Grass and Forage Science (1996) Volume 51, 318–323

RESEARCH NOTE

Effect of silage additives on big-bale grass silage

P. M. HAIGH†, D. G. CHAPPLE‡ AND T. L. POWELL†
†ADAS Pwllpeiran Research Centre, Cwmystwyth, Aberystwyth, Wales, UK, and ‡ADAS, Rosemaund, Preston Wynne, Hereford, UK

Abstract

Data from twenty-two experiments conducted at four ADAS Research Centres during 1980–92 were used to compare untreated silages with silages treated with formic acid, with or without added formalin, commercial inoculants or molasses. The sillages were made from herbage whose dry-matter (DM) and water-soluble carbohydrate (WSC) contents were 277 (s.e. 0·46) g DM kg^{-1} and 36 (s.e. 8·1) g kg^{-1} respectively. Inoculant use significantly decreased silage pH and ammonia-N, significantly increased lactic acid and total acid content, and decreased butyric acid and total short-chain fatty acids. Formic acid use significantly increased silage lactic acid and total acid content, and decreased butyric acid content, whereas formic acid+formalin significantlydecreased silage ammonia-N level. Molasses had little effect upon silage fermentation. Improvements in silage fermentation, however, produced little benefit in terms of either silage DM intake or liveweight gain when the silages were offered to growing lambs.

It is suggested from the results that inoculant- and formic acid-based additives can be used to improve the fermentation of big-bale silages.

Introduction

In England and Wales in 1994, 6·2 million tonnes of big-bale silage were made. This amounted to 18% of the 34·1 million tonnes of grass silage made (MAFF, 1995). It has been shown that in the early 1990s, 45% of bunker silage made in England and Wales was treated with silage additives (Haigh, 1996a; 1996b; Jones, 1994). Little information is, however, available on the use of silage additives on big-bale silage; with Haigh and Peers (1992) and Haigh (1995) giving no indication of silage additive use in their reviews of big-bale silage quality in Wales and England respectively. In 1983–87 only 7% of big-bale silages made during the autumn in South Wales was treated with additive (Haigh, 1990a). In 1995 it was estimated that only 3% of bales (Malins, 1995) was treated with additive. Nevertheless, silage additive use is advocated on big-bale silage and products have been specifically designed for this purpose (Haigh, 1993). Independent assessment of silage additive use on big-bale silage is small, with Moran and Owen (1993) showing that inoculant treatment significantly improved fermentation compared with untreated silage.

In the period 1980–92 a series of trials comparing formic acid, formic acid+formalin, inoculant, molasses and untreated silages was conducted on four ADAS Experimental Research Centres – High Mowthorpe, North Yorkshire; Liscombe, Somerset; Pwllpeiran, Dyfed; and Trawsgoed, Dyfed. These results provide an opportunity to quantify responses to additive treatment.

Materials and methods

A total of twenty-two experiments was conducted. The number of experiments for specific treatments is subsequently shown in brackets. Perennial ryegrass (*Lolium perenne*)/white clover (*Trifolium repens*) leys, to which 74 (s.e. 2·6) kg N ha^{-1} had been applied 54 (s.e. 3·9) d before cutting, was cut as first-cut (two experiments) on 12 June, second-cut (seven) on 29 (s.e. 2·1) July or in the autumn (thirteen) on 22 (s.e. 3·3) September. The

Correspondence: P. M. Haigh, ADAS Pwllpeiran Research Centre, Cwmystwyth, Aberystwyth, Dyfed 5723 4AB, UK.

grass was cut with either a mower conditioner (eighteen), a disc mower (three) or a flail harvester (one) and wilted for 29 (s.e. 5·0) h before being harvested. The additives were applied using an electronic spray over the bale pick-up reel (fifteen) or watering can to the swath prebaling (seven).

The additives applied were formic acid ['Add F' (three trials), 'Add H' (one) and Foraform (one) – Trouw Nutrition Ltd], a formic acid and formalin mixture ['F100' (seven) – FSL Bells Ltd], inoculants [HM Inoculant (one) – Nutrimix Ltd, Ecosyl (one) or Ecobale (three) – Zeneca Bio Products or unspecified (six)] and molasses [(six) – Rumenco Ltd]. The application rates are given in Table 2. The weather conditions at ensilage were dry and sunny (eleven), cool, overcast with showers (six), wet (one) and unspecified (four). The number of bales per treatment was thirteen (s.e. 2·2), average bale weight 570 (s.e. 22·0) kg and the time taken from cutting to completion of silage making 2·5 (s.e. 0·43) d.

Standard laboratory techniques (MAFF, 1986) were used for analysis. Herbage was analysed for dry-matter (DM), protein (CP), modified acid detergent fibre (MADF) and water-soluble carbohydrate (WSC) in twenty experiments but ash was determined in seven of the experiments only. All the silages were analysed for oven DM, pH, CP and MADF. In the seventeen experiments in which toluene DM was not determined it was calculated according to the equation given by Haigh (1995). Other determinations (number) were ammonia-N (twenty-one), lactic acid and short-chain fatty acids (fourteen), formic acid (nine), ash (seven) and WSC and ethanol (six). DM loss during ensilage in eleven experiments was determined as described by Haigh and Parker (1985).

In five experiments, after storage for 45 (s.e. 8·3) d, the silages were offered *ad libitum* to mainly speckle-face hill lambs of mean intial weight 28·3 (s.e. 0·71) kg. The experiments started on 8 (s.e. 9·3) November and lasted 53 (s.e. 2·9) d. The number per treatment was 44 (s.e. 11·2). In one experiment silage was the sole feed. In the others 0·17 (s.e. 0·041) kg of a compound feed or home mix containing 187 (s.e. 17·6) g kg^{-1} CP was given either once (two) or twice (two) daily.

Residual maximum likelihood value (REML) was used to analyse the results statistically, to enable the analysis of unbalanced data and efficient combination of results from a series of trials (Robinson, 1987).

Results

Herbage composition

Results for herbage composition from the twenty experiments in which it was analysed are given in Table 1. The DM content of formic acid+formalin and molasses-treated silage was significantly ($P<0·05$) higher than other treatments, whereas that of formic acid-treated silage was significantly ($P<0·05$) less than other treatments. There were small but significant differences in CP, MADF, WSC and ash content of herbage before ensiling.

Silage composition

Silage analyses are given in Table 2. In general ammonia-N and lactic butyric and total acid concentrations of silage showed that formic acid and inoculant treatments enhanced fermentation compared with untreated silage, whereas formic acid+ formalin treatments only reduced the ammonia-N content and molasses treatments had little effect. The DM contents of inoculant-treated ($P<0·05$) and molasses-treated silages ($P<0·001$) were signifi-

Table 1. Chemical composition of herbage for ensilage (values are residual maximum likelihood values)

	Nil	Formic acid	Formic acid + formalin	Inoculant	Molasses	Average s.e. between two means
Number of samples	20	5	7	10	5	
Dry matter (g kg^{-1})	277^{bc}	258^{d}	298^{a}	283^{bc}	309^{a}	5·7
Composition (g kg^{-1} DM)						
Crude protein (CP)	150^{ab}	151^{ab}	156^{b}	154^{ab}	149^{a}	2·5
Modified acid detergent fibre (MADF)	300^{a}	298^{a}	283^{b}	297^{a}	281^{b}	5·7
Water-soluble carbohydrate (WSC)	129^{b}	117^{c}	139^{a}	128^{b}	146^{a}	4·4
Ash	81^{bc}	92^{a}	78^{c}	84^{b}	–	1·1

Means on the same line, with the same superscript or no superscript, do not differ significantly ($P<0·05$).

Table 2. Composition of silage (values are residual maximum likelihood values expressed on a toluene dry-matter (DM) basis)

	Nil	Formic acid	Formic acid + formalin	Inoculant	Molasses	Average s.e. between two means
Number of samples	22	5	7	11	6	
Application rate ($l\ t^{-1}$)		4·1	4·0	2·4	10·2	0·452
Oven DM ($g\ kg^{-1}$)	259^{cde}	251^{de}	266^{bcd}	273^{abc}	283^{ab}	5·3
Toluene DM ($g\ kg^{-1}$)	278^{cde}	271^{de}	285^{bcd}	292^{abc}	302^{ab}	5·3
pH	4.53^{a}	4.47^{ab}	4.46^{ab}	4.36^{b}	4.55^{a}	0·076
NH_3N ($g\ kg^{-1}$ N)	97^{a}	89^{b}	80^{bc}	78^{c}	99^{a}	4·1
Composition ($g\ kg^{-1}$ DM)						
CP	158^{a}	162^{a}	162^{a}	159^{a}	152^{b}	2·5
MADF	334^{abc}	332^{abcd}	335^{ab}	326^{bcd}	324^{cd}	4·0
Ash	85^{a}	78^{b}	90^{c}	85^{a}	–	1·5
WSC	44^{a}	47^{a}	30^{b}	45^{a}	–	5·2
Ethanol	12	5^{a}	–	11	–	0·4
Lactic acid	49^{a}	65^{b}	52^{a}	65^{b}	–	3·0
Formic acid	1	4^{a}	2	2	–	0·4
Acetic acid	8	8	10	8	–	1·0
Butyric acid	9^{a}	5^{b}	7^{ab}	5^{b}	–	1·1
Total short-chain fatty acids	19	18	19	15^{a}	–	1·2
Total acids	68^{ab}	83^{cd}	71^{abc}	80^{bcd}	–	5·5
Lactic acid (as proportion total acids)	0.73^{a}	0.79^{ab}	0.73^{a}	0.81^{b}	–	0·030
DM loss	129^{ac}	136^{a}	128^{abc}	107^{bc}	112^{bc}	10·3

Means on the same line, with the same superscript or no superscript, do not differ significantly ($P<0.05$).
Abbreviations as in Table 1.

cantly higher than those of untreated silage. Compared with untreated silage, formic acid use significantly increased the formic acid ($P<0.001$), lactic acid ($P<0.001$) and total acid content ($P<0.01$) and signicantly reduced the ammonia-N ($P<0.05$), ethanol ($P<0.001$) and butyric acid ($P<0.01$) content. Similarly, formic acid+formalin treatment significantly decreased the ammonia-N ($P<0.001$) and WSC ($P<0.05$) contents. Inoculant treatment significantly decreased pH ($P<0.05$), ammonia-N ($P<0.001$), butyric ($P<0.01$)and total short-chain fatty acid ($P<0.01$) contents and significantly increased the lactic acid ($P<0.001$), total acid ($P<0.05$) contents and lactic acid content expressed as a proportion of total acid ($P<0.05$) content. Inoculant treatment significantly ($P<0.05$) decreased DM losses during ensilage.

Animal performance

Animal performance is given in Table 3. Additive treatment had little effect upon either silage or total DM intake, daily liveweight gain or killing-out percentage, except that formic acid treatment significantly ($P<0.05$) increased silage DM intake compared with other treatments.

Discussion

Silage fermentation

Using an ammonia-N content of 80–100 g $(kg\ N)^{-1}$ (Haigh and Hopkins, 1977) as the criterion for fermentation, all the silages were satisfactorily fermented. Nevertheless, formic acid, with or without formalin, and inoculant use decreased the

Table 3. Silage intake and liveweight (LW) gains (values are residual maximum likelihood values)

	Nil	Formic acid	Inoculant	Molasses	Average s.e. of difference between two means
Number of samples	5	1	4	1	
Intake ($g\ kg^{-1}$ LW)					
Silage DM	0·572	0.608^{a}	0·573	0·559	0·012
Total DM	0·646	0·679	0·646	0·678	0·012
LW gain ($g\ d^{-1}$)	54	57	56	58	6·3
Killing-out %	44	–	44	43	0·6

Means on the same line, with the same superscript or no superscript, do not differ significantly ($P<0.05$).

ammonia-N content, in the former case probably because the formic acid and formalin treatments were effective in restricting proteolysis (McDonald *et al.*, 1991) and in the latter case because inoculants work best with high sugar content crops (Woolford, 1984). Formic acid with or without formalin additive use had little effect upon pH compared with that produced when the same additives were applied to bunker-made silages (Haigh and Parker, 1985), probably because big-bale silages undergo a more limited fermentation (McDonald *et al.*, 1991). Nevertheless, inoculant-treated silages had a low pH value, probably because the inoculants provided more than 10^6 organisms g^{-1} grass (ADAS, 1987), were added as liquids and were evenly distributed over the plant surface (Henderson and McDonald, 1984), thereby becoming active quickly (Seale, 1986).

Molasses treatment did not reduce the pH or ammonia-N levels compared with those of untreated silage. This is probably because it is difficult to apply (Woolford, 1984). The provision of extraneous sugar alone, particularly to high WSC crops, may be insufficient to permit lactic acid bacteria to compete with other components in the silage microflora.

Both formic acid and inoculant use produced higher levels of lactic acid in the silage, and the latter treatment improved the amount of lactic acid, when expressed as a proportion of total acids, suggesting that they improved the efficiency of fermentation (Woolford, 1984). The formic acid+formalin product used contained 32% formic acid and 62% formalin (Jacklin and Haigh, 1993). Its use had little effect upon either the amount of lactic acid or the total acid content of silages compared with untreated silage, which suggests that its use had little effect upon fermentation. Formic acid and inoculant use decreased the levels of butyric acid in silages, which were otherwise satisfactorily preserved, a situation also noted (Haigh and Parker, 1985) with wilted bunker-made silages.

Additive use had little effect upon the residual WSC content of the silages, perhaps because the silages were ensiled with a high WSC content and underwent a restricted fermentation compared with bunker-made silages. Nevertheless, the low value for the formic acid+formalin treatment is difficult to explain, particularly as the WSC content at ensilage was higher than for the other treatments except that of molasses.

The overall effectiveness of additive treatment in improving the fermentation of silages can be assessed by combining the mean percentage reductions in ammonia-N, pH, butyric acid and the percentage increase in lactic acid (Haigh and Parker, 1985). Using these criteria, formic acid treatment gave an improvement of 22%, formic acid+formalin treatment 12%, inoculant treatment 25% and molasses treatment little or no improvement. The improvement was greater than that generally found by Weddell (1995), probably because the present silages had a lower DM content.

Silage DM loss and animal performance

DM losses occurring during ensilage were much lower than those reported for bunker-made silages (Haigh and Parker, 1985; Haigh *et al.*, 1987), probably because the DM content of the present silages was much higher.

In terms of animal performance, the results show that the improvements in silage fermentation obtained from additive use at ensilage were not reflected in terms of either improved DM intake or animal performance when the silages were offered to growing lambs. These results contrast with those of Weddell (1995), who found little improvement in fermentation quality but improved animal performance when the silages were offered to store cattle. The present results may be attributed to the fact that the untreated silages were relatively well fermented, that the silages were long-chopped, additional feeds were given and that growing lambs are notoriously variable in their DM intake and liveweight gain.

Water soluble carbohydrates and preservation

A WSC concentration of about 37 g kg^{-1} in herbage for ensilage is desirable for silages made in bunker silos (Haigh, 1990b). Relationships found in the present work, indicating the minimum WSC concentration necessary to produce successful preservation, are given in Table 4. The relationships were generally not significant. Nevertheless, they indicate that the WSC necessary for successful preservation with untreated silage was about 35 g kg^{-1}. Formic acid and inoculant treatment reduced this to about 30 g kg^{-1}, whereas the other additives had no effect.

Conclusion

The results indicate that formic acid and inoculant application to big-bale silage enhanced subsequent

Table 4. Relationship between silage pH, ammonia-N and herbage water-soluble carbohydrate (g kg^{-1} fresh weight) for additive-treated and untreated silages

Results	Relationship with WSC	Minimum WSC for preservation	s.e.	r^2	*P*
Untreated silage					
19	45·2 − 0·100 NH_3-N	35	12·2	0·15	NS
19	−35·2 + 15·5 pH	33	10·3	0·39	NS
Formic acid					
4	−14·9 + 0·436 NH_3-N	29	5·8	0·81	NS
4	21·1 + 1·5 pH	28	10·1	0·13	NS
Formic acid + formalin					
6	64·2 − 0·189 NH_3-N	45	18·3	0·48	NS
6	−91·4 + 28·8 pH	35	18·4	0·48	NS
Inoculant					
10	52·5 − 0·225 NH_3-N	30	11·9	0·14	NS
10	6·5 + 5·8 pH	32	12·7	0·02	NS
Molasses					
5	85·7 − 0·4 NH_3-N	46	14·6	0·73	NS
5	−79·6 + 27·4 pH	41	17·4	0·61	NS

Estimated using ammonia–N ≤ 100 g kg^{-1} N (Haigh and Hopkins, 1977).
Estimated using pH ≤ 4·4 (Haigh, 1983).
NS, not significant.

silage fermentation and that formic acid+formalin and molasses treatment had little effect. No improvement in animal performance resulted from additive treatment when the silages were offered to growing lambs.

Acknowledgments

The authors thank the Livestock Division of the Ministry of Agriculture, Fisheries and Food (UK) for financing this work. They also acknowledge the co-operation of Farm Directors and staff at the ADAS Research Centres where the trials were conducted, Liscombe Research for permission to use their results and J. F. Potter, IGER, Aberystwyth for help with statistical analysis.

References

ADAS (1987) The ADAS guide to silage additives. *Farmers Weekly, Supplement*, 20 February.

Haigh P.M. (1983) *Effectiveness of silage additives on commercial farms*. M.Phil. Thesis, University of Nottingham.

Haigh P.M. (1990a) The effect of dry matter content on the preservation of big-bale grass silages made during the autumn on commercial farms in South Wales 1983–7. *Grass and Forage Science*, **45**, 29–34.

Haigh P.M. (1990b) Effect of herbage water soluble carbohydrate content and weather conditions at ensilage on the fermentation of grass silage made on commercial farms. *Grass and Forage Science*, **45**, 263–271.

Haigh P.M. (1993) Like it or not additives are here to stay. *Farmers Weekly, Quality Forage Supplement*, 19 February.

Haigh P.M. (1995) Chemical composition and energy value of big-bale silages made in England, 1984–91. *Journal of Agricultural Engineering Research*, **60**, 211–216..

Haigh P.M. (1996a) The effect of dry matter content and silage additives on the fermentation of bunker made grass silages on commercial farms in England 1984–91. *Journal of Agricultural Engineering Research*, **64**, 249–259.

Haigh P.M. (1996b) The effect of dry matter content and silage additives on the fermentation of bunker made grass silages on commercial farms in Wales 1987–93. *Journal of Agricultural Engineering Research* (in press).

Haigh P.M. and Hopkins J.R. (1977) Relationship between oven and toluene dry matter in grass silage. *Journal of the Science of Food and Agriculture*, **28**, 477–480

Haigh P.M. and Parker J.W.G. (1985) Effect of silage additives and wilting on silage fermentation, digestibility and intake, and on liveweight change of young cattle. *Grass and Forage Science*, **40**, 429–436.

Haigh P.M. and Peers D.G. (1992) A note on the chemical composition of big-bale silages on Welsh farms, 1984–1988. *Irish Journal of Agricultural and Food Research*, **31**, 193–197.

Haigh P.M., Appleton M. and Clench S.F. (1987) Effect of commercial inoculant and formic acid ± formalin silage additives on silage fermentation and intake and on liveweight change of young cattle. *Grass and Forage Science*, **42**, 405–410.

Henderson A.R. and McDonald P. (1984) The effect of a range of commercial inoculants on the biochemical changes during the ensilage of grass in laboratory studies. *Research and Development in Agriculture*, **1**, 171–176.

Jacklin D. and Haigh P.M. (1993) *Silage Additives 1993*. Oxford: Oxford Spires, ADAS.

Jones R.O. (1994) *The Impact of Regulating the UK Silage Additive Market*. Newport, Shropshire: Centre for Agri-Food Marketing Studies, Harper Adams Agricultural College, 70 pp.

McDonald P., Henderson A.R. and Heron S.J.E. (1991) *The Biochemistry of Silage*, Marlow: Chalcombe Publications.

MAFF (1986) *The Analysis of Agricultural Materials RB427, Ministry of Agriculture Fisheries and Food* 2nd edn. London: HMSO.

MAFF (1995) *December 1994 Agricultural Returns for the UK*. York: Government Statistical Service.

Malins M.I. (1995) Big bale silage – *Listeriosis* implications. *Grass Farmer*, **52**, 13–16.

Moran J.P. and Owen T.R. (1993) The efficacy of a bacterial inoculant on silage fermentation under a range of ensiling conditions. *Proceedings of the 10th International Conference on Silage Research*, Dublin City University, Dublin. pp. 87–88.

ROBINSON D.I. (1987) Estimation and use of variance components. *The Statistician*, **36**, 3–14.

SEALE D.R. (1986) Bacterial inoculants as silage additives. In: Benham C.H., Bateson M. and Skinner F.A. (eds) *Micro-organisms in Agriculture, Society for Applied Bacteriology Symposium Series No. 15*. pp 9–26. Oxford: Blackwell Scientific Publications.

WEDDELL J.R. (1995) The effects of additives on big-bale silage. *Proceedings of the 7th International Symposium on Forage Consevation. Nitra, Slovak Republic*. pp. 121–124.

WOOLFORD M.K. (1984) *The Silage Fermentation*. New York: Marcel Dekker.

(Received 4 January 1996; revised 1 April 1996)