Aus dem Institut für Pflanzenbau und Grünlandwirtschaft

Christian Paul
Horst Auerbach
Gerd-Joachim Schild

Intake of legume silages by sheep

Manuskript, zu finden in www.fal.de

Published in: Landbauforschung Völkenrode Sonderheft 234, pp. 33-38

Braunschweig
Bundesforschungsanstalt für Landwirtschaft (FAL)
2002
Intake of legume silages by sheep

Christian Paul 1, Horst Auerbach 2 and Gerd-Joachim Schild 1

Abstract

A feed evaluation study on prewilted silages prepared from lucerne (Medicago sativa L.), red clover (Trifolium pratense L.), goats rue (Galega orientalis Lam.), birds foot trefoil (Lotus corniculatus L.) with perennial ryegrass (Lolium perenne L.) as a control involved the assessment of intake and organic matter digestibility by sheep. In order to permit general conclusions to be drawn each of these species was represented in the experiment by five to seven independent forages harvested in different physiological stages over two years.

Silage intake increased with increasing organic matter digestibility but the relationships differed between forage species. Silage intake was higher for lotus than for any other legume, i.e. red clover, lucerne and galega. Intake of grass silage was inferior to all of the legume silages. Calculated for a level of 65% digestibility of the organic matter, dairy cows are predicted to ingest silages prepared from a) lotus, b) red clover, lucerne and galega and c) grass at rates of 122, 116 and 100 g dry matter per kg metabolic weight respectively. Based on the laboratory assessment of these silage samples it was confirmed that the intake of silages was most closely associated with their content of total cell wall and enzymatically insoluble organic matter.

Introduction

Forage quality as defined by both forage intake and digestibility is of primary importance in the accurate economic evaluation of forage legumes and their consideration in diet formulation for ruminants. Lack of sufficient reliable in vivo data is a limiting factor and often results in the necessity to estimate these characteristics by indirect means. In particular, comparison of different forage species tends to be hampered by the interaction between effects of species and physiological growth stage. The picture gets even more complicated when additional factors introduced by the ensiling process have to be considered, so that precise comparative assessments of forage species and varieties independent of the effects of cutting and ensiling treatments can not be obtained from the available literature.

The work presented here has attempted to resolve these problems by a special feed evaluation experiment which combined the standard assessment of in vivo digestibility at restricted feeding levels with consecutive assessment of dry matter intake at ad libitum feeding levels. The decision to carry out this experiment with sheep permitted the evaluation of a relatively large number of samples at reasonable costs. It is an integral part of the series of feed evaluation studies in LEGSIL.

Materials and methods

Choice, cultivation, harvesting and ensiling of forages

In 1997 and 1998 forage plots of more than 0.5ha size each were established at the FAL experimental station of Braunschweig-Voelkenrode. The forage legume species chosen (cultivars in brackets) were lucerne Medicago sativa L. (Planet), red clover Trifolium pratense L. (Maro), goats rue Galega orientalis Lam. (Gale), birds foot trefoil Lotus corniculatus L. (Leo). Perennial ryegrass Lolium perenne L. was used as a standard. For each individual forage species several samples spanning a range of physiological growth stages were cut in the first or second harvest years of 1998 and 1999. Thus the following number of samples became available (numbers of samples in brackets): lucerne (n=5), red clover (n=5), galega (n=6), lotus (n=7), grass (n=6). The crops were cut at heights of 8 cm (legumes) or 5 cm (grass) by a rotary mower. For speeding up prewitting, the forages were conditioned by means of a crusher employing rubber rollers (Krone Company, Germany). When dry matter contents in the field had reached above 28 %, the pre-wilted forages were picked up, chopped to a theoretical chop length of 15mm and transported to the barn. During the subsequent mechanical mixing of 1.5 t quantities of fresh herbage by means of a feeding wagon, the chemical additive Kofasil liquid was admixed at a rate of 3 l per t herbage. The forage thus treated was filled into plastic bins of 200 l volume, compacted and closed air tight for ensiling.

1 Institute of Crop and Grassland Science, Federal Agricultural Research Centre (FAL), Bundesallee 50, D-38116 Braunschweig, Germany,
2 Present address: Fa. Roethel GmbH, Schwänheid 10, 34281 Gudensberg
Feeding trials

After the end of the fermentation process, i.e. 5 - 6 months after filling, the silages were unloaded and single feeds from all silos holding one particular type of forage produced by mixing through a feeding wagon. The feeds were then subdivided so that each representative subsample formed a daily ration. These were then stored in a large freezer below -18°C until required for feeding.

For the feeding trials a total of 24 sheep wethers of the Leine Valley breed of 4 – 5 years of age and 80 to 100kg liveweight were available. The trials were conducted so that for each animal and forage a digestibility trial (18 days) was followed by an intake trial (10 days). In the standard digestibility trial the forages were provided at maintenance level (13 ± 2 g silage-DM per kg liveweight per day). During the 10 days adaptation period the animals were kept tied and only confined in metabolism cages for faeces collection for the subsequent 8 days trial. In the following intake trial, the feeding level was raised to twice the maintenance level and provided *ad libitum*. In this case, the average dry matter intake was calculated from refused feed collection over 8 days, following an adaptation period of 2 days.

The experiment was designed as a Latin square with the forages being tested in each of 2 years in 2 randomly stocked pools of animals consisting of 10 animals each. In each year and pool 5 silages were given simultaneously to 5 animal groups (consisting of two animals each) over 5 consecutive feeding periods. In addition to the 20 forages tested according to this design, a further 9 forages were tested in the final year using a reduced number of animals. In this case the animals were randomly grouped to form pools of 6 animals each. In each pool 3 silages were given to 3 animal groups (consisting of two animals each) over 3 consecutive feeding periods.

Silage analysis

The silage samples were analysed according to the catalogue of routine analytical methods established at the former Institute of Grassland and Forage Research and maintained by the present Institute of Crop and Grassland Science (FAL) for a number of characteristics relating to nutrient content and nutrient availability as well as silage quality. These included:

- Dry matter content corrected for volatiles lost during drying (DMc)
- Crude protein and crude fibre according to the Weende fractionation scheme
- Cell wall content assessed according to van Soest as neutral detergent fibre (NDF)
- Digestibility of organic matter *in vitro* according to Tilley and Terry (OMD T and T)
- Content of enzyme insoluble organic matter (EULOS) assessed according to a modification of the procedure developed by de Boever
- pH – value assessed by electrode (pH)
- Fermentation products all separated by gas chromatography but expressed as lactic acid (LA); summed acetic acid and propionic acid (AA); summed butyric acid, valeric acid and caproic acid (BA)
- Ammonia nitrogen (assessed by electrode) as a proportion of total nitrogen at the time of ensiling (NH₃-N)
- Silage quality index (DLG index points) evaluated according to the current scheme approved by the DLG (Deutsche Landwirtschafts Gesellschaft / German Agricultural Society).

Results and discussion

Characterisation of silages

A minimum number of five different forage samples of different physiological age were produced to represent each particular legume species (and perennial ryegrass, constituting the control). Technological measures to ensure minimal ensiling losses and good preservation included prewilting of the forage in the field and use of a chemical additive to speed up acidification in the ensiling process. With the possible exception of one galega sample which exhibited a DM content of only 20.7%, the average DM contents of the silages achieved across species of between 31% to 35% indicated that prewilting had proceeded to a sufficient degree and given silages in the target DM range (Table 1).

Table 1:
Dry matter content (DMc) of silage samples

<table>
<thead>
<tr>
<th>Species</th>
<th>N</th>
<th>Silage DMc %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
</tr>
<tr>
<td>Lucerne</td>
<td>5</td>
<td>33.7</td>
</tr>
<tr>
<td>Red clover</td>
<td>5</td>
<td>33.5</td>
</tr>
<tr>
<td>Galega</td>
<td>6</td>
<td>31.5</td>
</tr>
<tr>
<td>Lotus</td>
<td>7</td>
<td>31.8</td>
</tr>
<tr>
<td>Grass</td>
<td>6</td>
<td>34.8</td>
</tr>
</tbody>
</table>
As judged by the final pH of the silages, acidification in the different forages during ensiling had progressed to a variable extent. Lotus and red clover had reached low mean pH-values of pH 4.2 to 4.3 and as such similar values to grass. Lucerne, however, remained considerably above this level with a pH of 4.9 (Table 2) and galega was intermediate with a pH-value of 4.6.

Table 2:
Acidity and fermentation products of silage samples

<table>
<thead>
<tr>
<th>Species</th>
<th>pH</th>
<th>LA *</th>
<th>AA *</th>
<th>BA *</th>
<th>NH₃-N**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lucerne</td>
<td>4.9</td>
<td>7.6</td>
<td>5.3</td>
<td>.01</td>
<td>15.4</td>
</tr>
<tr>
<td>Red clover</td>
<td>4.3</td>
<td>12.1</td>
<td>4.0</td>
<td>.01</td>
<td>8.0</td>
</tr>
<tr>
<td>Galega</td>
<td>4.6</td>
<td>6.6</td>
<td>3.7</td>
<td>.02</td>
<td>10.2</td>
</tr>
<tr>
<td>Lotus</td>
<td>4.2</td>
<td>9.6</td>
<td>2.5</td>
<td>.01</td>
<td>7.2</td>
</tr>
<tr>
<td>Grass</td>
<td>4.2</td>
<td>9.3</td>
<td>2.6</td>
<td>.02</td>
<td>10.6</td>
</tr>
</tbody>
</table>

* % of DMc  
** % of total N at ensiling

This pattern was associated with lucerne having a low content of lactic acid (LA) and the highest content of acetic acid (AA) compared to all other silages. Butyric acid (BA) did not cause any concern in either legume or grass silages. Protein decomposition as indicated by the proportion of the total forage nitrogen converted to ammonia nitrogen (NH₃-N) was highest for lucerne which appeared to be causally linked to the lower degree of acidification during the ensiling of this species. Despite higher absolute protein contents in red clover, lotus and galega (data not shown) as compared to grass, the silage prepared from these legume species exhibited lower or equal proportions of nitrogen converted to ammonia.

The silages prepared from lotus and red clover forage were excellent as assessed according to the current silage quality evaluation scheme of the German Agricultural Society (DLG index points). In approaching the top score of 100 they were on average equal or better than silages prepared from grass. Galega silage had a slightly reduced average quality index which was, however, due to one particular sample achieving only a score of 42. Obvious problems were notable for lucerne silage with an average score of 60 and even the best lucerne silage had a score of only 81 points.

Table 3:
Silage quality expressed according to DLG index points

<table>
<thead>
<tr>
<th>Species</th>
<th>Mean</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lucerne</td>
<td>60</td>
<td>35</td>
<td>81</td>
</tr>
<tr>
<td>Red clover</td>
<td>93</td>
<td>88</td>
<td>98</td>
</tr>
<tr>
<td>Galega</td>
<td>85</td>
<td>42</td>
<td>97</td>
</tr>
<tr>
<td>Lotus</td>
<td>98</td>
<td>94</td>
<td>100</td>
</tr>
<tr>
<td>Grass</td>
<td>93</td>
<td>89</td>
<td>100</td>
</tr>
</tbody>
</table>

Feed evaluation of silages

The experimental procedure for measuring digestibility in vivo followed the standard procedure. However, the experiment design was intended to minimise the experimental error by more than customary replication and randomisation, i.e. feeding of each silage sample over several consecutive feeding periods to a minimum of 6 animals (9 feeds) and to 10 animals for most feeds (20 feeds).

As shown in Table 4 these measurements resulted in organic matter digestibility (OMD) values of more than 70% only for red clover (and for grass silage as a control). Lotus silage reached almost 66% and lucerne and galega silage both had mean OMD values of about 64%.

Table 4:
Organic matter digestibility in vivo (%) in silage samples

<table>
<thead>
<tr>
<th>Species</th>
<th>Mean</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lucerne</td>
<td>64.1</td>
<td>57.5</td>
<td>74.3</td>
</tr>
<tr>
<td>Red clover</td>
<td>70.7</td>
<td>61.3</td>
<td>77.8</td>
</tr>
<tr>
<td>Galega</td>
<td>63.5</td>
<td>56.4</td>
<td>72.0</td>
</tr>
<tr>
<td>Lotus</td>
<td>65.9</td>
<td>58.4</td>
<td>70.2</td>
</tr>
<tr>
<td>Grass</td>
<td>71.7</td>
<td>62.8</td>
<td>81.1</td>
</tr>
</tbody>
</table>

Turning to the dry matter intake (DMI) of the silages under study it is notable that the grass silage samples, despite having the highest OMD values in the experiment, were clearly inferior to the silages prepared from legumes (Table 5). On average the daily DMI of grass silage by an individual sheep was only 1.7 kg whereas that of the silage from any of the legume species was above or equal to 2.0 kg. There appeared to be an ascending order in terms of legume silage DMI starting with galega, continuing with
lucerne and red clover and with lotus reaching the highest level.

Table 5:
Dry matter intake of silage samples (kg dry matter per day per animal)

<table>
<thead>
<tr>
<th>Species</th>
<th>Mean</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lucerne</td>
<td>2.1</td>
<td>1.7</td>
<td>2.4</td>
</tr>
<tr>
<td>Red clover</td>
<td>2.2</td>
<td>1.7</td>
<td>2.6</td>
</tr>
<tr>
<td>Galega</td>
<td>2.0</td>
<td>1.7</td>
<td>2.2</td>
</tr>
<tr>
<td>Lotus</td>
<td>2.3</td>
<td>2.2</td>
<td>2.5</td>
</tr>
<tr>
<td>Grass</td>
<td>1.7</td>
<td>1.2</td>
<td>2.0</td>
</tr>
</tbody>
</table>

In order to be able to assess whether these seemingly small differences between legume species in DMI are caused by factors relating to the characteristics of a particular species or to its particular physiological growth stage at the time of harvest, DMI was studied as a function of OMD by means of simple linear regression analysis. The result is shown in Figure 1. A picture emerges which shows that at any given OMD, sheep ingest higher quantities of lotus silage than of silage prepared from either red clover, lucerne or galega. And – as stated before – grass silage, irrespective of its particular OMD level, results in the lowest levels of ingestion by sheep. Employing the simplest possible regression model y = a + bx each of these relationships is characterised mathematically by the regression coefficients given in Table 6. The coefficients of determination (RSQ) for the two legume groups indicate that 71% of the observed variation in intake for lotus and 86% of the observed variation in intake for red clover, lucerne and galega are explained by OMD alone. With regard to grass less than 50% of the observed variation in intake is explained by OMD.

Table 6:
Results of simple linear regression of organic matter digestibility in vivo (x) on kg dry matter intake per day and animal (y) in three groups of silage samples

<table>
<thead>
<tr>
<th>Silage group</th>
<th>Samples within group (n)</th>
<th>Regression coefficients</th>
<th>RSQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lotus</td>
<td>7</td>
<td>0.04</td>
<td>-0.29</td>
</tr>
<tr>
<td>Red clover, Lucerne, Galega</td>
<td>16</td>
<td>0.03</td>
<td>-0.23</td>
</tr>
<tr>
<td>Grass</td>
<td>6</td>
<td>0.03</td>
<td>-0.57</td>
</tr>
</tbody>
</table>

Figure 1:
Dry matter intake (DMI; kg DM per day per animal) as a function of organic matter digestibility in vivo (OMD) in three groups of silage samples prepared from a) lotus, b) red clover, lucerne and galega and c) grass.
Utilizing these intake data an effort was undertaken to predict dairy cattle intake from them. Research at the Centre de Recherches Zootechniques et Vétérinaires at INRA Theix in France permits prediction of g dry matter ingested per kg of metabolic weight by dairy cows from data with sheep (Chenost and Demarquilly, 1982). The corresponding equation is assumed to be valid for the relationship between “standard” sheep (castrated Texel rams of 1.5 to 3 years of age at about 60 kg liveweight) and dairy cows of 600kg liveweight producing 17 kg of milk. Even if these conditions were not quite in agreement with those of the sheep trials conducted here, the resulting predicted dairy cattle intake values can certainly be assumed to provide a fair illustration of the relative intakes by dairy cows. Calculated for a level of 65% digestibility of the organic matter, dairy cows are thus predicted to ingest silages prepared from a) lotus, b) red clover, lucerne and galega and c) grass at rates of 122, 116 and 100 g DM per kg metabolic weight respectively.

Feed factors influencing organic matter digestibility and dry matter intake

In any feed evaluation experiment, aside from the obvious factors under study such as the effect of species and physiological growth stage, typical constraints such as methods of harvesting and conditioning, ensiling and feeding may also influence the results obtained. In the experiment reported here a large number of quality characteristics were assessed in the laboratory. From among them only those which have been noted in previous studies to be linked with either OMD or DMI or both have been selected for discussion here. Furthermore, as cell wall content and cell wall composition are known to differ between forage legumes and grass, an attempt has been made to establish the relationships between either OMD or DMI and the results of laboratory analyses separately for legumes only and for the total set of forages under study here, i.e. legumes and grasses.

Table 7:
Simple linear correlation coefficients (r ) for the relationships between OMD (y) and diverse quality characteristics in silage samples

<table>
<thead>
<tr>
<th></th>
<th>Legumes +Grass</th>
<th>Legumes only</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMc</td>
<td>-.43</td>
<td>-.55</td>
</tr>
<tr>
<td>Crude protein</td>
<td>+.18</td>
<td>+.62</td>
</tr>
<tr>
<td>Crude fibre</td>
<td>-.83</td>
<td>-.93</td>
</tr>
<tr>
<td>NDF</td>
<td>-.59</td>
<td>-.92</td>
</tr>
<tr>
<td>OMD T and T</td>
<td>+.89</td>
<td>+.95</td>
</tr>
<tr>
<td>EULOS</td>
<td>-.93</td>
<td>-.98</td>
</tr>
</tbody>
</table>

According to the data shown in Table 7, OMD appears to be influenced only by the forage cell wall fraction, i.e. either as indicators of cell wall content or of cell wall digestibility. A much lower, in this case negative, influence is exerted by DM content. This finding would be surprising in grazed fresh forage but not so much in prewilted silage. Obviously, the final DM content after prewiling in this study still tended to be higher in silage from late cuts with lower OMD than in silage from early cuts with higher OMD. The content of crude protein is positively associated with OMD, but the relationship is less close in the mixed grass/legume sample set as compared to legumes only. The intensity of the negative association between OMD and either crude fibre or neutral detergent fibre content is similar in the legume samples. However, when grass is included in the sample set, the correlation coefficient for this relationship is much lower for NDF than for crude fibre. As to be expected, parameters such as in vitro digestibility correlate most strongly with OMD in vivo irrespective of whether the mixed grass/legume sample set or the legume only sample set is considered or whether the procedure is based on rumen fluid (Tilley and Terry) or the enzymatic EULOS assay (a modification of the cellulase procedure according to de Boever). The fact that the signs of the correlation coefficients are reversed between the two in vitro methods is due to the fact that the results in one case are expressed as digestibility percentage (Tilley and Terry) and in the other case as content of enzymatically insoluble organic matter (EULOS).

Table 8:
Simple linear correlation coefficients (r ) for the relationships between DMI (y) and diverse quality characteristics in silage samples

<table>
<thead>
<tr>
<th></th>
<th>Legumes +Grass</th>
<th>Legumes only</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMc</td>
<td>-.49</td>
<td>-.53</td>
</tr>
<tr>
<td>Crude protein</td>
<td>+.79</td>
<td>+.51</td>
</tr>
<tr>
<td>Crude fibre</td>
<td>-.67</td>
<td>-.82</td>
</tr>
<tr>
<td>NDF</td>
<td>-.85</td>
<td>-.83</td>
</tr>
<tr>
<td>OMD T and T</td>
<td>-.05</td>
<td>+.68</td>
</tr>
<tr>
<td>EULOS</td>
<td>-.63</td>
<td>-.84</td>
</tr>
</tbody>
</table>

When these types of relationships are assessed for DMI a different picture emerges (Table 8). Surprisingly, a negative influence is exerted by DM content. When adding grass samples to the set of legumes, crude protein content appears to be the only parameter which reacts to this by a marked increase in the correlation coefficient. Strong negative influences with DMI exist in the sample set containing legumes.
only for parameters which are indicative of the content of (indigestible) cell wall, i.e. crude fibre, NDF and EULOS. When the mixed grass/legume sample set is considered instead, the magnitude of the correlation coefficients is clearly reduced except for NDF. Strikingly, OMD T and T does not exhibit any relationship with DMI in the mixed grass/legume sample set, whereas in the pure legume set such an association does exist.

Taken together the results obtained in this study confirm the view that silage intake is clearly most influenced by the content of total cell wall (NDF) and by the content of indigestible organic matter (EULOS) in the forage.

Acknowledgements

This work was carried out at the former Institute of Grassland and Forage Research (Director: Prof. Dr. habil. F. Weissbach) and finalised at the present Institute of Crop and Grassland Science (Director: Prof. Dr. habil. J. M. Greef) of FAL. Thanks for stimuli and support are extended to both directors but also to Prof. R. J. Wilkins as coordinator of the LEGSIL project and to our colleague Dr. L. Schmidt for help in planning the experimentation.

The work force responsible for doing all the practical work in the field, barn, laboratory and other facilities consisted of many persons. Thanks are extended to the following female member of staff: Merle Alex, Magdalena Brettschneider, Sigrid Ehlers, Mechthild Heinrich, Annegret Hirsch, Erika Klöpper, Margarete Lehmann, Helga Mack, Ulrike Meyer, Petra Schwabe, Ulrike Sölter, Dagmar Strerath, Karin Trescher, Kathrin Wiegmann, Margarete Witkowski.

Work in the field, in the barn in the feeding trials but also in the lab was carried out by the following male members of staff who are also thanked for their contributions: H. Banach, A. Gottfried, D. Hillegeist, J. Morgenstern, M. Pachali, J. Reupke and H. Zoch

References


Summary of plenary discussion

1 Effects of fermentation quality

The possible effects on intake of silage fermentation quality, as reflected by high ammonia-N concentrations in the lucerne silages and concentrations of acetic acid were queried. It was pointed out that the ammonia figures would include some N from the additive, which contained both hexamine and sodium nitrate. Although this would have increased ammonia for all silages, it would not give a differential effect between the crop species.

The author considered that differences in silage fermentation characteristics were not having a major impact on intake with this population of silages. Some 85% of the variation in intake could be accounted for by digestibility.

2 Intake of lotus

In relation to the reason for the high intake of lotus silages, the author referred to rumen degradability studies carried out on these silages. These had shown that DM degradability was more rapid with lotus than the other legume silages and this was probably responsible for the high intakes.

Possible effects of tannins on N digestion were queried. Tannins had not been determined in these experiments. G. Broderick indicated that tannin concentrations were generally lower in Lotus corniculatus than in other tannin-containing legumes and did not think that major effects were likely. N. Nilsson-Linde referred to work in Sweden. She had shown large differences between varieties in tannins, but that values for Leo, the variety used in LEGSIL, was generally low. There was, however a negative relationship between tannin content and rate of protein degradation in the rumen, despite tannin concentrations being generally low.

Reporter: R.J. Wilkins