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A novel, wireless, automated system for measuring fermentation gas production kinetics of feeds and its application to feed characterization

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Abstract

This study describes a novel automated method of measuring fermentation gas production kinetics of feeds using sensors that intermittently measure the pressure arising from fermentation of feeds within culture bottles, and relays them to a server using a wireless radio frequency (RF) signal. Measurements can be downloaded from the server at any location that has internet access and saved in ASCII or Excel format. Consequently, once the measurement frequency is set, and the incubation commences, there is no need for attention to the system until the end of the fermentation. In order to validate the system, fermentation parameters of three 1 mm ground feeds (i.e., corn grain, dehydrated citrus pulp (DCP), Pensacola bahiagrass hay (*Paspalum notatum*) were determined using the RF sensors and compared to those determined with a digital manometer. A second experiment used both pressure measuring devices to determine fermentation parameters of 1 mm ground bermudagrass hay (*Cynodon dactylon*) treated with an esterase enzyme at 0, 1 and 2 g/100 g DM. Feed samples were incubated in buffered rumen fluid in quadruplicate (Experiment 1) or triplicate (Experiment 2) in 250 ml gas tight culture bottles at 39 °C. Each culture bottle was connected to a pressure sensor with a three-way Luer lock that was secured into a hole in the culture bottle cap. Pressure sensors made hourly pressure measurements to 96 h. A digital manometer was used to take pressure readings from the culture bottles after 0, 2, 4, 6, 8, 12, 24, 48, 60, 72 and 96 h of incubation, and an exponential model was fitted to fermentation gas production data from the sensors and the digital manometer.

Abbreviations: APES, automated pressure evaluation system; DCP, dehydrated citrus pulp; DM, dry matter; DMD, DM digestibility; PTT, pressure transducer technique; RF, radio frequency; RPT, reading pressure technique; VFA, volatile fatty acids

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Fermentation parameters were compared using a factorial (Experiment 1) or completely randomized design (Experiment 2). In both experiments, method of gas pressure measurement did not affect fermentation parameters, and there was no method×feed interaction. In Experiment 1, corn grain and DCP had bigger (P<0.001) gas pool sizes, faster fermentation rates and a longer lag phases than hay. Compared to DCP, corn had a longer (P<0.05) lag phase, similar fermentation rate and a bigger (P<0.01) gas pool size. In Experiment 2, increasing esterase enzyme levels did not affect fermentation rate, but increased (P<0.05) the lag phase and tended (P=0.063) to increase gas pool size. There was a good relationship between RF sensor and manometer-based estimates of gas pool size ($r^2 = 92$), fermentation rate ($r^2 = 83$), and lag phase ($r^2 = 60$). Total measured gas volume correlated to in vitro digestibility ($r^2 = 0.60$) and to stoichiometrically predicted total gas volumes ($r^2 = 0.74$). This study demonstrates the potential of this RF sensor technique to differentiate fermentation kinetics among feeds.

Keywords: Gas production; Fermentation; Digestibility; In vitro

1. Introduction

Animal feeding studies are the most accurate method of feed characterization, but require expensive purpose-built facilities, considerable time, expense and labour, and recently have become less attractive due to animal welfare concerns. Tilley and Terry (1963) and Van Soest et al. (1966) developed in vitro techniques to estimate the digestibility of feeds, which have been instrumental in their characterization for decades. Although they can be adapted to measure digestion kinetics by using different samples for each time point, this greatly increases the number of digestion tubes and increases the labor requirement.

In sacco rumen degradability techniques measure rate and extent of feed degradation but do not account for digestion of small particulate or soluble feed fractions, and they are more invasive than in vitro digestibility techniques. Several gas production monitoring systems to describe kinetics and extent of digestion of feeds, irrespective of particle size or solubility, have been developed (Menke et al., 1979; Pell and Schofield, 1993; Theodorou et al., 1994; Cone et al., 1996; Mauricio et al., 1999; Davies et al., 2000), and of these, the manual volumetric pressure transducer technique of (Theodorou et al., 1994) is one of the more widely used due to simplicity and low cost. However, this method is subject to errors from problems with syringe manipulation, non-simultaneous reading of syringes, visual estimation of volume, temperature fluctuations due to time required for reading and manual recording of data (Mauricio et al., 1999). To overcome some of these problems, Mauricio et al. (1999) developed the reading pressure technique, which uses a semi-automated direct data entry technique. This technique reduced time and potential error of gas measurements, and increased system capacity, but still relies on manually inserting a hand-held pressure transducer into each fermentation flask. The vented (Cone et al., 1996; Davies et al., 2000) and ventless (Pell and Schofield, 1993) fully automated gas production monitoring systems reduce labor, but complexity and cost has limited their adoption.

We describe a simple, relatively inexpensive, automated wireless technique to measure fermentation gas production kinetics and explore its application in feed characterization.