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Dietary starch source influences in growing goats: the intestinal losses of endogenous nitrogen and amino acids

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Four goats (20 (SD 2·5) kg) fitted with ruminal, duodenal and ileal cannulae were used in a 4 × 4 Latin square design to estimate the effects of a dietary starch source on the duodenal and ileal flows of endogenous N (EN) and endogenous amino acids (EAA) in growing goats. Goats were fed total mixed rations containing four starch sources (mainly from maize (MR), wheat (WR), paddy (PR) and sorghum (SR) treatments). There were no significant ($P>0·05$) effects of the dietary starch source on the intestinal flows of EN and EAA. The duodenal flows of EN were 2·40, 2·39, 2·18 and 1·56 g/d for the MR, WR, PR and SR treatments, respectively, as determined by the difference method, and the duodenal flows of EAA were 10·76, 11·29, 10·95 and 10·96 g/d by estimation with the amino acid profile method. The flows of EN and EAA at the ileum were 1·17, 1·12, 1·01, 0·70 and 4·87, 4·95, 4·94, 4·99 g/d, respectively, as estimated by the water-soluble method. The average intestinal reabsorption of EN and EAA was 57·5 %, and the endogenous Leu by the MR treatment was significantly ($P<0·05$) lower than that of the other three treatments. The present results indicate that losses of endogenous protein in the intestine were not affected by the dietary starch source.

Starch source: Endogenous nitrogen: Endogenous amino acids: Goats

The determination of the true digestibility of N and amino acids (AA) in feedstuffs is of great interest for animal production because it allows for better adjustment of the supply to the requirement and reduction of N pollution[1,2]. Correction of the significant losses of endogenous N (EN) and endogenous amino acids (EAA) occurring during digestion and absorption along the gastrointestinal tract is necessary for estimating the true digestibility of N and for measuring the N and AA requirements by factorial methods. The endogenous contribution has not received much attention until recently and the estimates used have been fairly low. Several reports have acknowledged that the endogenous protein makes up a considerable fraction of the duodenal N flow[3–5]. However, it is difficult to determine the losses of EN and EAA in ruminants because their N and AA supplies originate from both micro-organisms and ruminally undegraded feed protein. Prediction of the supply from each of these origins has to be based on experiments with ruminants cannulated at the start of the small intestine, and the total flows of N and AA must be separated with respect to the origin. This separation is complicated by the endogenous secretion of N and AA during digestion originating predominantly from various digestive secretions, mucoproteins, and desquamated epithelial cells shed from the gut lining and the intestinal flora[6,7].

Secretion and/or reabsorption of EN and EAA are influenced by many factors, including animal species[6], body weight[8], DM intake (DMI)[6,8], dietary protein content and quality[3] and dietary fibre content[6,9]. Starch usually supplies energy and is an important component of the animal diet, with cereal grains serving as the primary source of starch in ruminant diets. Maize, wheat, rice and sorghum are commonly used worldwide as a starch source in all animal feeds, including ruminants[10]. Grain texture plays a major role in the rate and location of starch digestion in ruminants[11], and variations in the starch granule structure among species of cereal grains may account for distinct rates of digestion patterns[12]. In a previous study, we demonstrated that the dietary starch source had significant effects on the ruminal degradation and intestinal digestion in goats[13,14]. Our hypothesis was that these variations influenced the losses of EN and EAA in ruminants. The AA composition of the endogenous protein at different sites of the digestive tract has received little attention in growing goats, and accurate determination of EN and EAA along the digestive tract is essential for

Abbreviations: AA, amino acid; AAP, amino acid profile; DAPA, diaminopimelic acid; DMI, dry matter intake; EAA, endogenous amino acid; EN, endogenous N; NDF, neutral-detergent fibre; TEAA, total essential amino acid; TN, total N.

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optimising protein nutrition in ruminants. Therefore, the objective of the present study was to investigate the effects of the dietary starch source on EN and EAA losses along the gastrointestinal tract in growing goats.

Materials and methods

Animals and management

The experiment was conducted according to the animal care and use guidelines of the Animal Care Committee, Institute of Subtropical Agriculture, Chinese Academy of Sciences, Changsha, China.

Four Liuyang black growing wethers (a local breed in the South of China) with initial body weights of 20 (SD 2·5) kg were each fitted with a ruminal plastic cannula (4 cm internal diameter) and proximal duodenal and terminal ileal fistulae (T-type, 1 cm internal diameter; Laboratory Factory, Yinchuan, Ninxia University). The animals were kept individually in stainless-steel metabolism cages in a temperature-controlled (21°C) and constantly lit animal house with free access to fresh water.

Experimental diets and design

The experiment was carried out in a 4 × 4 Latin square design, with four goats, four dietary treatments (the dietary starch sources were mainly from maize, wheat, paddy and sorghum) and four periods. The formal experiment for each period lasted for 24 d, consisting of 14 d for adaptation, 3 d for *in situ* degradability of dietary protein determination and 7 d for sample collection.

The ingredients and chemical composition of the experimental total mixed rations are shown in Table 1. The total mixed rations were offered and the refusals were collected and weighed daily for 7 d before the commencement of the formal experiment to measure the voluntary feed intake. During the formal experiment, the supplied experimental total mixed rations were fed in equal portions at 07.00 and 19.00 hours daily to meet 1·3 times the maintenance requirements of the metabolisable energy according to the nutrient requirements of Chinese goats[15]. To avoid feed refusals, the amount of the diets offered to each goat was controlled at 90 % of its voluntary feed intake measured before the commencement of the experiment.

Table 1. Ingredients and chemical composition of the experimental diets (% DM)

	Diets			
Dietary starch source…	Maize	Wheat	Paddy	Sorghum
Ingredients (% diet)				
Maize stover	60·00	60·00	60·00	60·00
Maize	25·27	–	–	–
Wheat	–	25·19	–	–
Paddy	–	–	28·73	–
Sorghum	–	–	–	25·62
Soyabean meal	6·83	5·92	2·48	5·47
Paddy hull	2·35	3·27	2·84	3·15
Fish meal	3·75	3·82	4·15	3·96
Sodium chloride	0·80	0·80	0·80	0·80
Premix*	1·00	1·00	1·00	1·00
Chemical composition				
Metabolisable energy (kJ/kg DM)†	10 157	9823	9739	9823
Crude protein (% DM)	13·13	12·76	12·52	12·67
Neutral-detergent fibre (% DM)	39·62	40·77	40·30	40·93
Starch (% DM)	25·61	24·89	24·64	24·98
Ca (% DM)	0·64	0·58	0·58	0·74
P (% DM)	0·24	0·24	0·41	0·31

* Premix (per kg): 243·8 g $MgSO_4.H_2O$; 15·8 g $FeSO_4.7H_2O$; 3·3 g $CuSO_4.5H_2O$; 13·0 g $MnSO_4.H_2O$; 14·5 g $ZnSO_4.H_2O$; 20 mg Na_2SeO_3; 60 mg KI; 40 mg $CoCl_2.6H_2O$; 28·5 mg vitamin A; 0·438 mg vitamin D; 1224 mg vitamin E.
† Metabolisable energy values were reported by Zhang & Zhang[65].

In situ *protein degradation*

The *in situ* degradability of the dietary protein was examined from day 15 to day 17 according to the modified procedure of Tan *et al.* [16]. The passage rate (K_p) was calculated according to the following equation described by the National Research Council[5]: K_p (%/h) = 3·362 + 0·479 × (DMI, % of body weight) − 0·017 × (% neutral-detergent fibre (NDF), DM basis) − 0·007 × (% concentrate in diet, DM basis). The calculated average K_p value was 0·051 %/h in the present study. The effective rumen degradability of the dietary protein was calculated by the equation of Øskov & McDonald[17]. The dietary rumen degraded protein was calculated by multiplying the effective rumen degradability by the dietary N or AA content, and the rumen undegraded protein was determined by subtracting the rumen degraded protein from the dietary protein content.

Sample collection

Feed samples were taken before feeding. From day 18 to day 24 of each period, a total of 4 g of chromic oxide (Cr_2O_3; 1 g every 6 h per d), as the particulate-phase digesta marker, was administered daily via the rumen fistulae at 06.00, 12.00, 18.00 and 24.00 hours[16]. Samples (50 ml of ruminal, 50 ml of duodenal and 30 ml of ileal digesta) were collected at 05.00, 11.00, 17.00 and 23.00 hours on day 22, at 03.00, 09.00, 15.00 and 21.00 hours on day 23 and at 01.00, 07.00, 13.00 and 19.00 hours on day 24. At the end of each period, equal portions of the ruminal, duodenal and ileal samples were pooled. The pooled ruminal digesta were collected to isolate bacteria, and the pooled duodenal and ileal digesta were collected to measure the digesta flows. The ileal samples were chilled to 5°C until all twelve samples were collected in order to avoid lysis of bacteria, which would introduce cellular content into the water-soluble phase. From day 18 to day 21, the total faeces and urine were collected and subsampled for analyses for the determination of the N balance.

Sample handling

The pooled ruminal digesta were used to isolate bacteria by differential centrifugation according to the procedure of Reed *et al.* [18]. The isolated bacteria were freeze-dried (GLZY-0·5B; Pudong Freeze Dryer Equipment Co., Ltd, Shanghai, China), and then mashed with a mortar and pestle for analysis of microbial DM, N and AA (including

diaminopimelic acid (DAPA)). The pooled duodenal and ileal digesta were separated as follows: one subsample of the duodenal and ileal digesta was freeze-dried and further analysed for DM, Cr, N and AA, respectively. The other subsample of duodenal digesta was used to isolate bacteria by differential centrifugation according to the procedure of Reed *et al.* [18], and the isolated bacteria were used to analyse the microbial DM, N and AA (including DAPA). A subsample (100 g) of the pooled ileal digesta was added to 100 g of demineralised water and then shaken for 5 min, and the resulting suspension was squeezed through two layers of cheesecloth. The remaining feed particles and protozoa were removed by centrifugation (409 ***g***; 5 min; 3°C), and the bacterial fraction in the ileal digesta was removed by centrifuging the supernatant fraction twice (17 300 ***g***; 20 min; 3°C). The supernatant fraction was frozen for the analysis of water-soluble N and AA[19]. A 50 g representative sample of each daily faeces was frozen at −20°C for later analyses. The urine was acidified daily with 50 ml of 0·75 M-H_2SO_4 during its collection. Subsamples of urine were taken daily and kept at −20°C until analysis.

Chemical analyses

The DM content of the feed, remaining feed (orts), faeces, digesta, incubated nylon bag samples and freeze-dried bacteria was determined by drying at 65°C to a constant weight. The faeces, feed, orts and digesta were ground through a 0·5 mm screen with a laboratory mill (DF-2; Changsha Instrument Factory, Changsha City, China). The total N content of the feed, orts, faeces, urine, digesta and incubated nylon bag samples was analysed according to AOAC methods[20] and that of bacteria was determined by the Dumas method according to Hansen[21]. The AA content, including DAPA, was determined according to Mason *et al.* [22]. Chromic oxide analysis on digesta was determined colorimetrically after oxidation to chromate according to Schurch *et al.* [23].

Calculations

The flows of DM, N and AA at the duodenum and ileum were calculated as described by Sun *et al.* [24]. The duodenal flows of microbial N and AA were determined by the internal microbial marker DAPA[25], and the microbial passage at the duodenum was calculated from the concentration of DAPA in isolated rumen bacteria and the passage of DAPA at the duodenum. The following equations were used to calculate the duodenal flows of microbial N and AA[26]:

$$R = \frac{DPd/Nd}{DPm/Nm}, \quad (1)$$

$$Mp = R \times DFN, \quad (2)$$

where R indicates the ratio of microbial N to total N or AA of digesta, DP_d and N_d stand for the concentration of DAPA and N in the digesta, respectively, DP_m and N_m are the concentrations of DAPA and N in isolated rumen bacteria, Mp is the flow of microbial N at the duodenum, and DFN stands for the flow of N in the digesta at the duodenum.

The calculated equation for the duodenal flows of EN or EAA is:

$$\text{Endogenous flow} = \text{total flow} - \text{microbial flow} - \text{undegraded feed flow}. \quad (3)$$

The duodenal flow of N and individual AA was also separated by origin by the amino acid profile (AAP) method[2,3,27,28]. This mathematical method estimates the contribution of total N and AA from each origin by solving the following equation using the least squares calculation with SAS procedure PROC REG (SAS Institute, Inc., Cary, NC, USA)[29]:

$$AA_i = \beta_1 \times FeedAA_i + \beta_2 \times MicAA_i + \beta_3 \times AboAA_i + \beta_4 \times BileAA_i, \quad (4)$$

where AA_i is the *i*th AA flow in the duodenum; *i* is the individual AA ($i = 1–16$); β_{1-4} is total AA from each origin; $FeedAA_i$, $MicAA_i$, $AboAA_i$ and $BileAA_i$ are the *i*th AA proportion in undegraded protein in total mixed rations, microbial protein, and endogenous protein in abomasum and bile, respectively. The AA profiles of abomasal fluid and bile were previously determined in our laboratory using twenty-three slaughtered goats.

The ileal EN and EAA were assumed to be located in the water-soluble phase and the apparent reabsorption of EN and EAA was calculated according to the method of Larsen *et al.* [19].

Statistical analyses

The results were analysed using the SAS procedure PROC GLM (SAS Institute, Inc.)[29] with the following model:

$$Y_{ijk} = \mu + Period_i + Goat_j + Treatment_k + \epsilon_{ijk},$$

where Y_{ijk} is the response, μ is the overall mean, $Period_i$ is the effect of the period ($i = 1–3$), $Goat_j$ is the effect of the goat ($j = 1–3$), and $Treatment_k$ is the effect of the dietary starch source treatment ($k = 1–3$). The error (ϵ_{ijk}) was assumed to be independent and N (0, σ^2). Statistical effects were considered to be significant when the probabilities (*P*) were below 0·05, and tendencies were considered at $0·05 < P < 0·10$.

Results

The duodenal flow, ileal flow and intestinal reabsorption of EN are presented in Table 2. There were no significant differences ($P > 0·05$) for N intake, duodenal flow of total N (TN), undegraded feed N, microbial N (MN), EN, ileal flow or intestinal absorption of EN. The average ratio of MN:TN at the duodenum was from 56·0 % (maize) to 63·8 % (sorghum), and the average absorption of EN in the intestine was about 53·1 %.

Table 3 presents the effects of the dietary starch source on the duodenal flow, ileal flow and intestinal reabsorption of EAA. There were no significant differences ($P > 0·05$) in the duodenal or ileal flow of EAA among treatments. The dietary starch sources had no effect on the intestinal reabsorption of EAA, except for Leu. The intestinal reabsorption of endogenous Leu was significantly ($P < 0·05$) lower for the maize

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Table 2. Effect of starch source on the duodenal flow, ileal flow and intestinal reabsorption of endogenous nitrogen (EN) in growing goats (g/d) (Mean values with their pooled standard errors)

	Treatments					
Item	Maize	Wheat	Paddy	Sorghum	SEM	*P*
N intake*	11·67	12·86	10·91	11·95	0·99	0·61
Duodenal flow						
Total N	12·61	13·77	11·77	12·67	1·28	0·63
Microbial N	7·06	7·94	6·90	8·08	0·63	0·43
Undegraded feed N	3·14	3·44	2·69	3·03	0·15	0·37
EN	2·40	2·39	2·18	1·56	0·12	0·31
Ileal EN flow	1·17	1·12	1·01	0·70	0·15	0·21
Intestinal reabsorption of EN	51·0	53·3	53·2	54·8	1·38	0·36

* Intake measured during the total collection period.

treatment than for the other three treatments. The average reabsorption of endogenous protein was 57·5 %.

Discussion

Effects of dietary starch source

Over the last few years, several studies have been conducted to test the effects of dietary factors on the loss of EN and EAA along the gastrointestinal tract on the DM intake[30,31], fibre content[2,6,32], protein quantity and quality[33] and anti-nutritive factors[34–36] in both ruminants and single-stomached animals. Some studies have been conducted to examine the influence of the dietary starch source on feed consumption, ruminal fermentation parameters, skeletal growth, blood metabolites, nutrient digestion, and growth performance in ruminants[37–41]. To our knowledge, few studies have been conducted to evaluate the effects of dietary starch sources on the flows of EN and EAA in ruminants. The results of the present study indicated that there are no effects of dietary starch source on the intestinal flows of EN and EAA in growing goats. The chemical components with unique physical properties of dietary starch, its relationship to proteins, and the cellular integrity of starch-containing units affect the availability to microbes, nutrient digestibility[42] and produce energy in the intestine[43], which may result in the variations of EN losses and EAA composition. Further studies are needed to investigate the effects of dietary starch levels and the ratios of starch:N on losses of endogenous materials along the gastrointestinal tract in ruminants.

Duodenal flows of endogenous nitrogen and endogenous amino acids

In the present study, Cr_2O_3 was selected as the particulate phase digesta marker. Within the last few years, considerable attention has been given to indicator methods for determining digestibility. The new methods are advantageous for saving time, labour and equipment. Hamilton *et al.* [44] used Cr_2O_3 to study estimated coefficients of digestibility and found that the length of the sampling period should be ≥ 3 d to reduce sampling errors. Crampton & Lloyd[45] concluded that Cr_2O_3 recovery was 98 to 99 % when sheep received a hay plus grain ration, even 3 d after Cr_2O_3 administration had stopped. To confirm the stable marker concentrations in the rumen and intestine, the goats were fed with total mixed rations and the Cr_2O_3 administration was continued for 7 d in the present study. Estimates of the flows of endogenous protein in the duodenum vary from 16 % of the total protein flow[46] to 56 %[47]. Van Bruchem *et al.* [48] used a continuous abomasal infusion of ^{15}N-labelled, grass meal–beer yeast suspension, and reported that the endogenous contribution accounted for 12 % of the duodenal N flow in sheep. In addition, Sandek *et al.* [49] reported that EN contributed to 3–12 % of the duodenal flow of total N determined by the ^{15}N-labelled method for diets ranging from 15 to 25 % of crude fibre content in sheep. Ouellet *et al.* [32] found that the average contribution of EN to TN at the duodenum was 14 % when estimated by the ^{15}N dilution technique in Holstein cows fed high-fibre (containing 37·4 % NDF) and low-fibre (containing 23·3 % NDF) diets. Using an infusion of [^{15}N]leucine in lactating cows, Lapierre *et al.* [50] demonstrated that the EN contribution to the duodenal N flow averaged at 18 % when silage was fed and at 20 % when hay was offered. In the present study, the average endogenous contribution to the duodenal TN flow was 17 %, which is within the range of previously published values. Variations between the various reports could be due to differences of cannulae positions, analytical methods, diet compositions and experimental animal species.

Larsen *et al.* [3] found that the average duodenal flow of EN was 10·0 g/kg DMI when estimated by the difference method in lactating cows fed diets low in AA content. Using the AAP method, Larsen *et al.* [19] reported that the average duodenal flow of total essential amino acids (TEAA) was 25·6 g/kg DMI in dairy cows. Ouellet *et al.* [32] demonstrated that the mean duodenal flow of EN was 4·4 g/kg DMI, which was estimated by the ^{15}N dilution method in Holstein cows fed with diets containing different NDF contents. By contrast, Jensen *et al.* [51] reported that the duodenal flow of EN was 7·9 g/kg DMI using the AAP method in lactating Danish Holstein–Friesian cows fed maize silage. Zhou *et al.* [2] found that the mean duodenal flows of EN and TEAA were 2·1 and 11·8 g/kg DMI by estimation with the difference method and the AAP method in growing goats fed diets containing different NDF levels, respectively. In the present study, the average duodenal flows of EN and TEAA were 3·7 and 19·0 g/kg DMI, as determined by the difference and AAP methods, respectively. The differences of EN and TEAA between goats and dairy cows might result from the different computational processes among the determination methods. Furthermore, the big size and relatively large amount of protein turnover for dairy cows might result in greater losses of EN at the duodenum[50], which needs to be further examined in future studies. The flows of EN and TEAA in the present study were higher than those of our previous study[2], probably because of the greater dietary NDF content (40·4 *v.* 35·6 %) in the present study, an important factor affecting the endogenous protein losses[6,8,52,53], or the lower level of feed intake (only 1·3 times the maintenance requirement for metabolisable energy). Some studies have shown that endogenous losses are sensitive to feed intake[30,31,54–56]. The losses of EN and EAA (measured in g/kg DMI) in pigs fed at the maintenance metabolisable energy are twice that if pigs are fed three times

Table 3. Effect of starch source on the flow of endogenous amino acids at the duodenum and ileum and intestinal reabsorption in growing goats (g/d)

(Mean values with their pooled standard errors)

Item	Treatments				SEM	*P*
	Maize	Wheat	Paddy	Sorghum		
Arg						
Duodenum	0·65	0·59	0·65	0·58	0·03	0·26
Ileum	0·23	0·21	0·24	0·20	0·02	0·29
Reabsorption	63·8	65·0	62·6	66·1	1·83	0·60
His						
Duodenum	0·45	0·41	0·43	0·46	0·04	0·80
Ileum	0·15	0·15	0·14	0·15	0·02	0·99
Reabsorption	67·3	63·6	66·8	66·4	3·53	0·88
Ile						
Duodenum	0·87	0·86	0·87	0·91	0·03	0·74
Ileum	0·33	0·32	0·31	0·34	0·03	0·88
Reabsorption	62·0	62·0	64·3	62·5	2·54	0·90
Leu						
Duodenum	1·02	1·15	1·03	1·08	0·05	0·36
Ileum	0·36	0·35	0·32	0·34	0·02	0·61
Reabsorption	65·0[b]	69·2[a]	68·9[a]	68·3[a]	0·88	0·05
Lys						
Duodenum	1·01	0·98	0·94	0·95	0·04	0·64
Ileum	0·34	0·33	0·31	0·35	0·02	0·37
Reabsorption	65·8	66·5	66·7	62·6	1·84	0·43
Phe						
Duodenum	0·65	0·91	0·82	0·83	0·05	0·07
Ileum	0·24	0·29	0·30	0·27	0·02	0·30
Reabsorption	63·5	68·0	63·5	67·2	1·60	0·18
Met						
Duodenum	0·07	0·06	0·08	0·07	0·01	0·24
Ileum	0·03	0·02	0·03	0·03	0·01	0·16
Reabsorption	63·1	65·0	65·2	64·6	2·39	0·92
Thr						
Duodenum	0·73	0·68	0·78	0·76	0·07	0·80
Ileum	0·49	0·46	0·52	0·51	0·05	0·81
Reabsorption	33·0	33·1	33·2	33·1	0·09	0·42
Val						
Duodenum	0·65	0·77	0·70	0·69	0·05	0·50
Ileum	0·24	0·26	0·26	0·23	0·01	0·50
Reabsorption	63·2	66·7	62·3	65·8	1·88	0·38
Ala						
Duodenum	0·53	0·61	0·57	0·54	0·04	0·52
Ileum	0·19	0·21	0·20	0·20	0·02	0·75
Reabsorption	64·8	65·6	64·3	62·8	1·29	0·53
Gly						
Duodenum	1·17	1·10	1·13	1·09	0·04	0·47
Ileum	0·75	0·70	0·73	0·70	0·02	0·49
Reabsorption	35·9	36·1	36·0	36·1	0·17	0·88
Tyr						
Duodenum	0·39	0·37	0·36	0·43	0·02	0·18
Ileum	0·14	0·12	0·14	0·15	0·01	0·26
Reabsorption	64·2	68·4	61·8	64·6	2·12	0·27
Asp						
Duodenum	1·07	1·30	1·20	1·08	0·05	0·07
Ileum	0·67	0·81	0·76	0·68	0·03	0·06
Reabsorption	37·4	37·3	37·0	37·5	0·12	0·10
Cys						
Duodenum	0·01	0·02	0·02	0·02	0·01	0·35
Ileum	0·01	0·01	0·01	0·01	0·01	0·39
Reabsorption	64·7	65·8	67·7	65·4	1·29	0·48
Ser						
Duodenum	0·71	0·70	0·64	0·70	0·06	0·82
Ileum	0·24	0·23	0·23	0·26	0·02	0·62
Reabsorption	65·9	66·8	64·8	62·3	2·19	0·54
Glu						
Duodenum	0·76	0·76	0·72	0·77	0·03	0·62
Ileum	0·47	0·47	0·45	0·44	0·02	0·73
Reabsorption	38·2	38·0	38·0	42·3	1·19	0·10
Total						
Duodenum	10·76	11·29	10·95	10·96	0·29	0·65
Ileum	4·87	4·95	4·94	4·99	0·10	0·86
Reabsorption	54·7	56·1	54·8	54·4	0·70	0·38

[a,b] Mean values within a row with unlike superscript letters were significantly different ($P<0·05$).

maintenance metabolisable energy[56], and the level of feed intake also significantly influences the losses of EAA[31,54,55].

Ileal flows of endogenous nitrogen and endogenous amino acids

The flow of endogenous protein at the terminal ileum balances between secretion and reabsorption. With ^{15}N marker techniques, Larsen *et al.* [19] found that the ileal proportion of water-soluble non-amino-N (NAN) of the total ileal NAN is similar to the proportion of the ileal EN in sheep[44,48,49], supporting the assumption that endogenous protein in the ileum is located in the water-soluble phase. Zhou *et al.* [2] reported that the average ileal flow of EN located in the water-soluble phase is 5·0 g/kg DMI in growing goats. In the present study, the average ileal flow of EN was 1·7 g/kg DMI, with the differences potentially ascribed to different experimental diet compositions.

It was reported that about 70–80 % of secreted endogenous protein is hydrolysed and reabsorbed before reaching the distal ileum[5758]. The major part of the remaining endogenous protein originates from deconjugated bile salts and mucin glycoprotein because these components are largely resistant to proteolysis and therefore escape reabsorption[59–61]. Glycine accounts for more than 90 % of the total AA content of bile, and mucin glycoprotein is rich in Thr, Asp and Glu[62]. Gardner[63] provided evidence for a substantial flux of Pro and Gly from the enterocytes into the intestinal lumen. It has also been reported that Thr, Asp and Glu are more slowly absorbed from the intestinal lumen than most other AA[59]. Therefore, endogenous protein usually has a high content of these AA[59,64]. The AA composition of endogenous protein in the present study is in agreement with this hypothesis.

Larsen *et al.* [19] demonstrated that the small-intestinal reabsorption of EAA showed some extremes when the duodenal flows were estimated by the difference method, and pointed out that the reabsorption of EAA is related to the secretion of digestive juices with specific AA compositions. The average apparent reabsorption of EAA in the small intestine ranges from 62·3 to 82·5 % in sheep[46,48]. The average apparent reabsorption of EAA was about 57·7 %, which was close to the lowest reported value in the present study. The significant differences of intestinal reabsorption of endogenous Leu need to be further studied.

Conclusion

In conclusion, the dietary starch sources did not significantly affect the duodenal and ileal losses of endogenous protein or the AA composition in growing goats.

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