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ScienceDirect
Animal Feed Science and Technology
136 (2007) 297–311

ANIMAL FEED SCIENCE AND TECHNOLOGY

www.elsevier.com/locate/anifeedsci

Effects of phenolic acid structures on meadow hay digestibility

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Received 18 April 2006; received in revised form 5 September 2006; accepted 7 September 2006

Abstract

The objectives were to evaluate effects of phenolic acid content and composition on the digestibility of six meadow hays from Northern Portugal. Digestibility was assessed by gas production, *in vitro* and *in situ* degradation methods. Four cows fed diets at energy maintenance were used for *in situ* incubations and to provide rumen fluid for *in vitro* incubations. There were no relationships between phenolic acid concentrations and other cell wall components. The dry matter (DM) potential degradation ($a+b$) was positively related to the etherified fractions of ferulic acid (FAeth, P=0.012) and *p*-coumaric acid (PCAeth, P<0.001) and to the total amount of ferulic acid (FAtotal; P=0.033). The insoluble, but potentially degradable, constant (b) of DM had a positive relationship with PCAeth (P=0.008). The *in vitro* neutral detergent fibre digestibility (IVNDFD), and the estimated asymptotic

Abbreviations: a, immediately soluble fraction; A, estimated asymptotic gas production; $a+b$, potential degradation; ADFom, ADF expressed exclusive of residual ash; b, insoluble but potentially degradable fraction; B, time of incubation at which half of the asymptotic gas production has been formed; c, rate constant for the degradation of fraction b; C, sharpness of the switching characteristic for the profile; CP, crude protein; DM, dry matter; ED, effective degradability; FAest, esterified fraction of ferulic acid; FAeth, etherified fraction of ferulic acid; FAtotal, total amount of ferulic acid; IVDMD, *in vitro* dry matter digestibility; IVNDFD, *in vitro* NDF digestibility; NDFom, NDF not assayed with stable amylase expressed exclusive of residual ash; PCAest, esterified fraction of *p*-coumaric acid; PCAeth, etherified fraction of *p*-coumaric acid; PCAtotal, total amount of *p*-coumaric acid; R, fractional rate of substrate fermentation; $R_{max}G$, maximum rate of gas production; $TR_{max}G$, time at which maximum rate of gas production is reached

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0377-8401/$ – see front matter
doi:10.1016/j.anifeedsci.2006.09.009

gas production of the second phase (A_2), were positively related to the esterified fraction of ferulic acid (FAest, P<0.05), FAeth (P<0.01) and FAtotal (P<0.05). The total amount of *p*-coumaric acid (PCAtotal) had a positive relationship with IVNDFD (P=0.047). *In vitro* DM digestibility (IVDMD) was positively correlated with FAeth and FAtotal (P<0.05). In contrast, lignin (pm) concentrations negatively correlated with DM effective degradability (ED; P=0.005) and the maximum rate of gas production of the second phase ($R_{max}G_2$; P=0.009). Degradation kinetic constants *i.e.*, (c) of DM and NDF tended to be negatively correlated to the phenolic acid concentrations, mainly with the PCAeth fraction (P=0.056 and P=0.006, respectively). The same trend occurred for the fractional rate of fermentation of the second phase (R_2; P=0.09). Principal component analysis confirmed that lignin (pm) concentration (principal component 3) is one of the major limiting factors to *in vitro* DM digestibility of these hays. Thus it seems that for these meadow hays, both lignin (pm) content and cross-linkages between cell wall polymers influenced rate and extent of DM degradation.

Keywords: Digestibility; Meadow hays; Lignin; Phenolic acids

1. Introduction

It is widely accepted that diets containing large amounts of forage negatively affect animal production due to low digestibility of structural carbohydrates. This limitation is mainly attributed to lignification (Jung, 1989) and to covalently bound hydroxycinnamic acids (Jung and Fahey, 1983). However, recent studies have supported negative effects of lignin (Jung et al., 1997; Lavrencic et al., 1997; Fonseca et al., 1998), although published data on the effect of ferulic (FA) and *p*-coumaric (PCA) acids on forage digestibility are limited, and research has largely been directed towards individual plant species, distinct plant parts and even specific tissues.

There is evidence that these compounds effect on digestibility are dependent on the content and bonding mode in the cell wall structure; but results are not consistent. If the majority of PCA is esterified to lignin (Jung and Deetz, 1993), and if PCA ethers are only linked to lignin (Lam et al., 1992a), it is probable that these components do not directly affect digestion. Nevertheless, the concentrations of PCA, and the ratio of PCA to FA, have been reported to have a negative effect on cell wall digestibility (Gabrielson et al., 1990; Grabber et al., 1992). Etherified FA, being a measure of cross-linking between lignin and arabinoxylans, have a negative effect on cell wall digestibility (Casler and Jung, 1999; Lam et al., 2003). However, for esterified FA the results are not consistent (Jung and Casler, 1990, 1991). More recently, Casler and Jung (2006) reported negative effects of esterified FA on *in vitro* 24 h neutral detergent fibre (NDF) digestibility of smooth bromegrass and reed canarygrass, but the relationship changed to positive values when digestibility was measured at 96 h.

Given the relevance of these compounds and the shortage of results regarding its influence on hay digestibility, the objectives of this study were to evaluate the influence of phenolic compounds on digestibility of meadow hays, with special relevance to the study of degradation kinetics.