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Application of the gas production technique to feed evaluation systems for ruminants

J. Dijkstra [a,*], E. Kebreab [b], A. Bannink [c], J. France [b], S. López [d]

[a] *Animal Nutrition Group, Wageningen Institute of Animal Sciences, Wageningen University, Marijkeweg 40, 6709 PG Wageningen, The Netherlands*
[b] *Centre for Nutrition Modelling, Department of Animal and Poultry Science, University of Guelph, Guelph, Ontario N1G 2W1, Canada*
[c] *Animal Sciences Group, Nutrition and Food, P.O. Box 65, 8200 AB Lelystad, The Netherlands*
[d] *Department of Animal Production, University of Leon, 24007 Leon, Spain*

Abstract

A range of feed evaluation techniques is available to predict the nutritional value of ruminant feedstuffs. The aim of this paper was to critically evaluate use of gas production (GP) data as inputs to current feed evaluation systems, as well as to mechanistic rumen models. Topics discussed include prediction of rumen degradation of feed, efficiency of microbial synthesis, and the profile of volatile fatty acids (VFA) produced. Derivation of GP models to permit calculation of extent of degradation of organic matter (OM) has been of great value, as well as to reveal assumptions underlying models to analyse GP data. Gas production techniques (GPT) have good potential to predict rumen OM degradation, in particular through provision of kinetic information, but the potential to provide parameters of degradation of OM components seems limited. Optimal use of GP data to predict microbial efficiency and VFA formed is best achieved when the possibilities, and limitations, of batch culture GPT are recognised. The mechanisms governing microbial efficiency and VFA molar proportions in the GPT are not necessarily applicable to in vivo situations. A simple model based on classic microbial growth and substrate utilisation equations for batch cultures is used to illustrate the need to carefully interpret microbial efficiency in batch culture for use in in vivo situations. The profile of VFA in GPTs is only a reflection of the dynamic VFA profile in vivo. Of crucial importance for estimation of OM degradation, microbial efficiency and amount and type of VFA formed is knowledge of the fractional

Abbreviations: GE, gross energy; GIT, gastro-intestinal tract; GP, gas production; GPT, GP technique; OM, organic matter; ME, metabolizable energy; MP, metabolizable protein; NDF, neutral detergent fibre; NDS, neutral detergent soluble; NE, net energy; NGR, non glucogenic to glucogenic VFA ratio; PF, partitioning factor; VFA, volatile fatty acids; Y, yield of gas produced per unit substrate degraded

* Corresponding author. Tel.: +31 317 484082; fax: +31 317 484260.
E-mail address: jan.dijkstra@wur.nl (J. Dijkstra).

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passage rate of ingesta from the rumen. The value of the GPT is greatly enhanced in combination with mechanistic modelling. However, the role of the technique is not in giving direct predictions of nutrient supply.

Keywords: Gas production; Rumen; Mathematical modelling; Microbial efficiency; Substrate degradation

1. Introduction

Ruminants account for almost all of the milk and about one-third of the meat production worldwide (Food and Agriculture Organization, 2004). In view of this substantial contribution to the human food supply, it is not surprising that a great deal of research has been completed on the digestive system of ruminants, making it possible to develop quantitative approaches to increase understanding and integrate its various aspects (Dijkstra et al., 2005). Based on quantitative research, feed evaluation methods were developed for various purposes. Feed evaluation is the use of methods to describe feedstuffs with respect to their ability to sustain different types and levels of animal performance (France et al., 2000b). The practical importance of feed evaluation is obvious with respect to optimising efficiency of feed utilisation, ruminant output and financial return to the producer. Moreover, its importance to minimizing excretion of nutrients to the environment is gaining importance.

To evaluate feedstuffs or diets of ruminants, the feed or diet should ideally be fed to the ruminants of interest and production responses determined. Testing all possible feeds in all possible situations in vivo would clearly provide the most accurate ranking of feedstuffs in terms of nutritive quality, but it is neither practicable nor cost effective. Therefore, a range of feed evaluation techniques have been developed to predict feed value. In current feed evaluation systems worldwide, energy or protein available for absorption from the gastro-intestinal tract (GIT) is generally represented, followed by quantitative approaches to describe the required amounts of energy or protein for maintenance and production. The amount available for absorption from the GIT per unit feed consumed is largely determined by digestibility of the feed. A number of in vitro and in situ techniques have been developed to estimate degradability of feedstuffs in the rumen and their digestion in the whole GIT, including batch culture digestibility with rumen microbial inocula or added enzymes and in situ methods (e.g., López, 2005). Regression equations are applied to predict in vivo digestibility from these in vitro or in situ methods. More recently, rate of degradation of feeds has been studied using gas production (GP) profiles obtained from manual or automated systems of in vitro fermentation of feeds. The popularity of in vitro GP stems mainly from the ability to exercise experimental control, the capacity to non-destructively screen a large number of substrates, the kinetic information obtained and relatively low costs. Several equations have been proposed to describe GP profiles, and France et al. (2005) derived a general compartmental model to link the gas production technique (GPT) output to animal performance. Although a lot of GP data for several feedstuffs are available, these have generally not been incorporated to current feed evaluation systems.