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Ensiling of legumes

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Abstract

The objective of the task was to provide reliable techniques for the conservation of forage legumes, which are difficult crops to ensile due to low contents of sugars and high buffering capacity. In Germany, Sweden and Finland the same four species, lucerne (*Medicago sativa),* red clover *(Trifolium pratense),* lotus *(Lotus corniculatus)* and galega *(Galega orientalis)* were established, harvested and ensiled at two stages of maturity, slightly and heavily wilted, with addition of formic acid (FA) or the silage inoculant Ecosyl® (ECO) and compared to an untreated control (C). At harvesting all fresh crops had very poor ensilability- indicating the need to take technological measures to reliably prevent undesirable fermentations. However, slight wilting to a target DM of approx. 250 g kg^{-1} was not sufficient to prevent butyric acid production, particularly with lucerne and galega. This could be achieved by wilting to about 400 g DM kg^{-1}, but silage quality was still significantly improved by use of the additives. FA was more effective than the inoculant in reducing ammonia content, but, especially in the high DM silages, the inoculant enhanced lactic acid production and the rate of pH decline. Aerobic deterioration was generally no problem in the resulting silages.

Methodology

The investigation was carried out on a laboratory scale, using 3 replicate silos of 1.5 to 30 l capacity. The target DM contents (*c*. 250 g kg^{-1} and *c*.400 g kg^{-1}) were achieved within maximum wilting times of 1 and 2 days for the two DM levels. Each crop received the ensiling treatments of no additive (C) vs. formic acid (FA), with amounts of 6.0 or 3.5 l t^{-1} for the low and high level of wilting, vs. the bacterial additive, Ecosyl (ECO) at an inoculation rate of 10^6 colony forming units (cfu) g^{-1} fresh matter of the crops at ensiling.

The analyses carried out on the forage crops and the silages are shown in Table 1.

Results and discussion

Ensilability of the legumes was characterised by their fermentability coefficient (FC), which summarises in one figure the effects of DM content, the quantity of fermentable substrate and buffering capacity of the crop according to the equation (Pahlow and Weissbach, 1999):

$$FC = DM\,[\%] + 8\ WSC\ BC^{-1}$$

A value above 45 indicates good fermentability. This FC did not differ significantly between the three countries and the four species. However, the clear effect on the FC of differences in DM content, achieved by wilting, is shown in Table 2 for the freshly harvested legumes and the crops wilted to the two target DM levels.

Table 1:
Assessments of the crops at ensiling and of silages after 90 days storage time

Crop composition at ensiling	
Crop parameter	Dimension
Epiphytic LAB	log cfu g^{-1} FM
DM content	g DM kg^{-1}
Water soluble carbohydrates	g kg^{-1} DM
Buffering capacity	g LA $100g^{-1}$ DM
NO_3 nitrogen	g kg^{-1} TM
Silage composition after 90 days storage	
Silage parameter	Dimension
pH value	
DM content	g DM kg^{-1}
Fermentation products	g kg^{-1} DM
NH_3- nitrogen	NH_3 N in % of TN
Aerobic stability	Days at 20°C

Table 2:
Fermentability coefficients of legume species as influenced by DM content

Legume	Direct cut	250 g DM kg^{-1}	400 g DM kg^{-1}
Lucerne	27	35	48
Red clover	27	38	50
Lotus	24	34	47
Galega	29	35	47
Mean	27	36	48
SD	1.8	1.5	1.2

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The low FC for all direct-cut legumes shows that they would be very difficult to ensile, indicating the need to take measures to prevent butyric acid fermentation, which is unavoidable at a FC around 27. The FC of 36, corresponding with the slightly wilted forage, is still not sufficient to guarantee good fermentation quality. Only the higher wilt to *c*. 400 g DM kg^{-1} resulted in FC values above the critical threshold of 45.

An alternative approach was investigated at FAL. The legumes were mixed at the point of ensiling with grass of higher FC. The grass component, used in the mixtures was *Lolium perenne* with a content of WSC varying from 100 to 200 g DM kg^{-1}. This resulted in increase in the FC of the mixture to *c*. 40, when at 250 g DM kg^{-1} (Table 3). However, at this low DM content, the grass component alone was not sufficient to achieve a fermentation quality as good as with the additives. The FC of the mixtures remained below the target value of 45, indicating the risk of undesirable fermentation.

Table 3:
Fermentability coefficients of legumes, grass and legume-grass-mixtures at 250 g DM kg-1

Legume species	Legume 250 g DM kg^{-1}	Grass 250 g DM kg^{-1}	Legume-Grass Mixture
Lucerne	35	50	40
Red clover	38	52	43
Lotus	34	47	39
Galega	35	45	40
Mean	36	48	40
SD	1.5	2.8	1.5

Silage quality was classified by a single figure by using the DLG point scoring system. This method considers concentrations of butyric acid, acetic acid and ammonia nitrogen, together with pH in relation to DM content. The maximum value is 100 points for the highest fermentation quality.

The effect of additive treatments on indicators of silage quality is shown in Table 4.

All additives had significant effects on quality parameters. Ecosyl enhanced the lactic acid content. Both additives reduced protein decomposition to ammonia, with formic acid being the most effective treatment. For silage quality, characterized by the DLG scoring system, there were clear differences in ranking, with values being higher with Ecosyl than with formic acid; the untreated control gave the lowest values. However, it has to be stated that this scoring system has limitations where fermentation is severely restricted, such as the silages with high rates of formic acid. This relationship is emphasised by the content of Table 5, which gives the effect of additive treatment on all relevant fermentation products.

Table 4:
Silage quality and protein decomposition as influenced by type of additive

Additive treatment	Lactic acid g kg^{-1} DM	NH_3 % of TN at ensiling	DLG score (max. 100 points)
Control	66 b	12 a	71 c
Ecosyl®	88 a	8 b	85 a
Formic acid	22 c	5 c	77 b
HSD	4.8	0.8	3.6

Table 5:
Effect of biological and chemical additives on main fermentation products

Additive treatment	Lactic acid	Acetic acid	Butyric acid	Ethanol
	g kg^{-1} DM			
Control	66 b	23 a	4.6 a	6.9 a
Ecosyl®	88 a	21 b	0.9 b	4.5 b
Formic acid	22 c	8 c	0.6 b	1.8 c
HSD	4.8	1.6	1.3	1.5

The homofermentative bacterial additive Ecosyl significantly reduced the volatile fatty acids as well as ethanol. The inoculant was as effective as FA in reducing butyric acid production. FA dramatically restricted the silage fermentation.

The effect of legume species on silage quality is shown in Table 6. There were statistical differences between species for all three indicators of silage quality. These followed the same pattern, clearly indicating that lucerne and galega were particularly difficult to ensile, whilst better fermentation quality was generally achieved for red clover and lotus. This occurred despite very close similarity between all four species in FC, shown in the last column.

Table 6:
pH value, NH_3 fraction and DLG score in silages from different legumes

Legume species	pH value	NH_3-N in % of TN	DLG score	FC
Lucerne	4.8 a	10.7 a	71 a	41 a
Red clover	4.5 b	7.2 b	81 b	43 a
Lotus	4.5 b	6.6 b	82 b	41 a
Galega	4.6 a	8.4 a	75 a	41 a
Mean	4.6	8.3	77	41.5
SD	0.09	0.99	4.6	3.5

The preservation of forage protein is considered more deeply in Table 7, in view of its importance for the entire LEGSIL project.

Only the low DM control silages contained NH_3 N in concentrations >10 %, a value which brings about a negative effect on silage quality. Wilting to 400 g DM kg^{-1} *per se* reduced the concentration of ammonia nitrogen from 14 to 8 %. As stated above, FA was most effective in restricting protein decomposition.

In addition to the routine determination of ammonia nitrogen, all FAL lab silages from 1998 were analysed for their content of free amino acids (FAA) by IGER. In Figure 1 the regression between the (calculated) bound protein nitrogen and the respective NH_3 nitrogen content is shown. The R^2 of 0.871 indicates the good relationship between these parameters.

Lowest concentrations of NH_3 N from protein decomposition during ensiling correspond with highest contents of intact protein which has survived the fermentation process.

The protein protection can be attributed primarily to the effect of the additives. However, as shown already in Table 6, there is also a plant-species effect with significantly less protein decomposition in red clover and lotus than in lucerne and galega.

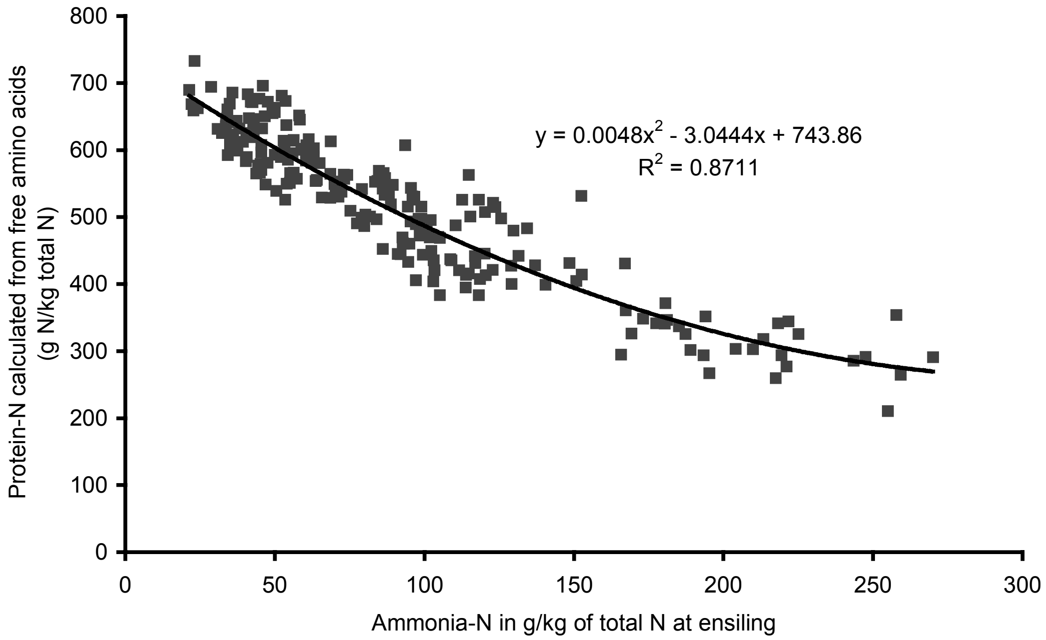

Figure 1:
Regression between bound protein N and ammonia N in legume silages

Table 7:
Protein protection by silage additives at different DM levels of legume silages (means and standard deviations)

	DM content	Control	Ecosyl ®	Formic acid
NH_3 N % of TN	250	14 ± 4	9 ± 4	4 ± 1
NH_3 N % of TN	400	8 ± 2	7 ± 3	5 ± 2

In all silages from the first experimental year, the aerobic stability was determined by measuring the temperature rise above ambient over a period of seven days according to Honig (1990). There was generally high stability, with none of the silages showing an increase in temperature within the first four days (Table 8).

Table 8:
Minimum duration of aerobic stability of legume silages measured upon exposure to air at 20 °C (n = 264)

Percentage of silages, aerobically stable for at least:			
4 days	5 days	6 days	7 days
100	99	97	89

Of the 30 unstable silages, the vast majority were from either red clover (15) or galega (13). A preliminary report of this research is given in Pahlow *et al.* (2000).

Conclusions

The results from both experimental years in all countries indicated that a DM content of 250 g DM kg^{-1} alone is not sufficient to avoid poor fermentation reliably and, particularly for lucerne and galega, a chemical additive such as formic acid at a rather high rate is required to achieve good fermentation at that low DM content. In general the recorded differences in the ensiling potential of the four legume species could be overcome by adopting appropriate ensiling technology. Wilting to a higher DM concentration is preferred and with that treatment the use of an inoculant resulted in further improvements of silage quality. A similar conclusion applies to the question of growth stage at harvest (budding or flowering), with crop yield and nutritive value being more important than ensilability of the respective plant species. The DLG score system for the classification of silage quality is less suitable if fermentation was severely restricted, as in the silages prepared with addition of large amounts of formic acid. For the range of treatments studied in this task, the best single index of successful preservation was the ammonia – nitrogen fraction, expressed as percent of the total nitrogen content of the crop at the time of ensiling.

Recommendations

- Harvest at flowering rather than at budding stage, provided the digestibility of the silage crop is not unacceptably reduced.
- Use a mower conditioner to reduce the wilting time. Dry to at least 300 g DM kg^{-1} with a field period of maximum 48 hours.
- Additive use is generally advisable for forage legumes in order to enhance protein protection and to improve fermentation quality of the resulting silage.

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Summary of plenary discussion

1 Assessment of silage fermentation quality

The author confirmed that the DLG scores for silages treated with high rates of formic acid had been penalised, sometimes by 5-6 points, because contents of acetic acid were below 20g kg DM^{-1}, which tends to reduce aerobic stability. There was also some penalty because final pH values were higher than when inocula were used. It is doubtful whether these factors did really reduce silage quality for this type of silage with its high indigenous stability upon exposure to air. For that reason ammonia-N had been considered to be a better single index of silage quality. There had been shown within LEGSIL to be a close relationship between ammonia-N and the extent *of protein breakdown calculated from assessments of ammonia and free amino acids.*

It was suggested that the content of WSC in the silage (high when high rates of formic acid or other chemical inhibitors of fermentation are used) should be considered in the silage evaluation scheme.

2 Larger-scale ensiling

Experience in LEGSIL with pilot-scale and farm-scale ensiling supported the results obtained on the laboratory scale. Silages with good fermentation quality had been made from all the legume species in situations in which DM targets were reached and additives used. This applied with 200 l barrels, big bales and with bunker silos.

At the larger scale it is important to take steps to reduce field losses. Good results had been obtained in Braunschweig and Aberystwyth with the use of a mower-conditioner with rubber rollers. This tended to even out the drying rates of leaf and stem and enable rapid achievement of target DM contents with minimum loss of leaf. It appeared to be very important to avoid re-wetting by rain of the conditioned crops.

3 Recommendations

The recommendation to harvest at flowering rather than an earlier stage of growth was challenged. The author indicated that this was a narrow conclusion relating only to ease of ensiling and picked out the statistically better preservation of silages made from material cut at flowering, reflecting mainly higher DM contents at harvest. He had pointed out that changes in digestibility with maturity could lead to a different conclusion in an overall analysis.

The recommendations made were not species specific, but the results had shown that lucerne and galega were similar in ensiling characteristics and offered a greater challenge than red clover and lotus. This was in line with differences between the species in WSC and buffering capacity. It is thus of even greater importance to achieve DM targets with the lucerne and galega.

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