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Relationship between the physical parameters, chemical compositions and rumen degradation kinetics parameters of certain feedstuffs for ruminants

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ABSTRACT

The primary objective was to investigate the relationship between the physical parameters, nutrient components, and degradation characteristics of feedstuffs. Thirteen kinds of feedstuff were selected to analyze the physical properties (including water holding capacity (WHC), swelling, bulk density, and feed solubility), chemical compositions and degradation parameters. The results showed that these parameters were widely altered among the feedstuff varieties. Correlation analysis indicated that WHC was negatively correlated with the contents of starch, crude protein (CP) and ether extract (EE). However, WHC had a highly positive correlation with the cell wall content parameters. Swelling had a high negative correlation with starch and EE, and had a positive correlation with ash. Bulk density was negatively correlated with neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL). DMSol (%DM) was negatively correlated with NDF, ADF and ADL, but highly positive correlated with CP content ($r_{Spearman} = 0.77$, $P < 0.0001$). Additionally, there was a positive association between the effective degradability of DM (ED_{DM}) and bulk density ($P < 0.05$) and DMsol ($P = 0.001$). Also, the effective degradability of CP (ED_{CP}) was negatively correlated with WHC ($r_{Spearman} = -0.46$; $P = 0.003$) and positively correlated with DMSol ($r_{Spearman} = 0.503$; $P = 0.001$). A stepwise linear regression analysis indicated that NDF, ADF and CP could be predictors of WHC, bulk density and DMSol, respectively. In conclusion, the physical properties can be taken as important evaluation indices, which might be potentially used to estimate the nutritive values of the feedstuffs and can also be applied in a ration formulation.

1. Introduction

The chemical components and rumen degradation kinetics of feedstuffs for ruminants are commonly used to estimate nutritive value; however, the physical properties are rarely considered and measured. Therefore, the relationships between the physical parameters and nutritional properties or physical parameters and degradation characteristics for feedstuffs are often neglected. There are great differences among feedstuffs for their physical and chemical characteristics. Certain physical parameters might, in part, affect and explain the degradation characteristics and utilization efficiency of feedstuffs in the rumen. Ehle (1984) and Martz and Belyea (1986) reported that particle density had remarkable influence on the

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rate of ruminal passage. Additionally, the particle density of feedstuffs affected the ruminal turnover as well as feed intake (Singh and Narang, 1991). Rapidly hydrating particles of feeds are more accessible to microorganisms for degradation and have faster increase in specific gravity than do those that absorb water more slowly (Singh and Narang, 1991). Owens and Goetsch (1988) and Dehority and Orpin (1997) reported that the particle size of feedstuffs affected the available surface area for microbial attachment and thus their populations and growth. Additionally, the physical properties play a significant role in the passage rate of feedstuffs through the digestive tract (Balch, 1950). Giger-Reverdin (2000) carried out research on the relationship between WHC, bulk density and NDF using 24 kinds of feedstuffs, which defined the regression relationships between them. However, limited information could be found about relationships between physical parameters and rumen degradation characteristics, which would restrict the application of physical property on nutritive value evaluation and diet formulation design. With the generalization and development of total mixed ration (TMR) technology, resources on feedstuffs, such as corn gluten feed, soybean hulls and bean residues, are becoming abundantly and widely used in ruminant diet. Therefore, researching the physical properties of various feeds may be important to evaluate the nutritional value of the feeds.

The objectives of this study were to: (1) determine the physical parameters of thirteen feedstuffs; (2) investigate the relationship between physical parameters, nutrient components, and degradation characteristics; and (3) establish predictive models based on the chemical composition and physical parameters of feedstuffs to estimate the physical parameters and degradation characteristics.

2. Materials and methods

2.1. Feedstuffs

Thirteen kinds of feedstuffs were collected including dry corn gluten feed, soybean hulls, sugar beet pulp, bean residue, wheat bran, maize, soybean meal, rapeseed meal, corn stover, corn silage-I, corn silage-II, alfalfa hay, and guinea grass. Corn silage-I and corn silage-II were collected from two different rangelands. All of the feed samples were air dried and ground through a 1 mm screen before chemical and physical analyses, which were performed in triplicate.

2.2. Measurement and analytical methods

The water holding capacity (WHC) was determined by a modification of the method of Robertson and Eastwood (1981b). Swelling was measured according to the method of Serena and Knudsen (2007). The bulk density was determined according to the method of Montgomery and Baumgardt (1965). Feed solubility (including DM solubility and ash solubility) were determined using the filtrate of the WHC measurement according to Giger-Reverdin (2000).

The contents of ash, EE and CP in the feeds were determined by the standard methods of AOAC (1990). Starch and water soluble carbohydrates (WSC) were analyzed by an enzymatic-colorimetric method described by Knudsen (1997). Neutral detergent soluble fiber (NDSF) was determined using the procedures described by Hall et al. (1999). Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined according to Van Soest et al. (1991) using an Ankom Fiber Analyzer (Ankom Technology, Fairport, NY).

Rumen degradation parameters were determined according to the *in situ* method described by Yu et al. (2003). Certain feed samples were incubated for 48, 36, 24, 12, 8, 4, 2 and 0 h; five forages were incubated for 72, 48, 36, 24, 12, 8, 4 and 0 h. The multi-bags for each feedstuff at each incubation time point in each operating run were 2, 2, 2, 3, 4, 4, 6, and 6 bags for the incubation times 0–48 or 72 h, respectively. The maximum number of sample bags in the rumen at any given time was less than 30. All of the treatments for each incubation time were performed in two experimental runs and randomly distributed to all three non-lactating cows fitted with a rumen cannula. After incubation, the sample bags (including 0 h bags) were removed from the rumen and rinsed under cold tap water to stop fermentation and remove the rumen contents. All of the bags were washed with cold water without detergent and then dried at 65 °C for 48 h. The dried samples were ground through a 1 mm screen and stored in Ziploc bags at 4 °C until ready for analysis (Yu, 2010).

2.3. Calculations

The degradation characteristics were calculated for DM, CP and NDF. The parameters were estimated by PROC NLIN of SAS (SAS Institute, 2008) using an iterative least squares regression (Gauss-Newton method). The extent of the effective degradation (ED) of DM, CP and NDF was calculated as $ED = S + D \times k_d/(k_p + k_d)$ as described by Yu (2010). In this equation, S is assumed to be the soluble fraction (%); *D* is the potentially degradable fraction (%); k_d is the fractional rate of degradation of the D fraction (% h^{-1}); k_p is a fixed fractional passage rate for DM, CP and NDF; and the k_p values of the feeds are different and listed in Table 3.

2.4. Statistical analyses

SAS package (SAS 9.2) was used for the statistical calculations. Correlation analysis was investigated using the PROC CORR procedures of SAS using a Spearman method which offers confidence limits and *P*-values for Spearman coefficients

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