Determination of ruminal dry matter and crude protein degradability and degradation kinetics of several concentrate feed ingredients in cashmere goat

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ABSTRACT

The objective of this study was to determine the dry matter (DM) and crude protein (CP) degradation parameters of several commercially available concentrate feed ingredients used in Shaanbei White Cashmere Goat (SWCG). Three 4-year-old female SWCGs fitted with permanent rumen fistula were fed with corn straw and concentrate feed. Tested energy and protein feed ingredients were corn, wheat bran (WB), corn germ meal, soybean meal (SBM), rape seed meal (RSM), and distillers dried grains. The feed samples were placed in a nylon bag and incubated in the rumen for 0, 2, 6, 12, 24, 36, and 48 h to measure the ruminal disappearance of DM and CP. The exponential model was used to calculate the degradation kinetics. There were significant differences between sources in terms of DM and CP disappearance and degradability. In terms of energy feed ingredients, the potential degradability of DM and CP of corn was significantly higher than those of the other energy feed ingredients, whereas the effective degradability (ED) of CP of WB at three outflow rates was significantly higher than that of the others. In protein feed ingredients, SBM had the highest potential degradability of DM and CP. Furthermore, the ED of DM of SBM at three outflow rates was significantly higher than those of the other protein feed ingredients, whereas the ED of CP of RSM at three outflow rates was significantly higher than those of the others. Those feed ingredients with low degradability can increase the bypass nutrients, which will be digested in the small intestine. The degradation parameters obtained in this experiment using SWCG would be useful in improving the accuracy of formulation of cashmere goat diet in Northwest of China.

1. Introduction

Nowadays, China is the largest producer of raw cashmere wool with an annual production of 18,000 t in the world (Zhou et al. 2003). Most of the fibre is harvested from several local cashmere goat breeds in China, such as Inner Mongolian White Cashmere Goat, Liaoning White Cashmere Goat, and Shaanbei White Cashmere Goat (SWCG; Zhang et al. 2009).

Cashmere, also known as cashmere wool, is one of the finest and softest luxury natural fibres of the world used mainly for clothing providing warmth and lightness (Ansari-Renani et al. 2012). Cashmere wool production is affected by genetic factors, and environmental factors and variations in animal nutrition are generally the most important environmental factors (McGregor 2009). Numbers of reports have declared that composition and nutrition level of diet can influence fibre production (Galbraith 2000; Ivey et al. 2000; Gurbuz & Kaplan 2008; Sun et al. 2008; Zhang et al. 2009; Celaya et al. 2010).

SWCG was bred from Liaoning White Cashmere Goat, and it inherited the high production both of quantity and quality. In recent years, the feeding model of SWCG was changed from grazing to feedlot feeding, which changed the structure of the daily diets. These changes may expose SWCG to the risk of suffering poor nutrition if the diet cannot meet the need of SWCG. For this reason, there are lots of works need to do to make the animal adapt to the new feeding model, including measuring the nutritional needs and feed ingredients nutrition value.

Determining the composition and degradability of the common feed ingredients of SWCG is essential to evaluate the nutritive value and utilization of feed ingredients. Only limited information has been reported on the degradability of feed ingredients on any other breed of Cashmere goat (Li et al. 2008; Ma et al. 2012). While little is known about the degradability of feed ingredients on SWCG. Thus, the objective of this study is to assess the chemical composition, in situ degradability of dry matter (DM) and crude protein (CP), and degradations kinetics of several common feed ingredients for SWCG in China.

2. Materials and methods

2.1. Animals and feed

The experiment was conducted in Yulin (N38°17′32″, E109°43′31″), Shaanxi province, China. Three 4-year-old female SWCGs with an average weight 30.17 ± 2.05 kg were used in this study. The goats were fitted with permanent rumen fistula and none of them were pregnant or lactating. They were housed in individual pens and had free access to salt and fresh water throughout the experiment. Basal diet was offered twice daily in equal proportion at 9:00 and 17:30. The basal diet was
composed of maize straw (MS) and concentrate supplement (CS) with a ratio of 7:3 (MS:CS). MS contains 94.05% DM and 69.39% neutral detergent fibre (NDF), 40.02% acid detergent fibre (ADF) of DM, respectively. The experimental procedures and surgical operations for animals were approved by the Northwest A&F University Animal Care and Use Committee.

2.2. Sample preparation

Energy feed ingredients – including corn, wheat bran (WB) and corn germ meal (CGM) – and protein feed ingredients – soybean meal (SBM), rape seed meal (RSM) and distillers dried grains (DDGs) – were collected from a local feed company in Yulin, Shaanxi province, China. The samples were dried at 65°C for 48 h and then ground using a domestic mill to pass through a 0.5 mm screen for chemical analysis, and a 1 mm screen for in situ rumen incubation.

2.3. Rumen incubations

Before the start of the study, the goats were allowed a 10-day adaptation period for diet adjustment. The study period was divided into six sub-periods by different incubation time (2, 6, 12, 24, 36, and 48 h) to determine the digestibility of the sample. In each sub-period, six nylon bags (two bags each sample; 6 cm × 10 cm; pore size, 48 µm) containing about 5 g of sample were prepared for each animal. The opening of each bag was tightly sealed using nylon strings and two bags of the same sample were bound to a plastic string. Then the bags were incubated in the rumen before the morning feeding following the schedule.

Immediately after removing from the rumen, the bags were washed with tap water until the washing run clear and become colourless. The bags were dried at 65°C for 48 h, weighed and then the residues in the two-bounded-bags (same time and same goat) were mixed for chemical analysis.

2.4. Chemical analysis

The feedstuff samples were analysed for content of DM, CP, ether extract (EE), NDF, ADF and ash using the methods described by AOAC (1995). The residues were analysed for DM and CP contents also. The rumen digestibility of DM and CP was calculated as the amount of DM and CP extracted from the bag divided by the amount of DM and CP in the sample.

2.5. Statistical analysis

All statistical procedures were performed using SPSS Statistics (IBM Corp., version 20, 2011). To estimate degradation parameters, data of DM and CP degradability after different incubation times were fitted to the model of Ørskov and McDonald (Ørskov & McDonald 1979).

Following the calculation of these parameters, the effective degradability (ED) of DM and CP in feed ingredients was determined using equation also described by Ørskov and McDonald (Ørskov & McDonald 1979; Gurbuz et al. 2008).

The ED of a feed was a measure of its digestion in the rumen over time, while considering the rate at which it flowed from the rumen to the small intestine (Gurbuz 2007). The effective DM degradabilities were calculated by using rumen outflow rates of 2%, 5%, and 8%.

\[ Y(t) = a + b(1 - e^{-ct}), \ t \geq 0, \]  

\[ ED = a + b \times c/(c + k), \]

where \( Y(t) \) is the fraction disappearance at time \( t \), \( a \) is soluble or rapidly degradable fraction, \( b \) is insoluble but potentially degradable fraction, \( c \) is degradation rate, \( t \) is incubation time, \( ED \) is effective degradability for response variables (%), and \( k \) is the outflow rate of passage (h⁻¹).

Degradation parameters were calculated using a non-linear regression while chemical composition and digestibility were subjected to the model one-way ANOVA. Treatment differences were considered significant at \( P < .05 \).

3. Results

3.1. Chemical compositions of feed ingredients

As expected, the compositions varied in different feed ingredients (Table 1). DM content ranged from 87.97% to 90.06%, CP from 8.44% to 46.09%, Ash from 1.32% to 11.33%, NDF from 8.80% to 40.28%, and ADF from 2.47% to 21.51%. Corn had the lowest on the content of DM, CP, Ash, NDF, and ADF and SBM had the lowest on the content of EE. Protein feed ingredient had higher CP and ash contents than energy feed ingredient. The NDF contents of energy feed ingredients except corn were considerable higher than protein feed ingredients. There was no significant difference between WB and CGM on both CP content and NDF content (\( P > .05 \)). In energy feed ingredients, corn was the lowest in the content of NDF and ADF while CGM was the highest one. In protein feed ingredients, SBM had the highest content for CP and the lowest in Ash, EE, NDF and ADF.

3.2. DM degradability of feed ingredients after different incubation time

The degradability of DM in nylon bags showed that the process of digestibility has been an uptrend over time of incubation and species have statistically significant differences (Table 2 and Table 1. Comparing chemical composition of the ingredients through chemical analysis (% DM).

| Item                      | DM   | CP   | Ash  | EE   | NDF  | ADF  |
|---------------------------|------|------|------|------|------|------|
| Energy feed ingredients   |      |      |      |      |      |      |
| Corn                      | 87.97 | 8.44 | 1.32 | 3.70 | 8.80 | 2.47 |
| WB                        | 89.76 | 18.75 | 5.91 | 3.02 | 40.28 | 10.56 |
| CGM                       | 89.59 | 18.75 | 1.60 | 4.89 | 57.28 | 13.34 |
| SEM                       | 0.36 | 2.17 | 0.96 | 0.24 | 8.98 | 2.06 |
| P-value                   | .001 | .001 | .011 | .001 | .001 | .001 |
| Protein feed ingredients  |      |      |      |      |      |      |
| SBM                       | 89.25 | 46.09 | 6.62 | 0.18 | 11.69 | 7.50 |
| RSM                       | 88.78 | 34.43 | 11.33 | 1.89 | 29.77 | 21.51 |
| DDGs                      | 90.06 | 22.73 | 7.78 | 4.33 | 37.67 | 21.22 |
| SEM                       | 0.24 | 4.28 | 0.93 | 0.52 | 4.86 | 2.92 |
| P-value                   | .001 | .001 | .017 | .001 | .001 | .001 |

Note: WB: wheat bran; CGM: corn germ meal; SEM: standard error of the mean; SBM: soybean meal; RSM: rape seed meal; DDGs: distillers dried grains.

\(^1\)Means within the same column with different superscripts differ (\( P < .05 \)).
Figure 1). The DM in energy feed ingredients were almost fully digested after 24 h incubation, since there were no significant differences among the digestibility after 24, 36 and 48 h ($P > 0.05$). When the incubation time was less than 24 h, WB had the most degradability of DM than corn and CGM ($P < 0.05$). However, at the end of the incubation, corn had the most and WB had the least degradability of DM ($P < 0.05$). The degradation parameters of the feed ingredients in rumen were presented in Table 3. WB had the highest content of soluble and free substance followed by corn ($P > 0.05$). Furthermore, it also had the fastest degradation rate ($P < 0.05$). Overall, corn had the highest and WB had the lowest potential degradability ($P < 0.05$). The effective DM degradability values decreased with increased outflow rates. Corn had the highest ED while the outflow rate was 2%. Nevertheless, when it was 5% or 8%, the WB regained the highest position.

Table 2. Average of DM degradability of feed ingredients after 0, 2, 6, 12, 24, 36, 48 h incubation in in situ technique (%DM).

| Incubate time (h) | SEM | P-value |
|------------------|-----|------|
| 0                | 0.006 |      |
| 2                | 0.01 |      |
| 6                | 0.007 |      |
| 12               | 0.001 |      |
| 24               | 0.193 |      |
| 36               | 0.048 |      |
| 48               | 0.001 |      |

Table 3. DM degradation parameters and ED of feed ingredients in rumen (% DM).

| Item | Degradation parameter | ED |
|------|-----------------------|----|
|      | a | b | a + b | c | K = 2% | K = 5% | K = 8% |
| Energy feed ingredients | 28.41 | 66.43 | 94.84 | 0.077 | 81.03 | 68.57 | 60.91 |
| WB | 33.22 | 46.19 | 79.40 | 0.244 | 75.90 | 71.54 | 67.99 |
| CGM | 16.22 | 73.53 | 89.75 | 0.068 | 72.64 | 58.13 | 49.59 |
| SEM | 2.55 | 4.13 | 6.68 | 0.029 | 1.41 | 2.24 | 2.85 |
| P-value | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |

Protein feed ingredients

| Item | Degradation parameter | ED |
|------|-----------------------|----|
|      | a | b | a + b | c | K = 2% | K = 5% | K = 8% |
| S3BM | 32.13 | 64.57 | 96.70 | 0.064 | 81.37 | 68.44 | 60.89 |
| RSM | 37.69 | 41.91 | 79.60 | 0.076 | 70.90 | 63.01 | 58.16 |
| DDGs | 35.93 | 33.87 | 69.80 | 0.057 | 60.96 | 53.92 | 49.97 |
| P-value | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |

Note: WB: wheat bran; CGM: corn germ meal; SEM: standard error of the mean; SBM: soybean meal; RSM: rape seed meal; DDGs: distillers dried grains.

1 Means within the same row or column with different superscripts (a, b, and c for rows and A, B, C for columns) differ ($P < 0.05$).

2 Means within the same column with different superscripts (a, b, and c) differ ($P < 0.05$).
The degradability of DM in protein feed ingredients was quite different with energy feed ingredients and they were more complicated. At first 6 h of incubation, RSM had the highest degradability \( (P < .05) \). While the feed ingredients were incubated in rumen over 12 h, the SBM kept the highest degradation of DM \( (P < .05) \). As Table 3 shown, RSM had the most soluble substances and degradation rate \( (P < .05) \). However, SBM had the highest potential degradability than the others \( (P < .05) \). The results of ED of DM were consisted with the potential degradability. No matter which kind of the process of digestion also has been an uptrend over incubation time and the degradability of feed ingredients was significantly different among species. In energy feed ingredients, WB kept the highest degradability since the incubation started. As shown in Table 5, RSM had the highest potential degradability \( (P < .05) \). However, when the outflow rate was 8%, SBM had the highest ED \( (P < .05) \).

Table 4. Average of CP degradability of feed ingredients after 0, 2, 6, 12, 24, 36, 48 h incubation in \textit{in situ} technique (% DM).

| Incubate time (h) | 0 | 2 | 6 | 12 | 24 | 36 | 48 | SEM | \(P\)-value \(^1\) |
|-------------------|---|---|---|----|----|----|----|-----|----------|
| \textbf{Energy feed ingredients} |   |   |   |    |    |    |    |     |          |
| Corn              | 28.84\(^{aB}\) | 36.67\(^{bB}\) | 48.50\(^{aB}\) | 65.75\(^{ab}\) | 86.90\(^{aB}\) | 91.47\(^{ab}\) | 92.98\(^{aB}\) | 5.56 | .001    |
| WB                | 41.66\(^{bc}\) | 69.25\(^{bc}\) | 81.44\(^{ab}\) | 95.03\(^{b}\) | 95.06\(^{a}\) | 95.94\(^{a}\) | 3.77 | .001    |
| CGM               | 22.94\(^{AB}\) | 25.34\(^{AB}\) | 48.44\(^{AC}\) | 60.65\(^{AB}\) | 86.67\(^{AB}\) | 92.17\(^{AB}\) | 92.80\(^{B}\) | 6.33 | .001    |
| SEM               | 5.83 | 6.60 | 5.01 | 3.78 | 1.43 | 0.73 | 0.61 | .61 | –       |
| \(P\)-value       | .001 | .001 | .001 | .001 | .001 | .021 | .028 | –   | –       |
| \textbf{Protein feed ingredients} |   |   |   |    |    |    |    |     |          |
| SBM               | 10.90\(^{aA}\) | 25.98\(^{AB}\) | 40.65\(^{bC}\) | 64.75\(^{cA}\) | 80.57\(^{bC}\) | 92.31\(^{bC}\) | 92.96\(^{bC}\) | 6.73 | .001    |
| RSM               | 31.72\(^{AC}\) | 48.11\(^{AB}\) | 59.50\(^{cA}\) | 61.59\(^{AB}\) | 75.12\(^{AB}\) | 81.66\(^{AB}\) | 83.65\(^{AB}\) | 3.82 | .001    |
| DDGs              | 11.00\(^{AB}\) | 20.38\(^{AB}\) | 26.27\(^{bA}\) | 30.20\(^{aA}\) | 45.34\(^{bA}\) | 45.73\(^{bA}\) | 55.00\(^{bA}\) | 3.25 | .001    |
| SEM               | 4.38 | 4.24 | 4.86 | 5.53 | 5.59 | 7.09 | 5.81 | .81 | –       |
| \(P\)-value       | .001 | .001 | .001 | .001 | .001 | .001 | .001 | –   | –       |

Note: WB: wheat bran; CGM: corn germ meal; SEM: standard error of the mean; SBM: soybean meal; RSM: rape seed meal; DDGs: distillers dried grains.

\(^1\)Means within the same row or column with different superscripts \((a, b, and c for rows and A, B, C for columns)\) differ \( (P < .05) \).

The data from Table 4 and Figure 2 illustrated that the CP consisted in protein feed ingredients were nearly fully digested after 36 h incubation, except RSM which was after 24 h. SBM had the highest degradability before 12 h and after 12 h, SBM was the highest one and DDGs was always the lowest one since the incubation was started. As shown in Table 5, SBM had much more soluble components and the highest degradability rate and ED and SBM, but SBM has the highest potential degradability \( (P < .05) \). When the outflow rate was 2% or 5%, SBM and RSM had the highest ED and there was no significant difference between each other \( (P = .103, \text{outflow rate} = 2\%; \ P = .208, \text{outflow rate} = 5\%) \). However, when the outflow rate was 8%, RSM had the highest ED than the others \( (P < .05) \).

4. Discussion

4.1. Chemical compositions

Generally, wide variations existed in the chemical composition of the investigated feed ingredients. The nutrient content of these feed ingredients had some differences with former reports (Prestløkken 1999; Cone et al. 2002; Betsha & Melaku...
For example, the NDF and ADF content of WB were slightly lower than a former reporter (Betsha & Melaku 2009). Those differences may result from differences in plant growing conditions or industrial processing methods employed in different countries (Rezaeenia et al. 2014; Riaz et al. 2014). Overall, the nutrient contents were comparable with the former studies, except for CGM, which has a lower content of CP and was considered as an energy feed in our study. The reason why we regarded CGM as an energy field was that its CP content was 18.75% (less than 20%), which was lower than 22.4% (Gurbuz 2007). Such differences in CP content could be attributed to the difference in the method employed in the production. It is important to point out that the differences found among the tested feeds were obtained with one batch of these feeds only.

4.2. DM degradability and degradation parameters

The DM degradability of the feed ingredients in rumen increased with increasing incubation time. Energy feed ingredients degradation were on an up trend before 24 h incubation and after this time the process slowed down, while protein feed ingredients were at the time 36 h except for DDGs, which was on up trend all the time. This indicated that feed ingredients were nearly fully digested at 24 h for energy feed ingredients and 36 h for protein feed ingredients, respectively.

In energy feed ingredients, the degradation parameters of corn were consisted with the findings of, except the rapid degradable DM fraction \((a)\) which was a little lower (Li et al. 2012; Lashkari & Taghizade 2013). This may be due to the variations of growing conditions and breeds. However, the parameters of CGM were quite different with the other report (Gurbuz 2007). Its rapid degradable fraction \((a)\) was much lower and the ED was a little higher in our study when compared with the previous results (Gurbuz 2007; Du et al. 2016). It is obvious that the compositions of CGM were quite different with other researches. Unfortunately, we have not found any reports on the kinetics of WB in rumen. In present study, WB had the highest content of rapid degradable fraction \((a)\), degradation rate \((c)\), and ED when the outflow rate = 5% and 8%. Because of the high content of rapid degradable fraction \((a)\), WB had a higher degradation rate \((c)\) and ED than corn and CGM.

In protein feed ingredients, the degradation rate \((c)\) of SBM was similar to the results obtained in early studies (Tuncer & Sacakli 2003; Gurbuz 2007), but lower than other reports (Røistølken 1999; Sadeghi & Shawrang 2007). However, its rapid degradable fraction \((a)\) was higher than those reports but similar to the findings by Prestølken (1999) and Woods, Mara et al. (2003a). The degradation parameters of RSM were similar to the results by Tuncer & Sacakli (2003), but considerably different with those reports (Prestølken 1999; Sadeghi & Shawrang 2006; Gurbuz 2007). The potential degradable fraction \((b)\) of DDGs was much lower and degradation rate \((c)\) was a little higher when compared to the findings by (Li et al. 2012; Maxin et al. 2013). Furthermore, the EDs of these protein feed ingredients in our study were higher than those studies mentioned before. These discrepancies might be attributed to varietal differences in the chemical compositions, basal diet or variation in the methods used for sample preparation and processing, and in the bags used for incubation.

4.3. CP degradability and degradation parameters

Disappearance of CP from the bags incubated in the rumen increased with increasing time. After 48 h incubation time, most of the feed ingredients had a CP disappearance exceeded 90% except RSM and DDGs.

In energy feed ingredients, as well as the DM degradation, the CP degradation also had the slowed down process, which was the after 36 h incubation time for corn and CGM and 24 h for WB. The degradation parameters of corn were agreed with the data of (Li et al. 2012). As for WB, the degradation parameters were consisted with the result of Abbeddou et al. (2011) except for the degradation rate \((c)\) which was a little lower than Abbeddou's finding. However, the results of CGM were considerably different with the report of Gurbuz (2007). The rapid degradable fraction \((a)\) in our study was lower and the degradation rate \((c)\) and ED was higher than the data of Gurbuz (2007) and Brassard et al. (2015). This may be mainly due to the differences of the CP content of CGM.

In protein feed ingredients, the rapid degradable fraction \((a)\) of SBM was 11.8%, which was closed to the reports of 12.94% (Woods, Moloney et al. 2003b) and 12.3% (Tuncer & Sacakli 2003) and lower than those reports (Manterola et al. 2001; Gurbuz 2007). The degradation rate \((c)\) and ED of SBM was...
higher than some studies (Tuncer & Sacakli 2003; Gurbuz 2007) and lower than others (Prestlékken 1999; Woods, Moloney et al. 2003b; Sadeghi & Shawrang 2007). The rapid degradable fraction (α) and degradation rate (c) of RSM was higher than some reports (Sadeghi & Shawrang 2006; Gurbuz 2007) and lower than the results found by (Tuncer & Sacakli 2003). The effective CP degradability of RSM was close to some findings (Sadeghi & Shawrang 2006) and also, was lower than the finding of Tuncer & Sacakli (2003). The degradation parameters of DDGs in rumen fermentation were lower than the results of Li et al. (2012).

Except the different chemical compositions and the manufacturing processes, all these differences between studies could be explained by the fistulated animals, size and pore size of nylon bag and milling screen size used in studies. In the present experiment, three goats were used, whereas cows were used in the experiment carried in previous studies (Woods, Mara et al. 2003a; Sadeghi & Shawrang 2007). In this experiment, size and pore size of nylon bag was 6 cm × 10 cm and 48 µm, respectively, whereas in the experiment carried out by Tuncer & Sacakli (2003) the same parameters were 9 cm × 14 cm and 45 µm, respectively. The milling screen size used in this study was 1 mm, whereas it was 3 mm in a previous study Gurbuz (2007). It was also likely influenced by the basal diet used in different studies.

5. Conclusions
In summary, a comparable data set of in situ DM and CP degradation parameters for commercially available concentrate feed ingredients used in SWCG were determined and results show that the quality of feed ingredients could vary from source to source. Almost all degradation parameters examined were influenced by the source of feeds in the present study. However, a feed ingredient with a low degradability in the rumen could increase the bypass nutrients which would be digested in the small intestine. The degradation parameters obtained in this experiment using SWCG would be useful in improving the accuracy of formulation of goat diet in Northwest China. Furthermore, ruminal degradation from different sources of feed needs to be measured in order to guarantee an accurate nutrient supply to the animal.

Disclosure statement
No potential conflict of interest was reported by the authors.

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