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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 prélévés 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

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

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:

\[
\begin{align*}
\text{GP 8 h} &= -2.4 + 0.310 \text{DMdeg 8 h} \\
\text{GP 12 h} &= 4.7 + 0.350 \text{DMdeg 12 h} \\
\text{GP 24 h} &= 8.6 + 0.402 \text{DMdeg 24 h} \\
\text{GP 48 h} &= 12.6 + 0.417 \text{DMdeg 48 h} \\
\text{GP 72 h} &= 14.3 + 0.416 \text{DMdeg 72 h}
\end{align*}
\]

(n = 299, r = 0.64, RSD = 5.9 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:

\[
\begin{align*}
GP_{8\,h} &= 7.8 + 0.321 \, \text{DMdeg}\,8\,h - 0.0168 \, \text{CP} - 0.0392 \, \text{ADL} \quad (n = 145, \, r = 0.67, \, \text{RSD} = 5.5 \, \text{ml}) \\
GP_{12\,h} &= 16.2 + 0.300 \, \text{DMdeg}\,12\,h - 0.0208 \, \text{CP} - 0.0675 \, \text{ADL} \quad (n = 145, \, r = 0.65, \, \text{RSD} = 6.7 \, \text{ml}) \\
GP_{24\,h} &= 25.8 + 0.360 \, \text{DMdeg}\,24\,h - 0.0344 \, \text{CP} - 0.112 \, \text{ADL} \quad (n = 145, \, r = 0.69, \, \text{RSD} = 8.4 \, \text{ml}) \\
GP_{48\,h} &= 41.7 + 0.273 \, \text{DMdeg}\,48\,h - 0.0422 \, \text{CP} - 0.158 \, \text{ADL} \quad (n = 145, \, r = 0.69, \, \text{RSD} = 8.9 \, \text{ml}) \\
GP_{72\,h} &= 47.0 + 0.255 \, \text{DMdeg}\,72\,h - 0.0501 \, \text{CP} - 0.170 \, \text{ADL} \quad (n = 145, \, r = 0.69, \, \text{RSD} = 9.1 \, \text{ml}) 
\end{align*}
\]

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:

\[
\begin{align*}
\text{DMD} &= 28.1 + 0.413 \, \text{DMdeg}\,72\,h \quad (n = 97, \, r = 0.62, \, \text{RSD} = 6.6\%) \\
\end{align*}
\]

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:

\[
\begin{align*}
\text{VDMI} &= 21.9 + 1.11 \, \text{GP}\,8\,h - 0.757 \, \text{GP}\,12\,h \quad (n = 73, \, r = 0.55, \, \text{RSD} = 5.8 \, \text{g/kg LW}) \\
\end{align*}
\]

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.

\[
\begin{align*}
\text{VDDMI} &= 5.65 + 1.48 \, \text{DMdeg}\,72\,h - 1.66 \, \text{DMdeg}\,48\,h + 0.523 \, \text{DMdeg}\,12\,h \\
& \quad (n = 73, \, r = 0.57, \, \text{RSD} = 5.8 \, \text{g/kg LW}) \\
\end{align*}
\]

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 browse, pastures and straws that were the basis for this study and which can sustain part of livestock production, especially in tropical areas.

References


