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The effect of paraformaldehyde on the fermentation quality and feeding value of ryegrass and lucerne silages

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SUMMARY

Crops of perennial ryegrass and lucerne were each ensiled without additives and after the addition of paraformaldehyde to provide about 0·1, 0·2 or 0·4 % HCHO/t crop fresh weight. The ryegrass and lucerne silages were offered *ad libitum* to sheep in separate experiments of identical design.

All the ryegrass silages were well preserved with low pH values, the level of butyric acid was very low and ammonia-N comprised less than 8 % of total N. The lucerne silage made without additive had a pH of 5 and acetic acid comprised the major part of the total fermentation acids. Ammonia-N comprised over 12 % of total N. All levels of paraformaldehyde addition restricted fermentation in both crops and led to an increase in the proportion of total N which was insoluble in hot water.

Voluntary intake of organic matter (OM) was higher for the lucerne than for the ryegrass silages but digestible organic matter (DOM) intake was higher for the ryegrass. Intakes of OM and DOM were not significantly affected by paraformaldehyde treatment. The addition of paraformaldehyde significantly depressed apparent digestibility of OM and cellulose with the ryegrass but had less effect with the lucerne. Nitrogen digestibility was significantly depressed in both crops at all paraformaldehyde levels. Paraformaldehyde addition resulted in increased faecal N output and decreased urinary N, but retention of N was not significantly affected.

The lack of response in feeding value to paraformaldehyde treatment may have been due to the relatively high intake and N retention of the untreated silages which were fairly well preserved.

INTRODUCTION

The use of formaldehyde (HCHO) as a silage additive has been the subject of considerable study in recent years, and additives containing formalin, an aqueous solution of HCHO, are available commercially. Such additives are unpleasant to handle, with a pungent smell, and the volatile nature of the components can lead to high application losses. Formalin can also induce a clostridial-type fermentation in the silo when applied alone at application rates of less than 4·5 l (0·17 % HCHO)/t fresh crop (Wilkins, Wilson & Woolford, 1974).

Paraformaldehyde, a solid polymer of HCHO, has been examined as a silage additive in an attempt to overcome some of the disadvantages of formalin (Wilson & Wilkins, 1978). Applied as a 98 % powder, at 0·3 % (HCHO) of crop fresh weight (FW), paraformaldehyde was less effective than formalin in restricting silage fermentation in ryegrass and lucerne, but it was more effective at lower application rates in preventing clostridial-type fermentations. An 82 % prill was as effective as formalin in restricting fermentation.

The nutritive value of silage made with paraformaldehyde has been studied by Waldo, Keys & Gordon (1975). They found that when paraformaldehyde was applied to lucerne–cocksfoot grass at 0·1 % (HCHO) of crop FW, silage intakes and live-weight gains by growing heifers were similar to those obtained from the same crop ensiled with formic acid, and better than those of heifers offered untreated silage.

Since HCHO applied as formalin has had beneficial effects on silage intake and nitrogen utilization (Barry, Fennessy & Duncan, 1973; Wilkins, Wilson & Cook, 1974; Waldo, 1977), further research into the effect of paraformaldehyde seemed desirable. In the experiment reported here

perennial ryegrass and lucerne were ensiled without additives or after the application of paraformaldehyde at three different rates up to 0·4% HCHO/t crop FW. The silages were given to sheep and measurements of intake, digestibility and nitrogen utilization were made.

MATERIALS AND METHODS

Ensiling

Perennial ryegrass (*Lolium perenne*) cv. S.24 was cut by a rotary mower on 16 May and lucerne (*Medicago sativa*) cv. Europe on 25 July, and picked up within 3 h by a precision-chop forage harvester (6 mm theoretical chop length). Each crop was ensiled in a PVC bag silo, without additive (untreated), or after addition of paraformaldehyde at rates intended to provide 0·1, 0·2, or 0·4% HCHO of the crop FW. Paraformaldehyde was applied as a 98% prill (Synthite Ltd) via a powder applicator ('Kylamate') mounted on the harvester. It was not possible to use the 82% prills because they were less free flowing and therefore difficult to apply with the applicator employed. The silos, which each contained about 1·5 t of fresh crop, were sealed and weighted with sandbags. After approximately 7 months the silages were removed from the silo and stored at −15 °C before being thawed for feeding.

Animal feeding

The ryegrass and lucerne silages were used in separate experiments of identical design. In each experiment the silages were offered, without supplementation, to 12 individually caged Suffolk × Scottish halfbred wether lambs (9 months of age). A mineral block and water were available to the animals at all times. For about 2 weeks prior to the start of each experiment they were fed an untreated ryegrass silage. The sheep were allocated at random to a two-period, balanced, incomplete block design with three sheep allocated to each treatment in each period. During each period of 25 days, silages were offered *ad libitum* with refusals allowed at 15% of feed consumption. The sheep were fed the silages manually, twice daily, in approximately equal quantities at 09.00 and 16.00 h. Intake, digestibility and N retention were measured over the last 10 days of the period with the collection of faeces and urine lagging behind the measurement of feed offered by 24 h.

Analytical methods

Dry matter (D.M.) content of the silages was determined by distillation with toluene (Dewar & McDonald, 1961) and that of the fresh crops and faeces by drying in a forced draught oven at 100 °C for 16 and 40 h respectively. Buffering capacity of the untreated fresh crop was determined by the method of Playne & McDonald (1966) and pH values of the silages were measured with a glass electrode on juice expressed from the fresh materials.

Fermentation acids and ammonia-N were determined as described by Wilson & Wilkins (1978). Total nitrogen (N) content of silage, faeces and urine was determined on the fresh material, and ash on oven-dried material, by the methods of the Association of Official Agricultural Chemists (1965). Insoluble nitrogen content of the ensiled crop and silage was determined as total nitrogen of the residue after extraction of the fresh material with boiling water. Water-soluble carbohydrate (WSC) determination was carried out on freeze-dried samples using an automated ferricyanide method (Technicon N9B). The cellulose content of the silages and faeces was determined on oven-dried samples by the method of Crampton & Maynard (1938). Values for ash and cellulose content of the silages were adjusted for losses of volatile material during oven drying. The content of digestible organic matter (DOM) in D.M. (D-value) was determined *in vitro* on oven-dried material by the method of Tilley & Terry (1963).

Treatment means were compared using the Student–Newman–Keuls multiple range test as described by Miller (1966).

RESULTS

Crop composition

The composition of the crops at ensiling is given in Table 1. Differences in D.M. content between the ryegrass and lucerne were associated with differences in moisture content in the crop prior to cutting and with a slightly longer interval (up to 3 h) between cutting and harvesting the lucerne than the ryegrass. The ryegrass was higher in D-value and N content than the lucerne; WSC content was much higher and buffering capacity much lower in the ryegrass than the lucerne.

Table 1. *Composition of the crops at ensiling*

	Ryegrass	Lucerne
Dry matter (%)	18·8	23·6
Nitrogen (% D.M.)	2·89	2·72
Water-soluble carbohydrates (% D.M.)	20·2	7·74
Ash (% D.M.)	7·25	8·45
Digestible organic matter in the dry matter (%)	73·1	55·5
Buffering capacity (m-equiv/100 g D.M.)	26·7	36·8

Table 2. *Composition of the silages*

	Ryegrass				Lucerne			
Paraformaldehyde level								
% of fresh crop ...	0	0·15	0·20	0·37	0	0·09	0·21	0·38
g HCHO/100 g CP* ...	0	4·2	6·0	10·9	0	2·2	5·0	9·3
Dry matter (%)	18·7	19·3	18·4	19·6	22·4	23·9	25·3	25·1
pH	4·0	4·2	4·1	4·2	5·0	4·6	4·4	4·5
Chemical composition (% D.M.)								
Water-soluble carbohydrates	1·2	7·5	7·3	10·2	< 1·0	1·5	1·7	2·3
Lactic acid	7·3	2·5	3·0	1·3	1·7	2·9	3·1	2·1
Acetic acid	6·5	2·6	1·9	2·2	7·0	2·3	1·8	1·7
Propionic acid	0·4	0·1	0·1	0·1	0·5	0·05	0·05	0
Butyric acid	0·1	0·1	0·1	0	Trace	0·05	0	0
Ash	8·2	8·2	7·9	7·6	9·0	8·7	8·7	8·4
Cellulose	25·6	25·6	25·8	24·4	35·4	32·5	33·0	33·5
Total nitrogen (N)	3·3	3·2	3·2	3·1	2·9	2·9	2·9	2·8
Hot water insoluble-N (% total N)	27·0	35·6	45·8	42·6	31·2	38·0	36·6	42·2
Ammonia-N (% total N)	7·3	6·6	5·5	5·6	12·2	9·4	5·7	6·2

* Crude protein.

Table 3. *The effect of paraformaldehyde on the intake, digestibility and nitrogen utilization of ryegrass silage*

	Untreated				
Paraformaldehyde level					
% of fresh crop ...	0	0·15	0·20	0·37	S.E.
g HCHO/100 g CP ...	0	4·2	6·0	10·9	
Voluntary intake					
Organic matter (g/kg $W^{0·75}$)	56·1	56·3	60·3	58·8	±2·89
Digestible OM (g/kg $W^{0·75}$)	45·8	43·9	46·1	43·7	±2·07
Nitrogen (g/head)	36·1	35·7	37·4	35·3	±1·96
Digestibility (%)					
Organic matter	81·8^{a}	77·9^{b}	76·8^{b}	74·7^{c}	±0·38
Cellulose	87·4^{a}	84·7^{b}	84·8^{b}	81·7^{c}	±0·38
Nitrogen	78·7^{a}	68·7^{b}	63·9^{c}	57·9^{d}	±0·56
Nitrogen					
In faeces (g/day)	7·8^{c}	11·1^{b}	13·8^{ab}	15·2^{a}	±0·98
In urine (g/day)	19·5	16·1	15·4	13·6	±1·41
Retention (g/day)	8·8	8·5	8·2	6·5	±1·06

Means with the same or no superscripts are not significantly different ($P > 0·05$).

Silage fermentation

The rates of paraformaldehyde application and composition of the silages are given in Table 2. The intended rates of additive were achieved except for ryegrass at the lowest level of HCHO addition where the application rate was higher than intended.

Ryegrass. The silage made without additive was well preserved with a low pH value, fermentation acids comprised over 14% of D.M., the level of butyric acid was negligible and ammonia-N comprised only 7·3% of total N. Fermentation was severely restricted by all levels of paraformaldehyde addition as indicated by the production of less fermentation acids and substantial amounts of WSC remaining unfermented, the effect being greatest with the highest level of HCHO. The proportion of the total N which was insoluble in hot water was increased and that of ammonia-N decreased by paraformaldehyde addition.

Lucerne. Although the silage made without additive had a pH value of 5 it was well preserved; fermentation acids comprised over 9% of D.M. with acetic acid making up the major part of this fraction. The amount of butyric acid present was

Table 4. *The effect of paraformaldehyde on the intake, digestibility and nitrogen utilization of lucerne silage*

	Untreated				
Paraformaldehyde level					
% of fresh crop ...	0	0·09	0·21	0·33	S.E.
g HCHO/100 g CP ...	0	2·2	5·0	9·3	
	Voluntary intake				
Organic matter (g/kg $W^{0·75}$)	67·4	67·2	67·4	73·4	±2·11
Digestible OM (g/kg $W^{0·75}$)	39·7	39·4	38·9	41·6	±1·37
Nitrogen (g/head)	38·3	37·3	37·9	40·4	±1·43
	Digestibility (%)				
Organic matter	$58·9^{a}$	$58·9^{a}$	$57·8^{ab}$	$59·6^{b}$	±0·42
Cellulose	58·9	55·8	55·4	56·6	±0·86
Nitrogen	$74·9^{a}$	$69·6^{b}$	$64·2^{c}$	$56·5^{d}$	±0·56
Nitrogen					
In faeces (g/day)	$9·6^{c}$	$11·6^{bc}$	$13·5^{b}$	$17·5^{a}$	±0·62
In urine (g/day)	$21·1^{a}$	$18·1^{b}$	$16·6^{b}$	$16·9^{b}$	±0·71
Retention (g/day	7·6	7·6	7·8	6·0	±0·76

Means with the same or no superscripts are not significantly different ($P > 0·05$).

small and ammonia-N comprised 12·2% of total N. Addition of paraformaldehyde led to a reduction in the total amount of fermentation acids produced but there were slight increases in lactic acid compared with that of the untreated material. As with ryegrass the proportion of total N which was insoluble in hot water was increased and that of ammonia-N decreased by paraformaldehyde addition.

Animal feeding

Ryegrass silages. Intake, digestibility and N utilization by sheep are shown in Table 3. There were no significant differences in intake of organic matter (OM) or DOM between the silages. The apparent digestibilities of OM (OMD), cellulose and N were highest for the untreated silage, and declined with increase in paraformaldehyde application rate; the reduction was particularly marked for N-digestibility at 21 percentage units between extreme treatments. Intake of N was not significantly affected by treatment, however. Although the addition of paraformaldehyde increased faecal-N output there were no significant differences in N-retention between the four treatments, because urine-N output was reduced by paraformaldehyde treatment.

Lucerne silages. Intake, digestibility and N utilization by sheep are given in Table 4. There were no significant differences in intake of OM or DOM, although values tended to be highest for the silage made with the highest rate of HCHO. There were depressions in the apparent digestibility of OM and cellulose as paraformaldehyde rate increased, but differences between treatments were small and only significant for OMD ($P < 0·05$), at the highest rate of HCHO addition. Apparent digestibility of N, however, decreased considerably ($P < 0·01$) as paraformaldehyde rate was increased. As with the ryegrass, N-intake was not significantly affected by treatment. Faecal-N output again increased with increasing paraformaldehyde, but there were no significant differences in N-retention, because of the significant reduction ($P < 0·01$) in urine-N excretion as a result of paraformaldehyde treatment.

DISCUSSION

The addition of paraformaldehyde as a 98% prill restricted silage fermentation in both crops at all application rates. The pH values of the treated ryegrass silages (4·1–4·2) were, however, surprisingly low in view of the low contents of fermentation acids (3·6–5·3% of the D.M.). We have no explanation for the low pH, but similar values were found by Wilson & Wilkins (1978). Paraformaldehyde improved the fermentation quality of the lucerne silage, but had less effect on the ryegrass which was well preserved without additive. Where paraformaldehyde was used, the extent of fermentation was similar for both crops and did not vary with rate of application. It appeared that some fermentation occurred before sufficient HCHO was released to prevent further microbial activity, thus supporting the findings of Wilson & Wilkins (1978) regarding the lower solubility and activity of the 98% polymer compared with formalin.

The OM intakes by sheep of the lucerne silages

were higher than those of the ryegrasses, but DOM intakes were similar, which is in agreement with the findings of Wilkins (1975). OM intakes of both the ryegrass and lucerne were not significantly improved by paraformaldehyde addition.

The failure of paraformaldehyde to increase silage intake was associated with relatively high intakes of the untreated silages, which were reasonably well preserved. The intakes of well fermented silages made from untreated crops, as characterized by a low pH and with $<10\%$ of total-N as ammonia, have frequently not been increased when formic acid (Wilkins & McLeod, 1970) or formalin (Wilkins, Wilson & Cook, 1974; Kaiser, 1979) have been employed as additives. Although the untreated lucerne had a pH of 5·0 and acid content of 7% of D.M., ammonia-N content remained relatively low at 12% of total N.

The application of paraformaldehyde at up to 10·9 g HCHO/100 g crude protein (CP) did not affect the intake of either crop. This contrasts with the conclusions of Wilkinson, Wilson & Barry (1976) that ryegrass silage intake was depressed by formalin at application rates in excess of 8 g HCHO/100 g CP. The results reported here are, however, in agreement with those obtained from sheep fed ryegrass silages of a similar digestibility and N content, treated with formalin at equivalent levels of HCHO addition (Wilkins, Wilson & Cook, 1974). The intakes of the lucerne silages treated with paraformaldehyde at up to 9·3 g HCHO/100 g CP support the conclusions of Wilkinson *et al.* (1976) who found no decline in the intake of lucerne until formalin exceeded 15 g HCHO/100 g CP.

Although intake was unaffected, paraformaldehyde significantly reduced the OMD at all levels of addition in the ryegrass silages, and at the highest rate in the lucerne. The fall in digestibility was similar in magnitude to that recorded for ryegrass and lucerne treated with similar levels of formalin (Wilkins, Wilson & Cook, 1974; Barry, Cook & Wilkins, 1978; R. J. Wilkins and J. E. Cook, unpublished data).

Cellulose digestibility was significantly depressed by paraformaldehyde addition in ryegrass, but not in lucerne. The reduction in cellulose digestibility probably arose from a reduced rate of cellulose digestion in the rumen, as reported for formalin-treated silages by Wilkins, Wilson & Cook (1974) and Kaiser (1979). This difference in response between crop species may, as suggested by Kaiser (1979), be due to differences in the composition of the cell-wall constituents between grasses and legumes, resulting in less binding of HCHO with cell-wall constituents in lucerne.

The depression in apparent digestibility of N in both crops at all levels of paraformaldehyde addition is also in line with that obtained in experiments in which silages made from ryegrass (Wilkins, Wilson & Cook, 1974; Beever *et al.* 1977) and lucerne (Wilkins, Wilson & Cook, 1974; Barry *et al.* 1978) with equivalent rates of formalin were given to sheep. It seems likely that, as occurred with formalin (Beever *et al.* 1977), HCHO applied as paraformaldehyde suppressed protein degradation in the rumen and caused a shift in the site of N digestion to the small intestine.

N retention of all the silages was high and was not affected by paraformaldehyde application. It is possible that the values measured were at a maximum for the sheep used and this may account for the absence of a response to paraformaldehyde treatment. Animals of this type have been used for several years at the Grassland Research Institute in silage feeding experiments and N retention has not been higher than the values reported here.

The balance of evidence suggests that there is no justification for applying paraformaldehyde, or formalin, to lucerne or ryegrass at rates in excess of 0·2% HCHO/t crop FW (5–6 g HCHO/100 g CP) either to restrict fermentation and protein degradation in the silo or to improve animal performance. At application rates of 0·1% HCHO, formalin, when applied alone, has led to problems of clostridial fermentation (Wilkins, Wilson & Woolford, 1974) but paraformaldehyde has not (Wilson & Wilkins, 1978). There is a need therefore to compare the effect on fermentation of the two sources of HCHO, particularly at rates at which a clostridial fermentation is likely when formalin is used. It will then be necessary to compare the feeding value of such silages with that of well-preserved untreated silage using animals with a higher requirement for protein than the sheep offered the silages in this experiment.

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