhang [10]. Sheep were fed two equal meals at 09:00 and 18:00 h. Concentrate and roughage were offered at the same time and the refusals were collected and weighed daily for 7 d of the formal experiment to measure the voluntary feed intake, and feed intake was measured by pen, and water was available *ad libitum*. The Chemical composition of the diets and DM intake were shown in *Table 1*.

Sample Collection and Handling: Sheep weight and feed intake were measured weekly during the formal experimental periods. The diets and refusals for both groups were equally sampled, oven dried at 65ºC, air equilibrated, ground to pass a 1-mm sieve, and stored pending laboratory analysis. At the end of the experiment (after 20 days of the formal experiment), all the sheep were selected for slaughter after being fasted overnight. All sheep were electrically stunned and slaughtered at the same day, by exsanguination under commercial procedures, according to the animal ethics committee of the Institute of Subtropical Agriculture, the Chinese Academy of Sciences. The sheep were hung to remove the skin, head (at the occipito-atlantal joint), forefeet (at the carpal-metacarpal joint), and hind feet (at the tarsal-metatarsal joint). The viscera, such as heart, liver, kidney, epinephros, lungs, spleen, and thymus, as well as the gastrointestinal tissues (forestomach, such as rumen, reticulum, omasum and abomasums; the small intestine, such as duodenum, jejunum, and ileum; the large intestine, such as cecum, colon, and rectum) were removed and the weight was recorded, respectively. Additionally gastro-intestinal tissues length was recorded. Afterward, carcasses were weighed and subsequently chilled under commercial conditions at 4ºC for 12 h in total darkness. Thereafter, the left side of carcass was used for meat quality variable measurements. Carcass was deboned at 24 h postmortem. About 200 g of left longissimus dorsi muscle (LM) were sampled. Approximately 50 g fresh LM was weighed and placed in a Whirl-Pak bag, suspended in a 4°C for the determination of drip loss. After that, 100 g subsample of LM and GM were taken and stored at 4ºC for 24 h for the determination of cooking loss, the other subsamples was immediately stored at -20ºC for subsequently chemical composition measurements.

Chemical and Physical Analysis: The cooking loss of muscle at 24 h postmortem was measured according to the methods reported by Ramírez et al.[11]. Briefly, the muscle samples were weighed (F), vacuum-packed in plastic bag, and cooked at 80ºC for 1 h by immersion in a water bath. After that, cooked samples were cooled under running water for 30 min, removed from the bags, blotted, and weighed (C). Cooking loss was calculated as (F-C) × 100/F [12]. Dropping loss was estimated without freezing on the day of slaughter according to the following procedures [13]. Approximately 50 g fresh LM was weighed (W1) and placed in a Whirl-Pak bag, suspended in a 4°C cooler for 24 h, reweighed (W2), and dropping loss was calculated. To measure the loin eye area of the longissimus dorsi muscle, each carcass was bisected and a transverse cut was made in the left half of the carcass at the level of the 12th and 13th ribs, an outline of the cranial section was made using a transparency sheet and a pen, which was then used to calculate the area of the section [14].

The frozen meat samples were thawed overnight (approximately 14 h) in a chill at 4ºC. DM contents of the thawed samples were determined by drying at 105ºC in an oven (DHG-9023A, Jing Hong, shanghai) for 48 h to a constant weight, then the samples were ground through a 0.5 mm with a laboratory mill (DF-2, Changsha Instrument Factory, Changsha city, Hunan province, China). Total nitrogen (N) was analyzed according to the methods of AOAC [15]. Fat content was determined according to the method described by Hara and Radin [16]. ADF content and NDF content was determined according to the methods of AOAC [17] and Van Soest et al.[18].

The amino acid (AA) contents were determined according to Mason et al.[19]. To isolate the AA fraction (AAF), 0.5 g of dried tissue was hydrolyzed with 15 mL 6 N HCl under N_2 for 20 h. The hydrolysate was filtered through glass fibers to eliminate particulate matter. Filtered hydrolysate was diluted to 50 mL with pure water. AAs were isolated from 10 mL of the diluted hydrolysate using cation exchange chromatography according to the methods of Nissen and Haymond [20]. The fraction containing AAs was dried under a stream of N_2 at 60ºC.

Calculations: The calculations were calculated as the formula below:

Yields (%) of the hot body(Y):

Y = carcass weight/body weight x 100

The weight of the viscera (the heart, liver, kidney, epinephros, lungs, spleen, thymus, stomach, and intestines) were summed to determine the yield of the non-carcass components relative to body weight at slaughter [14].

Dry matter intake (DMI)

DMI = offered weight (DM) - refusals weight (DM)

Cooking loss:

Cooking loss (%) = (F-C) × 100/F

Crude protein (CP):

CP = total nitrogen x 6.25

Dropping loss:

Dropping loss = (W1-W2)/W1 × 100

Statistical Analyses: Statistical analyses of data were evaluated through a one-way ANOVA procedure, and animal were used as experimental unit. Statistical significance was set at $P<0.05$ and tendencies at $0.05 \le P \le 0.10$. All statistical analyses were conducted with JMPR 12.1.0. (SAS Institute Inc.).

RESULTS

All the sheep were healthy and consumed their feed allowance throughout the experiment. The average DMI was 582 and 609 g/d for sheep fed BS and OH, respectively *(Table 1)*.

The ADG and slaughter performance (initial BW, final BW and dressing percentage) did not affected between the two treatments *(Table 2)*. The weight of lungs for OH treatment was greater ($P \le 0.05$) than that of BS treatment, while the weight of other viscera (heart, liver, kidney, epinephros and spleen) had no significant differences ($P>0.05$) between the two treatments *(Table 2)*.

The weight and length of the gastrointestinal tissues in sheep fed BS and OH diets were shown in *Table 3*. The weight of the rumen, reticulum and abomasum for OH treatment was 10.31%, 31.22% and 33.44% ($P \le 0.01$) higher than that of BS treatment, while there was no significant ($P>0.05$) differences in the weight of the abomasum, the small intestine and the large intestine tissue between BS and OH treatments. The length of the colon in sheep fed

Table 1. *Chemical composition of the diets and dry matter intake of Tibetan sheep*

Items[1]	Forage[2]		Diet[3]		SEM[4]	P
	BS	OH	BS	OH		
DM (%)	95.5	94.9	96.7	95.5	-	-
OM (g/kg•DM)	923	952	918	932	-	-
CP (g/kg•DM)	14.2	43.4	59.4	73.9	-	-
NDF (g/kg•DM)	709	597	539	483	-	-
ADF (g/kg•DM)	458	387	300	264	-	-
Starch (g/kg•DM)	61	75	179	186	-	-
EE (g/kg•DM)	61	62	65.7	69.4	-	-
NFC (g/kg•DM)	139	250	254	306	-	-
ME[5] (MJ/kg•DM)	1.11	1.41	7.13	7.76	-	-
DMI[6] (g/d)	-	-	582	609	13.3	0.32

[1] DM = dry matter; OM = organic matter; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; EE = ether extract; NFC = non-fibrous carbohydrates; calculated by the equation of OM-CP-EE-CF; [2] BS = barley straw; OH = oat hey; [3] Forage plus concentrate diet (1:1), the concentrate contained (g/kg): soybean meal (45), wheat bran (424), calcium carbonate (7), palm oil (9), sodium chloride (9), and premix (36); [4] Pooled standard error of means; [5] Metabolizable energy (ME) was estimated according to Zhang and Zhang (1998); [6] Dry matter intake

Table 2. *Effects of dietary fiber sources on the daily gain, dressing percentage and viscera weight in sheep*

Items[1]		Treatments[3]		SEM[4]	P
		BS	OH		
Slaughter performance	Initial BW[1] (kg)	15.83	16.42	0.51	0.43
	Final BW (kg)	20.69	20.78	0.50	0.90
	Carcass weight (kg)	7.20	7.38	0.25	0.62
	Dressing percentage (%)	35.49	34.79	0.69	0.48
	ADG[2] ($g{\cdot}d^{-1}$)	0.17	0.14	0.01	0.28
Viscera weight (g)	Heart (g)	85.13	86.02	2.65	0.82
	Liver (g)	321.9	339.9	10.46	0.24
	Kindey (g)	24.35	26.54	0.88	0.09
	Epinephros (g)	0.98	1.11	0.05	0.11
	Lungs (g)	198.6^b	224.7^a	6.08	0.006
	Spleen (g)	40.74	43.48	2.23	0.39

[1] BW = Body Weight; [2] ADG = average daily gain; [3] BS = barley straw, OH = oat hay; [4] Pooled standard error of means; [a,b] Mean values within a row with unlike superscript letters were significantly different (P<0.05)

OH diet was longer (P≤0.01) than the sheep fed BS diet, whereas the length of the small intestine tissues, cecum and rectum had no significant (P>0.05) difference between the two treatments *(Table 3)*.

As shown in *Table 4*, no differences were found in dropping and cooking loss, loin eye area and chemical composition of LM (P>0.05). For AA composition, the content of His in longissimus dorsi muscle of OH treatment was greater (P≤0.05) than that of BS treatment, while there were no significant (P>0.05) differences between the two treatments for the other individual AA, umami AA, essential AA and total AA *(Table 4)*.

DISCUSSION

The average daily gain of sheep was not influenced by the type of forage offered *(Table 2)*, and it was around 150 g/d for both diets. This value was similar to those reported by Costa et al.[21] and Lima et al.[22] for the same genotype consuming diets, because barley and oat both belonged to C3 photosynthetic pathway plants [23], and both forages presented a similar anatomical arrangement. Replacement with an alternative food did not affect the weight gain of the sheep evaluated by Atti and Mahouachi [24]. We obtained dressing percentage similar to those reported by Ekiz et al.[25], Cloete et al.[26], and Andrade et al.[27] for

Table 3. *Effects of dietary fiber sources on weight and length of gastrointestinal tissues in sheep*

Items		Treatments[1] BS	Treatments[1] OH	SEM[2]	P
Weight (g)	Rumen	403.5[b]	445.1[a]	10.24	0.009
	Reticulum	74.21[b]	97.38[a]	5.57	0.008
	Omasum	61.86	72.77	5.42	0.17
	Abomasum	76.59[b]	102.2[a]	4.60	0.0007
	Duodenum	11.57	13.64	0.80	0.08
	Jejunum	272.7	290.7	13.51	0.36
	Ileum	144.5	167.3	10.51	0.14
	Cecum	89.89	97.91	3.86	0.16
	Colon	144.8	154.4	6.86	0.33
	Rectum	36.23	35.56	1.79	0.80
Length	Duodenum (cm)	24.08	27.79	1.28	0.06
	Jejunum (m)	13.25	13.50	0.48	0.72
	Ileum (m)	6.34	7.16	0.37	0.13
	Cecum (cm)	78.17	87.08	3.17	0.06
	Colon (m)	3.94[b]	4.62[a]	0.15	0.004
	Rectum (cm)	31.0	31.77	2.05	0.79

[1] BS = barley straw, OH = oat hay; [2] Pooled standard error of means; [a,b] Mean values within a row with unlike superscript letters were significantly different (P<0.05)

indigenous breeds. This indicates that the native breeds of sheep have potential for meat production.

The variations in nutrition level, diet quality and feed intake induced variation in the mass of splanchnic tissues [28]. Although splanchnic tissues only represent 6-10% of body weight, they can account for up to 50% of total energy expenditure [29]. As a consequence, variations in the weight of splanchnic tissues contribute to the adaptations in maintenance requirements of the animal according to its feeding level. The changes in visceral organ mass may in response to dietary CP and ME levels on sheep [30,31] and beef cattle [32]. In the present study, we did not find any changes in visceral organ mass such as heart, liver, kidney epinephros, spleen and thymus, the lack of difference may be related to the insufficient experimental period. However, we found that the lungs mass decreased for sheep fed forage from BS in the present study, the lower organ weight of lung indicated that the lung was more powerful to resist inflammation especially in the special plateau climate environment.

The gastrointestinal tract (GIT) represents only 5 to 7% of body mass, yet consumes roughly 15 to 20% of whole-body oxygen [33]. Therefore, development of GIT is very sensitive to dietary nutrition. Differences have been reported in visceral organ mass and in individual mass of metabolically important organs due to DMI and physical form and energy density of the diet [32,34]. Forestomach mass appears to respond to physical form of the diet and fiber content [32,34], and the intestinal mass appears to be dependent on both [32]. Previous works in lamb [35,36] and steers [32,34] has shown that reticulo-ruminal mass is responsive to physical form of the diet. In the current study, we found that the weight of the rumen, reticulum and abomasums for sheep fed forage from BS decreased than that fed OH, it resulted from the difference of physical form of forage between treatments, especially for the difference of physical form between BS and OH. Even though dietary ME content was not different between treatments, it seems to be similar to previous results, an increased rate of passage and greater ruminal outflow rates for native forage (BS) have contributed to the response [37]. In ruminants, digestive tract tissues are affected by changes in ME intake [30], protein intake [35,38], and nutrient restriction [32,39], as well as dietary density [30,32]. The length of small intestine, cecum and rectum did not affect for both treatments, it might result from the similar dietary composition and actual intake of important ingredients such as protein and ME for both treatments. The greater length of colon when feeding OH compared with BS might be due to the greater supply of energy to the colonic epithelium when feeding OH as demonstrated by the greater absorption of short-chain fatty acids (SCFA) to the portal vein [40].

Previous research reported that there was no effect of crambe meal level on chemical composition and quality of the longissimus dorsi (LD) muscle and cooking loss [41]. Fasae et al.[42] also reported that proximate composition of the meat from the LD muscle indicated that the DM, CP, fat and ash contents were not influenced by the dietary treatment (varying levels of maize and cassava hay).

Table 4. *Effects of dietary fiber sources on meat quality, chemical composition and amino acids contents of the longissimus dorsi muscle in sheep (DM basis)*					
Items[1]		**Treatments[2]**		**SEM[3]**	**P**
		BS	**OH**		
Meat quality	Dropping loss (%)	5.81	4.21	0.83	0.17
	Cooking loss (%)	32.56	28.33	1.77	0.19
	Loin eye area (cm^2)	7.32	5.53	0.52	0.06
Chemical composition	DM (%)	27.45	28.16	1.96	0.26
	CP (%)	21.03	21.88	3.52	0.14
	CF (%)	4.82	4.87	0.65	0.27
AA composition (mg/g)	Asp	20.24	21.09	0.80	0.46
	Thr	11.04	11.50	0.46	0.48
	Ser	9.26	9.59	0.39	0.55
	Glu	44.59	45.94	1.76	0.59
	Gly	8.41	9.04	0.29	0.14
	Ala	12.63	13.37	0.37	0.17
	Cys	1.95	2.15	0.09	0.14
	Val	10.14	10.45	0.26	0.39
	Met	4.81	4.29	0.48	0.45
	Ile	10.05	10.66	0.36	0.23
	Leu	18.12	19.14	0.64	0.27
	Tyr	8.61	9.03	0.34	0.39
	Phe	8.12	8.52	0.27	0.31
	Lys	20.07	21.11	0.82	0.38
	His	6.73^b	7.56^a	0.28	0.04
	Arg	14.29	14.94	0.55	0.41
	Pro	8.12	8.89	0.43	0.22
	Umami AA (%)	36.87	36.63	0.22	0.45
	Essential AA (%)	37.86	37.75	0.15	0.61
	Total AA	217.0	227.5	7.86	0.35

[1] DM = dry matter, CP = crude protein, CF = crude fat; [2] BS = barley straw, OH = oat hay; [3] Pooled standard error of means; [a,b] Mean values within a row with unlike superscript letters were significantly (P<0.05)

Bonanno and Di Miceli et al.[43] determined the effects of sulla forage on meat quality of lambs compared with annual ryegrass, reported that the physical, chemical, and sensory properties of the lamb meat were not influenced. It was similar to the present study, that the dropping loss, cooking loss, loin eye area and the chemical composition (DM, CP and CF) were not affected by the dietary treatment. However, Byong et al.[44] reported that CP of the LD muscle was significantly lower when feeding with mulberry silage supplementation, and as reported by Abdullah et al.[45] that cooking loss, as one measure of water-binding capacity of meat, had a strong genetic determination and was also influenced by handing of the animal and the meat.

There were a large amount of glutamic acid (Glu), lysine (Lys), aspartic acid (Asp), leucine (Leu) and arginine (Arg) founded in the LD muscle of Tibetan sheep, the AA content the LD muscle not only could reflect the character of Tibetan sheep mutton, but also allow for a selection of improving meat quality in the breed analyzed with more attractive sensory attributes. The umani AA, essential AA, total AA and individual AA except His was not different between treatments in the present study. Histidine (His) has been identified as a limiting AA for growing cattle [46], and previous studies showed that different protein concentration in the diet might have affected the histidase activity in cattle and rats [47,48]. The CP concentration in OH was numerically 24.42% higher than that of BS, and CP intake was numerically 30.18% higher than BS, which may improve histidase activity and histidine content in LD muscle.

Our results demonstrate that the growth performance, slaughter performance and meat quality was not affected when fed on indigenous BS compared to artificial cultivated OH for Tibetan sheep, but OH was beneficial for the gastro-intestinal development of Tibetan sheep.

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