Animal Feed Science and Technology 174 (2012) 119–130

Contents lists available at SciVerse ScienceDirect

Animal Feed Science and Technology

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

Review

A review on the use of indigestible dietary markers to determine total tract apparent digestibility of nutrients in horses

J. Sales*

Department of Nutrition and Feeding of Farm Animals, Institute of Animal Science, Přátelství 815, Uhříněves, 104 00 Prague 10, Czech Republic

ARTICLE INFO

Article history:
Received 9 November 2011
Received in revised form 17 February 2012
Accepted 7 March 2012

Keywords:
Horses
Total tract apparent digestibility
Indigestible markers
Total faecal collection
Review

ABSTRACT

This review was written to summarise knowledge available on the use of markers to determine total tract apparent digestibility in horses, and to quantify differences in estimates obtained between marker techniques and total collection of faeces. Differences were quantified with a unitless standardised effect size (Hedges's *g*) and effect sizes within marker, diet (all-forage, forage and concentrate) and nutrients were combined with random effects models to account for unexplained heterogeneity among experiments. Digestibility of all-forage diets estimated by total faecal collection was not different to measurements obtained with acid detergent insoluble ash, 2 N HCl acid insoluble ash, or the *n*-alkanes C27, C29 and C31. With diets containing forage and concentrate, acid detergent insoluble ash, chromic oxide, indigestible acid detergent fibre, indigestible cellulose or *n*-alkanes presented similar nutrient digestibility coefficients, and 2 N HCl acid insoluble ash higher dry matter digestibility, compared to total faecal collection. Acid detergent lignin resulted in lower apparent digestibility coefficients with both types of diets. However, combined effect sizes for acid detergent insoluble ash and *n*-alkanes were based on 2–3 experiments conducted in few (1–2) studies, and should be interpreted accordingly. It is concluded that acid insoluble ash currently presents the most reliable marker that, with certain precautions, could be applied to determine apparent total tract apparent digestibility in horses.

Contents

Abbreviations: ADF, acid detergent fibre; ADIA, acid detergent insoluble ash; AIA, acid insoluble ash; CI, 95% confidence interval; CP, crude protein; Cr_2O_3, chromic oxide; DM, dry matter; GE, gross energy; HCl, hydrochloric acid; lignin (sa), acid detergent lignin; NDF, neutral detergent fibre; OM, organic matter.

* Tel.: +420 267 009 741; fax: +420 267 710 779.
E-mail address: James_Sales_1@hotmail.com

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doi:10.1016/j.anifeedsci.2012.03.005

1. Introduction

Indigestible markers have found wide application in nutritional research. The diversified use of indigestible dietary markers is also illustrated in research on horse nutrition. Methodology related to markers that are utilised to determine passage rate of digesta through the gastrointestinal tract of the horse have been reviewed by Van Weyenberg et al. (2006). Polyethylene (Hertel et al., 1970), chromic oxide (Cr_2O_3; Hintz et al., 1971; Meyer et al., 1992), lignin (Martin-Rosset et al., 1987; Varloud et al., 2004) and acid insoluble ash (AIA; Varloud et al., 2004) were used to determine digestibility of macro nutrients in different segments of slaughtered horses. Pre-cecal, post-ileal and total tract digestibility in ileal- and cecal-cannulated horses and ponies were estimated with Cr_2O_3 (Reitnour et al., 1969; Gibbs et al., 1988, 1996; Farley et al., 1995; Swinney et al., 1995), lignin (Wolter et al., 1978) and indigestible acid detergent fibre (Alvarenga et al., 1997). A double marker technique, in which total tract digestibility was determined with an internal marker (AIA, indigestible neutral detergent fibre, *n*-alkanes, yttrium) and faecal output was calculated with an external marker (Cr_2O_3, ytterbium), have been applied by some authors to estimate dry matter (DM) intake of grazing horses (Moffitt et al., 1987; Martin et al., 1989; Barbisan et al., 1993; Holland, 1998; Shingu et al., 2000). Composition of browse and herbaceous feeds fed to horses was estimated by Ferreira et al. (2007) with the use of *n*-alkanes.

The use of inert dietary markers to study feed utilisation was proposed as far back as 1874 (Kotb and Luckey, 1972). Compared to the use of markers in digesta passage studies, marker based methods to determine total tract apparent digestibility are relatively undeveloped with horses (Goachet et al., 2009a). The current review aimed firstly to give a description of methodologies used when indigestible dietary markers were applied to calculate total tract apparent digestibility of nutrients in horses. A second aim was to quantify differences in estimates between marker techniques and the method of total faecal collection.

2. Total faecal collection

Quantifying of feed intake and total collection of faeces are considered to be the most accurate to determine total tract apparent digestibility in horses (Schurg, 1981; Bergero et al., 2009). However, this technique is time consuming, laborious, and restricts the number of animals per experiment (Schurg, 1981). Furthermore, it involves confinement of animals to stables or crates. Whereas confinement is accepted by some horses for short periods, exercise is essential for horses fed on large amounts of high-energy feeds (Frape et al., 1982). Other disadvantages of constant confinement included a possible influence on metabolism, as has been demonstrated in sheep (Bowers et al., 1993), and difficulties to justify it from an animal welfare perspective.

Accurate measurement of feed intake and precise collection of all faeces are demanding tasks (Sales and Janssens, 2003a). Over the years different equipment has been developed to accurately collect all faeces excreted by horses, such as a harness and bag-type collection apparatus (Friend and Nicholson, 1965), an equine metabolism stall and collection units that allow for separate collections of faeces and urine (Vander Noot et al., 1965), and an automatic device for daily collection of faeces based on rotating containers (Letourneau et al., 1974). However, these devices need constant attention for proper functioning (Vander Noot et al., 1965). They also increase costs because of additional special equipment and labour, and horses need to be adapted to devices. Some horses never adjust to harnesses (Parkins et al., 1982). Furthermore, large quantities of faeces have to be processed and stored (Takagi et al., 2002).

Time periods for total collection of faeces during digestibility measurements varied from 3 (*e.g.* Lindberg et al., 2006) to 10 days (*e.g.* Smolders et al., 1990). Martin-Rosset et al. (1984) recommended a 6-day collection period after 14 days of adaptation, whereas the Kentucky Equine Research Center (USA) has adopted an adjustment period of 3 weeks followed by total faecal collection for 5 days (Pagan, 1998). With pelleted and meal diets that contained 500 g/kg lucerne hay, Hintz and Loy (1966) found no differences in DM or crude protein (CP) digestibility coefficients (or standard deviations) when the period of faeces collection decreased from 7 to 3 days. This concurs with 3 consecutive days of collection recommended by Goachet et al. (2009a) to determine apparent digestibility of DM, organic matter (OM) and fibre fractions. However, digestibility of crude fat in the study by Hintz and Loy (1966) stabilised only after 4 days of collection. The above suggestions of a shortened faecal collection period is in contrast to Araújo et al. (2003), who, based on faecal collections of 2–7 days, recommended a 5-day collection period when diets either contained exclusively forage, or when forage is fed together with concentrate.

3. Indigestible dietary markers

Calculation of digestibility by the ratio of an indigestible substance (marker) in the feed and faeces would permit periodic collection of a representative sample of faeces instead of collection of all faeces. This would enable minimum changes in the daily management of horses, especially those who are exercised (Goachet et al., 2009a). Sales and Janssens (2003a,b) stated that a marker has to satisfy the following: (1) non-toxic; (2) unaltered during its passage through the digestive system; (3) no influence on the physiological processes in the digestive tract; (4) closely associated to the undigested nutrient in question or flowing at an identical rate as the nutrient; and (5) totally recovered in the faeces. Several studies that have used markers to determine total tract apparent digestibility of diets in horses are presented in Table 1.