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Comparison of methane produced by straw fed sheep in open-circuit respiration with methane predicted by fermentation characteristics measured by an in vitro gas procedure

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Abstract

Reducing carbon conversion of ruminally degraded feed into methane increases feed efficiency and reduces emission of this potent greenhouse gas into the environment. Accurate, yet simple, predictions of methane production of ruminants on any feeding regime are important in the nutrition of ruminants, and in modeling methane produced by them. The current work investigated feed intake, digestibility and methane production by open-circuit respiration measurements in sheep fed 15 untreated, sodium hydroxide (NaOH) treated and anhydrous ammonia (NH_3) treated wheat, barley and oat straws. In vitro fermentation characteristics of straws were obtained from incubations using the Hohenheim gas production system that measured gas production, true substrate degradability, short-chain fatty acid production and efficiency of microbial production from the ratio of truly degraded substrate to gas volume. In the 15 straws, organic matter (OM) intake and in vivo OM digestibility ranged from 563 to 1201 g and from 0.464 to 0.643, respectively. Total daily methane production ranged from 13.0 to 34.4 l, whereas methane produced/kg OM matter

Abbreviations: DOMI, digestible OM intake; EMP, efficiency of microbial production; MBP, microbial biomass; OM, organic matter; OMD, OM digestibility; OMI, OM intake; SCFA, short-chain fatty acids; TSD, true substrate degradability

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apparently digested in vivo varied from 35.0 to 61.8 l. The OM intake was positively related to total methane production ($R^2 = 0.81$, $P<0.0001$), and in vivo OM digestibility was also positively associated with methane production ($R^2 = 0.67$, $P<0.001$), but negatively associated with methane production/kg digestible OM intake ($R^2 = 0.61$, $P<0.001$). In the in vitro incubations of the 15 straws, the ratio of acetate to propionate ranged from 2.3 to 2.8 ($P<0.05$) and efficiencies of microbial production ranged from 0.21 to 0.37 ($P<0.05$) at half asymptotic gas production. Total daily methane production, calculated from in vitro fermentation characteristics (i.e., true degradability, SCFA ratio and efficiency of microbial production) and OM intake, compared well with methane measured in the open-circuit respiration chamber ($y = 2.5 + 0.86x$, $R^2 = 0.89$, $P<0.0001$, Sy.$x = 2.3$). Methane production from forage fed ruminants can be predicted accurately by simple in vitro incubations combining true substrate degradability and gas volume measurements, if feed intake is known.

Keywords: Methane; Ruminants; In vivo; Gas production

1. Introduction

Microbial degradation of feed in the rumen is characterized by formation of short-chain fatty acids (SCFA), mainly acetate, propionate and butyrate, gases (mainly carbon dioxide (CO_2) and methane (CH_4)), and microbial biomass (MBP). In proportion to the amount of feed degraded, less gas is produced if there is high feed conversion into microbial biomass (i.e., high efficiency of microbial production), than under proportionally high SCFA production (Beever, 1993; Leng, 1993; Van Soest, 1994). Methane is produced with acetate and butyrate, but not with propionate (Wolin, 1960). It was recently shown (Blümmel et al., 1997; Blümmel, 2000) that in vitro gas measurements, when combined with true substrate degradability measurements (TSD in mg), could be used to predict partitioning of degraded feed between microbial biomass production and SCFA and fermentative CO_2, CH_4 and H_2O. Using this approach, MBP could be calculated as: mg MBP = mg TSD − [ml gas × 2.2 mg/ml] and efficiency of microbial production (EMP) as: EMP = (mg TSD − [ml gas × 2.2 mg/ml])/mg TSD. The 2.2 mg/ml is a stoichiometric factor that expresses mg of C, H and O required for the SCFA gas complex associated with production of 1 ml of gas (for derivation of these relationships see Blümmel et al., 1997; Blümmel, 2000). An important source of variation in methane production, variation in EMP, can be easily quantified by an in vitro technique that measures gas volume and TSD in the same incubation.

The objective of this study was to examine relationships between in vitro EMP so determined and CH_4 production in forage fed sheep, and to compare predictions of CH_4 production by these in vitro degradation characteristics with CH_4 measurements in respiration chambers. Details of the in vivo work used for these relationships has been reported and discussed by Moss et al. (1994), and readers are referred to it for suitability of the standard equations frequently suggested in the prediction of methane production.