How to evaluate the degradation of feedstuffs for ruminants? Comparison of the gas-test and in situ methods from a literature review

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How to evaluate the degradation of feedstuffs for ruminants? Comparison of the gas-test and *in situ* methods from a literature review

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SUMMARY – Based on bibliographical data, the aim of this study was to compare 2 methods estimating the ruminal degradation of feedstuffs: the *in vitro* gas production method (HFT) and the nylon bag *in situ* method. Most of the 299 retained samples were either browses and pastures or straws. *In vitro* gas production and *in situ* dry matter degradability were quite highly correlated for a given duration of time, as the correlation coefficient varies between 0.49 and 0.64. However, the HFT was less discriminating in the first hours and underestimated feeds rich in nitrogen or in lignin. *In vivo* dry matter digestibility can be predicted from long term *in situ* dry matter degradability and voluntary dry matter intake from short-term gas production. Voluntary digestible dry matter intake is a function of medium and long term *in situ* degradability. It is concluded that the 2 methods give similar hierarchy for the feedstuffs considered and are complementary to estimate their nutritive value.

Keywords: Gas-test, *in situ*, browses, pastures, feedstuffs, ruminants.

RESUME – *"Comment évaluer la dégradation des aliments chez les ruminants? Comparaison des techniques de gaz et* in situ*". En s'appuyant sur des données bibliographiques, la présente étude a pour objectif la comparaison de 2 méthodes estimant la dégradation ruminale des aliments : la méthode de production de gaz (HFT) et la méthode* in situ *des sachets de nylon. Les 299 échantillons retenus étaient, pour la plupart, soit prélevés sur pâturages ou parcours, soit des pailles. La production de gaz* in vitro *et la dégradabilité* in situ *sont assez bien corrélées entre elles pour une durée d'incubation donnée, puisque le coefficient de corrélation varie entre 0,49 et 0,64. Cependant, la HFT est moins discriminante à court terme et sous-estime les aliments riches en azote ou en lignine. La digestibilité* in vivo *de la matière sèche peut être estimée à partir de la dégradabilité* in situ *à long terme et la matière sèche volontairement ingérée par la production de gaz à court terme. La matière sèche volontairement ingérée digestible dépend à la fois des dégradabilités* in situ *à moyen et long termes. En conclusion, les 2 méthodes donnent des hiérarchies comparables pour les aliments considérés et sont complémentaires pour estimer leur valeur nutritive.*

Mots-clés : *Gaz-test,* in situ*, parcours, pâtures, aliments, ruminants.*

Introduction

Predicting the feeding value of feedstuffs as accurately as possible and with methods of low cost and easy to handle is an important economical target. This goal is of particular importance for grazing and browsing ruminants that valorize local resources often of low and variable nutritive value. Chemical composition can give an idea of the nutritive value of feeds, but it is not sufficient (Krishnamoorthy *et al.*, 1995). Biological methods involving microorganisms and enzymes that are sensitive to factors influencing the rate and extent of digestion seem more appropriate in this case than chemical methods. Among them, the most popular are the *in situ* dry matter degradability (Mehrez and Ørskov, 1977) and the gas-test method (HFT) proposed by Menke *et al.* (1979) which is quite reproducible (Getachew *et al.*, 2002).

The aim of this paper is to compare these two methods on a great number of samples originating from browses and pastures coming from all around the world and to evaluate their relative potential as ruminants fed on. To face this question, we used a bibliographic approach and compiled papers with both HFT and *in situ* data measured at least over 72 h, because feeds of low nutritive value that have a quite long retention time in the digestive tract need to be evaluated with such durations.

Material and methods

The retained papers contained measurements with both HFT and *in situ* methods performed in the same samples. For a given sample, data should be available for durations between 8 and 72 hours. Some data were calculated from the models proposed by the authors and in other cases, we adjusted parameters with the model usually proposed (Ørskov and McDonald, 1979).

We retained 27 papers: Ørskov *et al.*, 1988; Carro *et al.*, 1991; Blümmel and Ørskov, 1993; Khazaal *et al.*, 1993; Kibon and Ørskov, 1993; Siaw *et al.*, 1993; Khazaal *et al.*, 1994; Bonsi *et al.*, 1995; Khazaal *et al.*, 1995; Susmel *et al.*, 1995; Nsahlai and Umunna, 1996; Tuah *et al.*, 1996; Djouvinov *et al.*, 1997; Keir *et al.*, 1997; Salawu *et al.*, 1997a; Salawu *et al.*, 1997b; Tolera *et al.*, 1997; Apori *et al.*, 1998; Larbi *et al.*, 1998a; Larbi *et al.*, 1998b; Shen *et al.*, 1998; Tolera *et al.*, 1998; Tolera and Sundstol, 1999; Abdulrazak *et al.*, 2000; Ben Salem *et al.*, 2000; El-Hassan *et al.*, 2000; Lavrencic and Stefanon, 2001; Melaku *et al.*, 2003. The data set comprised 299 samples coming from three continents (Africa, Europe and Asia) covering important forages of these continents. Most of them were either browses and pastures or straws. It also included all the data available concerning chemical composition or *in vivo* measurements (dry matter digestibility and voluntary intake).

Results and discussion

Comparison between gas production and *in situ* dry matter degradability

We retained the 5 durations most often used: 8, 12, 24, 48 and 72 hours. Table 1 pointed out the variability between samples observed for gas production and *in situ* dry matter degradability:

Table 1. Statistics for gas production (GP) and *in situ* dry matter degradability (DMdeg) data

	Mean	Standard deviation	Minimum	Maximum	Variation coefficient
GP (ml/200mg)					
8 h	14	7.7	2.1	43.3	55.0
12 h	20	9.6	3.8	51.4	48.0
24 h	31	12.5	6.8	65.8	40.3
48 h	39	13.5	7.6	75.3	34.6
72 h	42	13.6	7.5	75.9	32.4
DMdeg (%)					
8 h	39	15.9	6.1	76.7	40.8
12 h	44	16.9	9.4	81.9	38.4
24 h	55	18.0	14.6	92.1	32.7
48 h	64	16.9	20.6	94.1	26.4
72 h	67	15.9	23.9	94.8	23.7

The *in situ* dry matter degradability and the *in vitro* gas production were quite highly correlated whatever the duration time considered, especially when taking into account that data came from several teams that never standardized their methods altogether:

GP 8 h = - 2.4 + 0.310 Dmdeg 8 h	(n = 299, r = 0.64, RSD = 5.9 ml)
GP 12 h = 4.7 + 0.350 Dmdeg 12 h	(n = 299, r = 0.62, RSD = 7.6 ml)
GP 24 h = 8.6 + 0.402 Dmdeg 24 h	(n = 299, r = 0.58, RSD = 10.2 ml)
GP 48 h = 12.6 + 0.417 Dmdeg 48 h	(n = 299, r = 0.52, RSD = 11.5 ml)
GP 72 h = 14.3 + 0.416 Dmdeg 72 h	(n = 299, r = 0.49, RSD = 11.9 ml)

As duration increased, the intercept and the slope of the regression increased. These results were in agreement with those observed on a data set including feedstuffs of better nutritive value (Giger-Reverdin *et al.*, 2000). This means that the *in situ* method is more discriminating than the HFT one in

the short and medium term degradation. Precision of the prediction decreased as duration increased. This can be explained by a distortion between methods increasing with time.

In order to better understand discrepancies between methods, we looked into the residual of the equation. It seemed that part of the residual variation was explained by crude protein (CP) and lignin content (ADL) expressed as g/kg DM when these data were available:

GP 8 h = 7.8 + 0.321 DMdeg 8 h – 0.0168 CP – 0.0392 ADL (n = 145, r = 0.67, RSD = 5.5 ml)
GP 12 h = 16.2 + 0.300 DMdeg 12 h – 0.0208 CP – 0.0675 ADL (n = 145, r = 0.65, RSD = 6.7 ml)
GP 24 h = 25.8 + 0.360 DMdeg 24 h – 0.0344 CP – 0.112 ADL (n = 145, r = 0.69, RSD = 8.4 ml)
GP 48 h = 41.7 + 0.273 DMdeg 48 h – 0.0422 CP – 0.158 ADL (n = 145, r = 0.69, RSD = 8.9 ml)
GP 72 h = 47.0 + 0.255 DMdeg 72 h – 0.0501 CP – 0.170 ADL (n = 145, r = 0.69, RSD = 9.1 ml)

Both crude protein and lignin contents had negative coefficients: HFT method underestimates feedstuffs with either high protein or high lignin contents. For protein, this can be explained by less gas being directly produced by protein fermentation compared to that of carbohydrates, and by the lack of indirect gas production as CO_2 released from the bicarbonate buffer to neutralize the production of VFA (Getachew *et al.*, 1998). These results were in agreement with those by Chenost *et al.* (2001). The increase in the coefficient of lignin might be explained by the loss of unfermentable residue from the nylon bag (Dewhurst *et al.*, 1995). The great difference between the HFT and *in situ* methods is that the HFT measures the production of gas due to the fermentation of feedstuffs in a nutritive medium and in the *in situ* method all the material passing through nylon bag pores is considered as degraded, even if it was not fermented. The data set did not allow to statistically point out some anti-nutritional factors such as tannins or phenolic compounds (Getachew *et al.*, 1998).

Interest and limits of gas production and *in situ* dry matter degradability to predict the nutritive value of feedstuffs

Three parameters were retained to express the nutritive value: *in vivo* dry matter digestibility (DMD), voluntary dry matter intake (VDMI) and voluntary digestible dry matter intake (VDDMI).

In vivo dry matter digestibility was available in 97 samples. It varied from 34.3 to 75.0% with a mean value of 54.9 (±8.5). The highest correlation was obtained between *in vivo* dry matter digestibility and *in situ* 72 h dry matter degradability:

DMD = 28.1 + 0.413 DMdeg72 h (n = 97, r = 0.62, RSD = 6.6%)

This result is in agreement with those by Khazaal *et al.* (1995) and Carro *et al.* (2002).

Voluntary dry matter intake (VDMI) varied from 9.6 to 40.6 g/kg LW for the data available in 73 samples. Its mean value was of 21.6 (±6.8) g/kg LW. Its variations were explained by the medium terms of gas production:

VDMI = 21.9 + 1.11 GP 8 h - 0.757 GP 12 h (n = 73, r = 0.55, RSD = 5.8 g/kg LW)

The values of the coefficients have to be taken with caution as GP 8 h and GP 12 h were highly correlated (r = 0.88, n = 73). VDMI is linked to the space left in the rumen or, in other words, to the fill value of feeds. It makes sense that VDMI is linked to the short time degradation and this agreed with other observations (Blümmel *et al.*, 1997; Getachew *et al.*, 1998), but not with those by Khazaal *et al.* (1993) or Carro *et al. (*2002).

Voluntary digestible dry matter intake (VDDMI) is a very important parameter as it expresses the quantity of digestible feed ingested by the animal and it is often the most limiting factor in harsh conditions. It varied from 3.9 to 30.5 g/kg LW, with a mean value of 12.1 (±5.4) g/kg LW.

VDDMI = 5.65 + 1.48 DMdeg72 h - 1.66 DMdeg48 h + 0.523 DMdeg12 h
(n = 73, r = 0.57, RSD = 5.8 g/kg LW)

VDDMI was correlated to medium and long-term parameters, as it is the result of digestibility and intake. These results are in agreement with the bibliography (Chenost *et al.*, 2001).

Conclusions

It is concluded that the HFT and the *in situ* methods were correlated and thus gave similar hierarchy between feedstuffs, even if they did not have exactly the same nutritional meaning. Long-term gas production is the best predictor for *in vivo* dry matter digestibility and the combination of *in situ* dry matter degradability in the medium and long terms are the best predictors for voluntary dry matter intake.

Thus, the HFT method is complementary to the *in situ* method and their combination seemed of great interest to predict the nutritive value of browses, pastures and straws that were the basis for this study and which can sustain part of livestock production, especially in tropical areas.

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