Animal Feed Science and Technology 188 (2014) 17–27

Contents lists available at ScienceDirect

Animal Feed Science and Technology

journal homepage: www.elsevier.com/locate/anifeedsci

Forage energy to protein ratio of several legume–grass complex mixtures

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ARTICLE INFO

Article history:
Received 11 September 2013
Received in revised form 25 October 2013
Accepted 14 November 2013

Keywords:
Complex forage mixtures
Energy to protein ratio
Yield
Digestibility
Nutritive value

ABSTRACT

The energy to protein ratio of forages affects ruminant N use efficiency but little is known on its variation among legume–grass complex mixtures. Our objective was to determine the variation in the ratio of forage readily-available energy to proteins along with the associated variation in yield and digestibility by mixing three or four grass species in combination with one of two legume species. Four grass mixes [#1 – timothy (*Phleum pratense* L.), meadow fescue (*Festuca elatior* L.), and Kentucky bluegrass (*Poa pratensis* L.); #2 – timothy, meadow fescue, reed canarygrass (*Phalaris arundinacea* L.), and Kentucky bluegrass; #3 – tall fescue [*Schedonorus phoenix* (Scop.) Holub], meadow bromegrass (*Bromus biebersteinii* Roemer & J.A. Schultes), orchardgrass (*Dactylis glomerata* L.), and Kentucky bluegrass; #4 – tall fescue, meadow bromegrass, reed canarygrass, and Kentucky bluegrass] were grown with either alfalfa (*Medicago sativa* L.) or birdsfoot trefoil (*Lotus corniculatus* L.) at two sites with measurements taken on two simulated grazing events of the first post-establishment year. The water soluble carbohydrate (WSC) to crude protein (CP) ratio among the eight legume–grass mixtures ranged from 0.64 to 1.04, while the ratio of readily fermentable carbohydrate fractions A and B1 to readily soluble protein fractions A and B1 [(CA + CB1)/(PA + PB1)], estimated using the Cornell net carbohydrate and protein system, ranged from 4.33 to 5.64. This significant variation in the two ratios used to characterize the energy to protein balance was due to both legume species and grass mixes. Alfalfa-based complex mixtures had greater WSC/CP and (CA + CB1)/(PA + PB1) than birdsfoot trefoil-based mixtures (0.94 *vs.* 0.69; 5.42 *vs.* 4.47) but a lower *in vitro* true digestibility (IVTD; 902 *vs.* 913 g/kg dry matter, DM). The grass species mix #2 (timothy, meadow fescue, reed canarygrass, and Kentucky bluegrass) provided the best combination of high readily-available energy to protein ratio (WSC/CP = 0.87; (CA + CB1)/(PA + PB1) = 5.08), high DM yield, and average IVTD. The complex mixtures including alfalfa and meadow fescue had the best readily-available energy

Abbreviations: ADF, acid detergent fibre expressed inclusive of residual ash; aNDF, neutral detergent fibre assayed with a heat stable α-amylase and expressed inclusive of residual ash; CP, crude protein; CNCPS, Cornell net carbohydrate and protein system; DM, dry matter; IVTD, *in vitro* true digestibility of dry matter; NDF, neutral detergent fibre; NDFD, *in vitro* digestibility of NDF; NIRS, near infrared reflectance spectroscopy; NSC, nonstructural carbohydrates; PCA, principal component analysis; (sa)-Lignin, lignin determined by solubilization of cellulose with sulphuric acid; TC, total carbohydrates; TN, total nitrogen; WSC, water soluble carbohydrates.

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0377-8401/$ – see front matter.
http://dx.doi.org/10.1016/j.anifeedsci.2013.11.006

to protein ratio and DM yield. Our results confirm the possibility of improving the balance between readily-available energy and proteins through the choice of species in complex mixtures made of one legume and three or four grass species.

1. Introduction

Rapid and extensive ruminal degradation of proteins in legume and grass forages generally leads to decreased protein efficiency (Broderick, 1995). When energy is limiting but there is an excess of peptides and amino acids of plant origin, the rumen microbial population uses amino acids for energy and liberates ammonia through deamination (Kingston-Smith and Theodorou, 2000). With a greater supply of readily fermentable carbohydrates in the rumen, more non-protein N and amino acids can be taken up by microorganisms and incorporated into microbial proteins. Forages with high water soluble carbohydrates (WSC) may, therefore, improve the balance and synchrony of the carbon (C) and nitrogen (N) (Miller et al., 2001) and increase microbial protein production in the rumen and animal productivity (Parsons et al., 2011). Increasing nonstructural carbohydrates (NSC) in alfalfa significantly decreased ruminal pH (6.85 *vs.* 7.08) and NH_3-N concentration in an *in vitro* continuous culture system (Berthiaume et al., 2010), increased *in vivo* protein synthesis by ruminal bacteria (Brito et al., 2009), and improved milk yield of late-lactation dairy cows (Brito et al., 2008). By increasing the NSC (250, 370, 540 g/kg DM) and reducing the neutral detergent fibre (NDF: 554, 308, 104 g/kg DM) concentrations of the diets, Stokes et al. (1991) also obtained greater microbial protein yield and proportion of carbohydrates digested. Lee et al. (2002) and Hristov et al. (2005) reported reduction of rumen ammonia when more fermentable sugars were available in the rumen.

The extent to which soluble N is utilized in the rumen depends on the rate of release and the concentration of carbohydrates and N availability (Hristov et al., 2005). It is suggested to have high energy availability in combination with a reduction in total N concentration or in N solubility to optimize microbial protein synthesis and improve N utilization (Bryant et al., 2012). Parsons et al. (2011) concluded that forage WSC/CP ratios, ranging from 0.5 to 2.4, were negatively correlated with N excreted in the urine. Carbohydrate and protein fractions of the Cornell net carbohydrate and protein system (CNCPS) can also be used to better synchronise the availability of energy and N in an attempt to reduce the loss of N compounds and methane production (Sniffen et al., 1992). Thus, the ratio between WSC and CP, and the ratio between readily fermentable carbohydrates (CNCPS carbohydrate fractions A and B1) and readily soluble N (CNCPS protein fractions A and B1) are important determinants of ruminal N losses. Parsons et al. (2011) concluded that any improvement in the forage WSC/CP ratio will lead to corresponding improvement in N use efficiency in dairy cows.

The choice of forage species may influence protein degradability in cattle diets (Cassida et al., 2000). In a previous study comparing 18 legume–grass binary mixtures (Simili da Silva et al., 2013), we have shown that the WSC/CP ratio varied between 0.39 and 0.70 among mixtures and that binary mixtures of either alfalfa or birdsfoot trefoil with meadow fescue provided the best combination of a high ratio of WSC/CP and yield, and average digestibility. Grass–legume complex mixtures with three species or more increase the yield of pastures (Papadopoulos et al., 2012) but little is known on the potential variation of their balance between readily-available energy and proteins due to their species composition. Our objective was to determine the variation in the balance between forage readily-available energy and proteins along with the associated variation in yield and digestibility by mixing three or four grass species in combination with one of two legume species managed under a frequent clipping system.

2. Materials and methods

2.1. Experimental design and treatments

The experiment was carried out at two sites: (1) Chapais Research Farm of Agriculture and Agri-Food Canada: Lévis, QC, Canada (46°48′ N; 71°23′ W, mean elevation: 43 m, soil type: Saint-Aimé fine sandy loam), and (2) Normandin Research Farm of Agriculture and Agri-Food Canada: Normandin, QC, Canada (48°51′ N, 72°32′ W, mean elevation: 137 m, soil type: Labarre silty clay). At the beginning of the study in 2010, soil pH (0–20 cm) and Mehlich-3 (Mehlich, 1984) extractable P and K content (kg/ha) were, respectively, 5.1, 63, and 291 at Lévis, and 5.9, 143, and 284 at Normandin. This experiment was simultaneously conducted in the same field than a previously published experiment on binary mixtures (Simili da Silva et al., 2013). In Lévis, the precipitation (217 mm) and the accumulation of degree-days (537 °C-d calculated on a 5° basis) during May and June were close to the 30-year average (220 mm and 542 °C-d, respectively). In Normandin, the precipitation (164 mm) and the accumulation of degree-days (435 °C-d) during the same period were also close to the 30-year average (161 mm and 426 °C-d, respectively) (Simili da Silva et al., 2013).

The experiment was seeded on 22 and 23 June 2010 at Lévis and on 2 July 2010 at Normandin. Eight complex mixtures made of one legume and three or four grass species were compared. Four grass species mixes were seeded with either a grazing type alfalfa (cultivar CRS1001) or birdsfoot trefoil (cultivar AC Langille). Alfalfa and birdsfoot trefoil were both seeded at the rate of 6 kg/ha. All grass mixes contained Kentucky bluegrass. The first two mixes were based on timothy and meadow fescue whereas the other two mixes were based on tall fescue and meadow bromegrass. The four grass species mixes with