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SIXTH SILAGE CONFERENCE

SUMMARY OF PAPERS

SILAGE PRODUCTION AND UTILIZATION

1981

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EDINBURGH.

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Finally, participants are indebted to the staff of Queen Margaret College for the facilities and services provided for this Sixth Silage Conference.

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INTRODUCTION

N.F. ROBERTSON

THE EDINBURGH SCHOOL OF AGRICULTURE.

When the first Conference was initiated by Dr. Peter McDonald and Professor W.F. Raymond in 1970, its potential growth and development could hardly have been foreseen. Its importance has grown for workers from the U.K. and from overseas, as a vehicle for the exchange of information and for the discussion of the strategy for further development.

At the last Conference held at the Hannah Research Institute, Ayr, in 1978, it was decided to publish the proceedings of the meeting in summarised form which would be available to other research workers and abstracting Journals. This procedure has also been adopted at the present meeting.

There has been a most encouraging response to the present Conference and in spite of the current economic restraints we have wide representation from overseas Universities and Research Institutes.

The papers selected at this meeting cover an extensive range of topics concerned with silage and we have introduced for the first time a poster session which we hope will give delegates an opportunity for informal discussion on the areas of specialised interest. I need hardly stress the crucial importance of a high level of silage technology for the adequate, between season, storage of conserved forage for animal production in large areas of the world. The Conference plays an important part in the advancement of that technology.

Dr. A.R. Henderson, of the Edinburgh School of Agriculture has acted as Secretary for the Conference, and all members are most grateful to her.

SESSION 1 BIOCHEMICAL AND MICROBIOLOGICAL STUDIES ON SILAGE (1)

PAPERS 1 - 4

CHAIRMAN - PROFESSOR N.F. ROBERTSON

Paper No. 1.

A STUDY OF THE FERMENTATION PATTERNS OF FIVE GRASS SPECIES

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The practical advantages of making silage relative to hay, in being less dependent on fine weather and having the potential of providing highly digestible fodder are well known. This has led to a steady increase in silage making in Ireland over the last 10 years and about 13 million tonnes are now made annually. About 85% of the grass used comes from old permanent pastures of mixed composition. About 30% of the silages fail to reach stable pH values. The reasons for this are unknown but are under investigation. There is evidence in the literature that this problem also occurs in the U.K.

In a 4 year study it was found that grass genus has some influence on the fermentation of grass silage. Ryegrasses (*Lolium sp.*) generally made excellent silages, other grasses notably *Dactylis glomerata, Festuca rubra,* and *Agrostis tenuis* gave many failures. *Agrostis* is fairly widely distributed in permanent pasture grass.

The following study is an extension of the above in which *Holcus lanatus, Poa trivialis, Festuca rubra, Dactylis glomerata* and *Lolium multiflorum* were ensiled on May 13 (cut 1) and June 25 (cut 2) in laboratory silos, and microbiological and chemical changes monitored on days 0,3,6,9,13 and 22.

Cut 1 silages were all well preserved. The pH of the *L. multiflorum* silages were significantly lower ($p<0.01$) than the others, and *P. trivialis* just reached a value that assured stability. In the cut 2 silages *L. multiflorum* and *H. lanatus* had significantly lower ($p<0.01$) pH levels than the others, while *D. glomerata* and *P. trivialis* both showed marked signs of instability.

In both cuts 1 and 2, total viable counts and lactobacilli showed rapid growth over the first 3 days followed by a slow steady decline. Coliform bacteria and yeasts declined rapidly from day 0 and had virtually disappeared by day 6.

The results confirmed a previous finding that certain grasses are relatively difficult to ensile. This is not attributed to a shortage of lactobacilli as their growth followed similar pathways in all the grasses. Grasses with the highest pH values on day 22 had also the highest counts of lactobacilli. Coliforms and yeasts which disappeared in a few days did not explain the differences noted between grasses. The results suggest that elevation of pH in some silages is due to neutralisation of the lactic acid by NH_3 and not to the metabolism of lactic acid which may take place at a later date.

In general, chemical measurements correlated poorly with silage quality. The reason why certain grasses are difficult to ensile still remains to be elucidated.

Paper No. 2.

RELATIONSHIPS BETWEEN CROP COMPOSITION AND SILAGE COMPOSITION

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The objective of this study was to determine how, and to what extent, the pattern of fermentation of crops ensiled without additives could be predicted by the quality of crops before ensilage.

A total of 231 silages made without additives were studied. Of these, 50% were from grasses (mostly *Lolium perenne*), 30% were from legumes (mostly *Medicago sativa*), and 20% were from annual forage crops (mostly *Zea mays*). All crops were harvested with a precision-chop machine and ensiled for a minimum of 60 days. Either laboratory silos were used, or well-sealed experimental silos with a capacity of up to 20 t fresh weight. Most of the crops were ensiled without wilting. The crop and silage characters used in the analysis are listed below:

Silage composition:

1. pH;
2. Water soluble carbohydrate, % fresh weight; (Z)
3. Total acids, % fresh weight;
4. Lactic acid, % total acids;
5. Acetic acid, % total acids;
6. Propionic acid, % total acids;
7. Butyric acid, % total acids;
8. Ammonia - N, % total N.

Crop composition:

1. Dry matter, %;
2. pH;
3. Water soluble carbohydrate, % fresh weight;
4. Buffering capacity (PK), m equiv. per 100 g fresh weight;
5. Z/PK;
6. Nitrogen, % fresh weight.

Multiple regression analysis is often used to investigate this type of problem but is often unsatisfactory. Two or more models which use different sets/...

sets of independent variables may give similar fits and this makes interpretation difficult. A large residual standard deviation will mean that the model is a useless predictor. Furthermore, in the present investigation, quality of preservation is determined not by one variable but by several variables acting together, and multiple regression only analyses one response variable at a time.

The techniques of multi-variate analysis allow several variables to be studied simultaneously. The eight silage characters listed previously were used to calculate a measure of similarity between each pair of silages. Furthest neighbour cluster analysis was then used to classify the silages into seven groups; three groups were considered to be well preserved, and four poorly preserved. Mean values of both crop and silage variables in all groups are tabulated in Wilkinson *et al* (1981). A brief summary of the seven groups is given below.

1. Group A contained few silages. These had undergone a restricted fermentation, but were well preserved with no butyric acid and little NH_3-N.
2. Groups B and C contained a large number of silages and were well preserved, but had different proportions of acetic and lactic acid.
3. Group D had a high pH and a high proportion of acetic acid, but little butyric acid and NH_3-N
4. Group E had a high pH, little lactic acid, and high proportions of lactic, acetic and butyric acids.
5. Groups F and G had a high pH, little lactic acid, and high proportions of acetic and butyric acids, and NH_3-N.

Groups A to G do not occur naturally; they represent an arbitary division of points in a continuum. Dimension reducing methods verify that the groups do not overlap.

All six crop variables differed significantly between the silage groups, but taken singly they were poor in allocating individual silages to groups. The poorly preserved groups all had lower "Z" contents than the well preserved groups and were also lower in DM and "Z/PK". Crop variables taken together may perform better and this is being investigated.

Reference: Wilkinson, J.M., Chapman, P.F., Wilkins, R.J. and Wilson, R.F. (1981) Interrelationships between pattern of fermentation during ensilage and initial crop composition. Proceedings of the 14th International Grassland Congress, Lexington.

Paper No. 3.

A BI-STABLE MODEL OF THE ENSILING PROCESS

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During ensiling, microbial and biochemical processes occur, which are intended to lead to the preservation of the material for subsequent feeding to animals. In simple terms, there are two qualitatively different possible outcomes, which are the result of the type of fermentation that takes place.

This investigation aims at a clearer understanding, and hence possibly better control, of the anaerobic phase of ensiling by means of a mathematical model. This incorporates the dominant interactions of lactic acid and butyric acid producing bacteria with carbohydrates, to predict a time course for fermentation. The weaker effects, involving for instance proteolysis, may be incorporated subsequently.

In the model, fresh silage is classified into water and dry matter by weight, and the main components of the dry matter are water soluble carbohydrates, lactic acid and lactates, butyric acid and butyrates, lactic acid bacteria and clostridial bacteria. Thus, the species of bacteria active during the anaerobic phase of ensiling are represented in the model by two types; the lactic acid bacteria that convert carbohydrates into lactic acid and the clostridia which convert the lactic acid into butyric acid. The concentrations of these five quantities are the state variables of the model, whose values completely define the system at any point in time.

An essential feature of the model is the pH dependence of the clostridial activity. pH is calculated from an empirical equation involving pK values and concentrations, the initial pH and a parameter reflecting the buffering capacity of the silage. The growth equations for the clostridia have, as a factor, a function of pH which allows the clostridia to flourish only above a critical pH value.

Water soluble carbohydrates are utilized by lactic acid bacteria at a rate proportional to the concentrations of carbohydrates and lactic acid bacteria, producing lactic acid and more lactic acid bacteria. Similarly, the clostridia are involved in utilizing lactic acid to produce butyric acid and more clostridia. The production rates are made proportional to the utilization rates using relevant yield factors, and death rates for the bacteria are incorporated. Five differential equations for the five state variables are obtained, which require fourteen parameters and five initial/...

initial values for integration. Some predictions of the model are shown in Table 1.

Table 1. Herbage soluble carbohydrate content and level and stability of silage pH.

Herbage DM content (%)	Water soluble carbohydrates (%DM)	Water soluble carbohydrates (kg/m^3)	Critical pH value	Minimum pH value	Minimum pH value (day)	Stable pH value	Start of stable pH (day)
15	10	18	4.0	3.93	16	4.80	55
20	10	25	4.5	-	-	3.91	11

When the carbohydrate concentration (kg/m^3) is high, the pH is reduced to a stable value of 3.91 on day 11; the lactic acid bacteria population reached a peak after 9 days and declined thereafter and that of the clostridia remained negligible. When the carbohydrate concentration (kg/m^3) is low, the pH is reduced to 3.93 on day 16 and then increased to a stable level of 4.8 from day 55 onwards. The clostridial population increased throughout.

Paper No. 4.

EFFECTS OF ADDED GLUCOSE AND STARCH ON THE OCCURRENCE OF AEROBIC DETERIORATION IN GRASS SILAGE

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In order to study the factors influencing the susceptibility to aerobic deterioration of silage, the effects of the addition of available carbohydrates at different dry matter (DM) levels were investigated.

Four separate experiments of the same design were conducted with Italian ryegrass *(Lolium multiflorum)* collected after pre-wilting from different fields on different dates. The DM contents were 32.1, 38.1, 40.3 and 60.7% for Experiments 1, 2, 3 and 4, respectively. Each experiment had eight treatments as shown in Table 1:-

Table 1. Experiment treatments.

	Water addition at ensiling	
	0%	20%
Control	1*	5*
Glucose 2% at ensiling	2	6
Starch 2% at ensiling	3	7
Glucose 2% at opening	4	8

* Treatment No.

After ensiling in PVC bag silos for 115 to 165 days, the silages were transferred to cylindrical containers of foamed polystyrene and kept in a room at 25°C for 7 days with the surface exposed to the air. The temperature of the silages in the containers was monitored, and chemical and microbiological analyses were conducted with the silages immediately after opening the PVC silos (Day 0) and after the 7-day aerobic exposure period (Day 7).

At the time of opening the pH values were lower with the silages made by water addition irrespective of the carbohydrate treatments. All of the control silages were of good quality, and lactic acid contents were not increased by the addition of glucose and starch at ensiling except the water addition group in Experiment 4.

Glucose addition either at ensiling or at opening, and starch addition at ensiling had no consistent effects on the viable counts of bacteria, yeasts and moulds at opening and on their increases during the 7-day aerobic exposure period. Changes in temperature, pH and chemical composition of the silages during the aerobic exposure period were not affected by the carbohydrate treatments.

Table 2. Viable counts of yeasts in silages kept under the aerobic conditions (Log cells g^{-1} fresh matter)

Experiment	Day	Treatments 1	2	3	4	5	6	7	8
1	0	2.89	4.23	3.54	2.89	1	1	1	1
	7	4.68	6.65	5.27	5.46	1	1	1	1
2	0	3.17	3.53	3.80	3.17	1	1	1	1
	7	5.69	5.80	5.21	6.42	2.15	3.31	1.74	3.49
3	0	4.32	5.11	4.85	4.32	4.32	4.36	4.42	4.32
	7	7.87	8.07	8.04	8.22	8.25	8.34	8.38	8.59
4	0	6.18	6.06	6.32	6.18	3.92	5.06	5.24	3.92
	7	8.66	8.63	8.51	8.70	7.42	9.06	8.12	7.57

Although small differences in the viable counts of bacteria and of moulds among the experiments were observed, the counts of yeasts on Day 0 and Day 7 were higher in Experiments 3 and 4 than in Experiments 1 and 2 (Table 2). The temperature of the silages under the aerobic conditions did not rise for 4 days in Experiments 1 and 2, whereas the rise started within 2 days in Experiments 3 and 4. In Experiments 1 and 2, addition of water at ensiling reduced yeast counts at the time of opening.

These results suggest that the occurrence of aerobic deterioration in good quantity grass silages by the luxuriant growth of yeasts is likely to be affected by DM content rather than the existence of sugars.

SESSION 2 BIOCHEMICAL AND MICROBIOLOGICAL STUDIES ON SILAGE (2)

PAPERS 5 - 8

CHAIRMAN - DR. Y. OHYAMA

Paper No. 5.

SPORES OF LACTATE-FERMENTING CLOSTRIDIA IN GRASS SILAGE

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Grass silages often contain high numbers of clostridial spores and the milk can be contaminated with these spores. When the milk is used for cheese making, nitrate has to be added to prevent the clostridial blowing of hard cheeses.

The aim of the present investigation is to understand the factors that govern clostridial growth in wilted silage.

The lowered water activity of wilted silage inhibits clostridial growth but nevertheless high dry matter silages sometimes contain more than 10^6 spores g^{-1}. A possible explanation was thought to be the heterogenous distribution of water in silages.

A number of farm silages were examined for their heterogenity. A vertical core with a diameter of 1.8 cm was drawn from silage clamps, transported intact to the laboratory and divided into slices. In each slice, corresponding to about 3 cm silage height, the spore number, dry matter content and pH was estimated. The results presented in Table 1 illustrate that the parameters can vary widely within one silage. Often the slices with high spore counts had a low dry-matter content. Parts with an extremely high pH (>7) had always a high number of spores, but the opposite was not true. Slices with a moderate pH ($5 < pH < 6$) and high dry matter content (> 40%) could also have high numbers of spores. It appeared that silages made from wilted grass and chopped before ensiling were more homogenous and had lower spore counts than silages harvested with a self-loading forage wagon.

Table 1/...

Table 1. Range of air-dry matters, clostridial spore counts and pH values in cores of nine farm silages.

Silage number	Dry matter (%)	pH value	Log. spores g^{-1}
1	50 - 67	5.6 - 6.1	< 2.6 - 2.9
2	31 - 45	4.3 - 6.1	< 2.6 - 4.1
3	31 - 47	4.5 - 8.1	< 2.6 - 5.6
4	36 - 61	4.6 - 6.0	< 2.6 - 4.1
5	32 - 58	4.6 - 5.9	< 2.6 - 4.4
6	21 - 40	4.6 - 5.6	4.6 ->6.4
7	25 - 46	4.9 - 7.9	3.6 ->7.4
8	24 - 76	5.2 - 7.0	< 3.6 ->6.4
9	50 - 75	4.9 - 7.3	< 2.6 - 4.0

In addition to the moisture content, the nitrate content of the grass and its metabolism during fermentation were found to be of considerable importance for clostridial growth. The influence of nitrate metabolism was studied in laboratory experiments. The laboratory silos were designed to permit repeat sampling of the grass and the gases in the headspace. It appeared that nitra was formed within a few hours after ensiling and reached maximum levels of 100-400 mg kg^{-1} fresh weight after 1 - 3 days with a rapid decline afterward Nitric oxide showed a similar pattern of production and disappearance but wa somewhat slower as compared to nitrate. Concentrations up to 8% nitric oxid were measured. Both nitrite and nitric oxide were shown to be effective inhibitors of clostridial growth during silage fermentation.

Spores were counted by a most probable number technique with the formation o gas in the anaerobically incubated lactate-acetate agar as a criterium for growth. Unfortunately, not only the spores of lactate-fermenting non-proteolytic clostridia were counted by this method but also those of the pro eolytic type. To obtain an impression of the developing clostridial microbi 77 strains were isolated from laboratory silages and roughly characterised. Thirty-seven strains were proteolytic lactate-fermenting clostridia. Sevent of the 41 non-proteolytic strains fermented lactose. The remaining 24 strai included *C. tyrobutyricum*. These results indicate that spores of *C. tyro-butyricum*, the most feared clostridium in cheese making, make up only a part the lactate-fermenting clostridial spores in silage.

Paper No. 6.

THE EFFECTS OF "H/M INOCULANT" ON SILAGE FERMENTATION

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"H/M Inoculant" is a selected, specific strain of dormant *Lactobacillus acidophilus* and is claimed to convert efficiently sugar to lactic acid with the minimum of loss. The recommended application rate is 0.5 kg of additive per t of forage and the bacteria quickly multiply to a high concentration. To be an effective additive however, these organisms must multiply more quickly and dominate the naturally occurring lactobacilli on the harvested grass. They must also convert the plant sugars to lactic acid more quickly and more efficiently than the naturally-occurring bacteria and thereby conserve sugars and reduce dry matter losses.

At Leeds, ryegrass cut in late September 1980 was ensiled in 50 t bunker silos and in 8 laboratory silos of 30 kg capacity. The grass was wilted prior to ensilage to about 280 g kg^{-1} DM and was ensiled within 24 h. In the farm silos Add F, at a rate of 1.6 l t^{-1} was compared with H/M Inoculant at a rate of 0.57 kg t^{-1} whereas in the laboratory silos the H/M treated grass was compared with untreated grass. Four samples were taken from each silo on days 0, 1, 4, 7, 14, 20, 60, 101 and 144 post ensilage to assess the main fermentation changes (Table 1).

At Bangor (Table 2) grass containing 189 g kg^{-1} DM and 81 g kg^{-1} DM WSC was ensiled in a series of 96 laboratory silos consisting of 150 ml glass test tubes fitted with fermentation locks in rubber bungs. There were 4 treatments; Control, H/M Inoculant at 0.5 kg t^{-1} (H/M x 1), H/M Inoculant at 1.0 kg t^{-1} (H/M x 2) and Add F at 3.1 kg t^{-1}. Three silos per treatment were opened on 1, 2, 3, 4, 7, 10, 21 and 60 days post ensilage. The results are given in Table 2.

At Newcastle grass cut in mid July was ensiled in 15 laboratory silos of 20 kg capacity. The material was wilted and ensiled at 309 g kg^{-1} DM and 124 g kg^{-1} WSC. There were 3 treatments; Control, H/M Inoculant applied at 0.5 kg t^{-1} (HML) and H/M Inoculant applied on the farm at 0.5 kg t^{-1} (HMF). The mean results are given in Table 3.

Table 3. Silage analyses (Newcastle).

WSC (g kg^{-1} DM)			Lactic acid (g kg^{-1} DM)			pH		
Control	HML	HMF	Control	HML	HMF	Control	HML	HMF
17	12	20	74	81	70	4.2	4.2	4.3

Table 1. Silage analyses, 0 - 144 d post ensilage (Leeds).

	Laboratory silos				Farm silos			
	WSC (g kg^{-1} DM)		Lactic acid (g kg^{-1} DM)		WSC (g kg^{-1} DM)		Lactic acid (g kg^{-1} DM)	
Days	Control	HMI	Control	HMI	Add F	HMI	Add F	HMI
0	153	125	5	-	90	81	-	9
1	39	38	29	37	70	57	20	34
4	36	24	43	42	43	26	28	40
7	27	20	53	51	29	18	28	53
14	-	-	-	-	-	-	47	59
20	-	-	90	72	-	-	58	64
60	-	-	84	76	15	13	57	65
101	-	-	-	-	-	15	62	64
144	-	-	-	-	15	10	64	72

The pH values in laboratory and farm silages were 4.0 and 4.1 respectively by d 20. In farm silos, the pH was 4.3 and 4.2 for Add F and HMI silages respectively by d 144.

Table 2. Silage analyses, 1 - 60 d post ensilage (Bangor).

	WSC (g kg^{-1} DM)				Lactic acid (g kg^{-1} DM)			
Days	Control	HMx1	HMx2	Add F	Control	HMx1	HMx2	Add F
1	65	53	50	79	28	21	30	2
2	48	47	47	75	41	33	43	6
3	39	37	34	71	51	53	51	8
4	39	46	42	72	57	54	57	17
7	27	21	20	71	78	78	73	18
10	24	10	13	65	89	96	86	23
21	26	10	10	78	80	107	94	29
60	6	15	6	48	103	105	112	64

On d 1 pH values for Control, HMx1, HMx2 and Add F treatments were 6.0, 5.9, 5.7 and 4.8 and by d 21 were 4.3, 4.3, 4.3 and 4.6 respectively.

The mean analyses for 73 samples of commercial silage where H/M Inoculant had been used showed pH values of 4.7, 4.7, 4.3 and 4.2 where DM contents were 180, 210, 230 and 247 g kg^{-1} respectively. Whilst the fermentation quality of the silages with a DM content above 220 g kg^{-1} might be expected to be satisfactory, the high pH values found with the wetter silages indicate insufficient acidity to provide a stable product.

In conclusion (i) H/M Inoculant supported a quicker and a higher concentration of lactic acid in the farm bunker silos, but this was not found in the laboratory silos. (ii) there was no evidence that H/M Inoculant had either changed the fermentation pathways or conserved plant sugars. (iii) fermentation quality of the experimental silages was similar on all treatments. (iv) limited data from farm silages with low DM failed to show any real benefit from the use of H/M Inoculant.

Paper No. 7.

STARTER ADDITION TO IMPROVE SILAGE QUALITY

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Lactic acid producing bacteria have been tested as a silage additive. This additive should improve silage quality by a rapid increase in lactic acid, a drop in pH and a decrease in the amount of yeasts and moulds. It is also more pleasant to handle than an acid additive.

The Starter culture used was a water solution of *Pediococcus acidilactici* and *Lactobacillus plantarum* applied at the forage harvester in the conventional manner. This mixture supplied 10^6 bacteria per g of fresh grass. The other three treatments were Starter + 10% grain, formic acid at 4 l t^{-1} and a no additive control.

A grass clover sward was direct cut with a chop length of 20 mm and filled into two types of silo as follows:

a) 10 kg experimental silos: opened after 1, 2, 4, 8 and 16 days to measure rate of fermentation and final quality.

b) 1 t pilot silos: used to measure silage nutritive value and losses.

In a further experiment, Starter and formic acid silages were stored in 10 kg silos at +5^0 C, +15^0 C and +24^0 C in order to record the rate of fermentation at different temperatures. The silos were opened after 2, 4, 8, 16 and 30 days.

Results from the 10 kg experimental silos indicate that the Starter addition gave a rapid production of lactic acid and a rapid drop in pH compared to formic acid. After 1 day 40% of the total lactic acid was produced. The final level of lactic acid in the formic acid silage was only 40% of that in the Starter and Starter + grain silage treatments. The ammonia-N (% TN) was 2% in the formic acid silage and 3% and 4% in the Starter + grain and Starter treatments respectively. Yeasts and moulds were 10 times greater in the formic acid silage than in the other treatments.

Table 1 presents the data from the pilot silos. Formic acid and Starter silages were similar. Increasing the dry matter by adding grain decreased DM losses and increased nutritive value.

Table 1. Nutritive value and DM losses (1 t pilot silos).

Treatment	DM (%)	OM (% of DM)	CP (% of DM)	ME ($MJ\ kg^{-1}$ DM)	DM losses (%)
Grass	18.1	90.5	13.5	10.1±0.1	-
Control	19.0	90.9	13.5	10.0±0.1	8.9
Formic acid	19.8	91.0	12.9	10.2±0.1	5.7
Starter	18.9	91.0	15.1	10.3±0.1	6.4
Starter + grain	25.3	92.2	13.4	11.5±0.1	3.3

The effect of storage temperature on fermentation indicates little activity when held at $+5^0$ C in either of the treatments although the formic acid silage was at a lower pH. At temperatures of $+15^0$ C and $+24^0$ C, fermentation was similar to that obtained in the 10 kg experimental silos.

In conclusion, the Starter when added to supply 10^6 living bacteria per g fresh grass, appeared to be as effective an additive as formic acid at temperatures over $+15^0$ C. An attempt is now being made to find cold resistent bacteria to ensure better results during cold weather conditions.

Paper No. 8.

AMMONIA AS A SILAGE ADDITIVE

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Whole-crop cereal silage attracts increasing attention from farmers in several countries, particularly where silage maize cannot be grown successfully. In Denmark an increasing number of farmers grow whole-crop cereal silage, and barley is the main cereal. Whole-crop cereals harvested 3-5 weeks after ear emergence can be ensiled with good results without the use of additives, if anaerobic conditions are established. Results from the ammonia treatment of straw, maize and wet hay make it reasonable to expect some advantageous effects of ammonia on whole-crop cereal silage.

In 1980, investigations were started to elucidate possible affects of ammonia on whole-crop barley silage. The following preliminary results are from laboratory experiments.

Barley was harvested at four stages of maturity (A, B, C and D), and ear emergence had started 4 weeks before the first harvest. The experimental crops were characterized by the following data:

Treatment	A	B	C	D
Date of harvest	29 July	8 Aug.	15 Aug.	26 Aug.
DM (%):	23	34	40	59

The finely chopped barley was ensiled in airtight, 2.8 m cylindrical silos. A control without ammonia (treatment 1) and two ammonia treatments (2 and 3), receiving 1.5 and 3.0% anhydrous ammonia respectively on a DM basis, were established.

In order to obtain an even distribution of ammonia, the silos were half filled and the ammonia was infused very slowly as the silos were rotated.

The silos were opened between 21 September and 3 October. The control silages were of good quality and had a normal chemical composition. The addition of ammonia decreased the contents of lactic acid in treatment A, B and C (Table 1). The contents of butyric acid increased in treatments A and B. The contents of total nitrogen, NH_3-N and pH increased markedly with the ammonia treatment.

Table 1. Analyses of silages.

Barley Treatment	Lactic acid	Butyric acid	Total N	NH_3-N	pH	OMD
	% of silage DM					
A1	6.84	0.00	1.92	0.22	4.1	64
A2	3.06	1.34	3.17	1.36	5.6	69
A3	1.40	1.32	4.30	2.28	7.7	72
B1	5.53	0.00	1.75	0.18	4.2	60
B2	1.89	0.37	2.90	1.13	7.5	66
B3	2.43	0.27	3.73	1.77	8.7	[illegible]
C1	3.87	0.00	1.79	0.16	4.6	[illegible]
C2	1.14	0.15	2.75	1.10	8.3	[illegible]
C3	1.84	0.00	3.36	1.32	9.0	[illegible]
D1	1.30	0.00	1.64	0.10	6.1	[illegible]
D2	0.49	0.00	2.67	0.66	8.7	[illegible]
D3	1.75	0.00	3.17	1.02	8.9	[illegible]

There were problems connected with the sampling and preparing of samples a[illegible] the results are not yet complete. It seems as if the recovery of N varies from 70 and 100%. The drier the crop, and the more ammonia added, the low[illegible] was the percentage recovered. The even distribution of ammonia was not achieved in the wet silage from treatments A2 and A3, and these silages ha[illegible] very bad smell.

Silage from treatments B2, B3 and C2 also had a bad smell and about 2 week[illegible] later they had a smell of ammonia. This then turned to the normal smell o[illegible] high-quality whole-crop cereal silage.

The stability of the silages, expressed as weeks from exposing test samples the atmosphere to visible mould occurring was extended from 1 - 4 weeks for control silages to 10 - 11 weeks for silage from treatments 2 and 3.

Organic matter digestibility determined with sheep increased by 5 - 9% un[illegible] treatment 2, and by 8 - 14 percentage units on treatment 3. The increase [illegible] highest in the more mature crops.

The addition of 1.5 and 3.0% anhydrous ammonia to whole-crop cereals at e[illegible] ing exerted marked effect on the fermentation in the silages. The additio[illegible] 1.5% ammonia improved the silage stability, and the digestibility of the organic matter by 7 - 8 percentage units.

There are no reasons for the addition of more than 1.5% ammonia and it se[illegible] doubtful whether it is justified to add more ammonia in order to achieve [illegible] maximum digestibility of organic matter.

Several chemical, biological and technical problems concerning the use of ammonia as a silage additive are unsolved, and further investigations are necessary.

SESSION 3 UTILISATION OF SILAGE (1)

PAPERS 9 - 12

CHAIRMAN - PROFESSOR M. VANBELLE

Paper No. 9.

NITROGEN VALUE OF GRASS SILAGES FOR DAIRY COWS

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The exact N value of grass silages must be known in order to calculate their nitrogen supplementation correctly. Many recent studies have shown that, with grass silages, milk production increased when the supply of DCP went beyond theoretical recommendations. This is not observed with rations based on either hay or maize silage.

Thus, for the milk production of cows given grass silage, it is not possible to calculate an accurate DCP supply. Sometimes a milk production response is observed with a supply exceeding 100 g of DCP kg^{-1}milk (165% of the theoretical needs). With the DCP system, the real N value of grass silages depends not only on their CP content, but also on their conservation quality as shown by measurements of the non-ammonia N arriving in, and absorbed by the small intestine (cf. BEEVER).

Recent results from Castle and Gordon have supplied practical advice on how to supplement grass silage, but without sufficient accuracy, to predict the N value of the grass silages. The relatively high recommendations could result in wastage of concentrates with the well-preserved silages.

In addition to their N content the N value of grass silages, and other forages, depends on the following.

(1) The amount of dietary protein escaping rumen breakdown and entering the small intestine. This amount depends on the CP content of the silage and its breakdown in the rumen which can be predicted by the solubility measured in the laboratory.

(2) The amount of microbial protein synthesized in the rumen which is related to the balance and synchronism of the energy and N supplies available for micro-organisms. Organic matter digestibility and CP solubility are the main factors in this synthesis.

The PDI system*, which attempts to predict these two aspects of protein, should allow a better calculation of the N value of grass silages.

During the winter 1978-1979 a trial was conducted in which two very different silages were used; one was treated with formic acid, the other without. Maximum milk production was attempted by increasing the PDI supply. In this experiment and those reported at the previous seminar (1978) it appears, that milk production is related to the PDI and DCP supply. The trials confirmed that the PDI system allowed the N value of grass silages to be predicted somewhat better.

The fact that a milk production plateau appeared also led to a conclusion that the value of 55 g of PDI kg^{-1} milk could be recommended to calculate the value of grass silages (50 g for maize silage and hay).

The PDI system seems to overestimate the value of grass silages, but it can be improved, particularly when the factors that govern bacterial synthesis are better known. It is possible that the organic acids taken into account in calculating digestible organic matter did not participate in microbial synthesis, but other factors might have come into play, particularly the soluble carbohydrate content (Grenet).

Predicting the N value of grass silages is therefore particularly complex and its estimation for milk production is also complicated because intake often increases with the N supply to the animals. Thus it is difficult, when milk production increases, to separate the effects of energy and nitrogen supply. In order to economise in the use of concentrates for ruminants, it will be necessary to conduct more trials with dairy cows to try and predict the N value of grass silages.

*Footnote PDI system: True protein (TP) digested in the small intestine.
PDI = undegraded dieting TP + microbial TP. Editor.

Paper No. 10.

A COMPARISON OF A RANGE OF GRASS SILAGE TYPES IN TERMS OF THEIR IN SACCO DEGRADABILITY

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ADAS, BRYN ADDA, BANGOR, GWYNEDD, WALES.

The degradability characteristics of a wide range of grass silage types were studied in bullocks, using the *in sacco* technique over a 48 h period. The nature of the silages is indicated in Table 1 and each was subjected to a range of standard chemical analyses.

Table 1. Characteristics of silage.

No.	Additive	Wilting time (h)	Remarks	Oven DM ($g\ kg^{-1}$)	CP in DM ($g\ kg^{-1}$)	NH_3-N in total N	*In vitro* D value
1	None	24	UK winner	415	161	0.05	0.70
2	HCOOH	8-20	Good	311	163	0.08	0.61
3	None	12-24	Good	285	161	0.08	0.65
4	None	Up to 24	Bad	146	316	0.68	0.49
5	HCHO/HCOOH	12-24	Good	240	145	0.07	0.60
6	$HCHO/H_2SO_4$	None	Italian RG	208	124	0.06	0.59
7	HCOOH	24-48	Bad	177	160	0.37	0.48
8	HCOOH	36	Overheated	493	126	0.04	0.37

Each silage was examined in three bullocks on two occasions, with pairs of bags being withdrawn at each sample time. Bullocks had an average live weight of 270 kg and were given silage, molassed sugar beet pulp and barley meal (5 : 3 : 2 DM basis) supplying 55MJ ME daily.

The losses of DM, N, cell contents, hemicellusose and cellulose from the bags were followed. For the carbohydrate fractions modifications of the methods of van Soest were used. For each of these components equations of the form:- $p = a + b\ (1 - e^{-ct})$ were fitted where a and b represented percentages of the chemical components originally present in the silage and c the proportional rate of degradation. Preliminary results provided the following information.

Nitrogen. The initial loss (a) was related to the proportion of N soluble in hot water (HWIN) (a = 100 - 75HWIN; r = 0.95) and the more slowly degradable fraction (b) to hot water solubility and the proportion of total nitrogen present in the neutral detergent fibre (CWN) (b = 104 HWIN - 81CWN - 9.1; R = 0.85). There were no significant differences in degradation rate (c), and the weighted mean value was - 0.077.

Cell contents. The percentage lost initially was related to the proportion of cell contents in silage dry matter (CC) (a = 156CC - 13.6; r = 0.85). The weighted mean values for b and c were 32.2 and - 0.062 respectively.

Hemicellulose. The percentage lost initially was small (weighted mean = 5.3). There were no significant differences between silages in the percentage ultimately degradable (a + b) or in degradable rate. The weighted mean values for b and c were 87.7 and - 0.030 respectively.

Cellulose. The percentage lost initially was 12.2 (weighted mean) and the percentages ultimately degradable were not signficantly different between silages. Weighted means for b and c wer 72.6 and - 0.037 respectively.

The ability of these equations to predict the degradation of DM and N at various times is shown in Table 2. Clearly the prediction equations should be tested on other silages and with bullocks offered other rations.

Table 2. Predicted (P) and actual (A) DM and N losses (*per cent* of original amount).

Time	Silage No.															
	1		2		3		4		5		6		7		8	
(h)	P	A	P	A	P	A	P	A	P	A	P	A	P	A	P	A
							Dry matter									
4	51	51	41	42	38	37	33	30	35	43	32	36	33	34	33	43
16	68	69	59	61	56	55	51	50	53	59	50	52	51	51	48	53
48	86	90	78	80	76	77	72	76	73	75	72	72	71	70	65	66
							Nitrogen									
4	75	78	67	65	62	60	84	86	58	62	70	75	73	77	54	56
16	86	90	79	80	77	75	89	91	74	79	82	84	85	86	64	65
48	92	95	86	90	86	87	91	93	84	83	89	88	92	86	69	70

Microbial protein synthesis requires energy largely derived from carbohydrate fermentation and the differences in the pattern of nitrogen and carbohydrate degradation noted may influence synthesis. Silages with a high initial loss of nitrogen and no concurrent loss of dry matter may not be highly suited for microbial synthesis.

Paper No. 11.

IN SACCO DEGRADABILITY OF NITROGEN IN SILAGES MADE WITH VARIOUS ADDITIVES

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Silage additives have been evaluated mainly in terms of the resulting fermentation pattern, and the extent of proteolysis within the silo. A further aspect of silage quality, which is of considerable nutritional importance, is the rumen degradability of the N fraction of the silage. Certain additives, notably formaldehyde, have been reported to reduce the rumen degradability of silage N. The following work was designed to investigate the effect of silage additives, applied to grass before ensiling, on the rumen degradability of the resulting silages.

The silages were prepared from chopped (20 mm) grass, and the additives were applied at the manufacturers' recommended rate. The grass was then packed into laboratory silos, each holding approximately 2 kg. For each treatment, there were three silos. The silos were sealed, and held at ambient temperature for 120 d. At the end of this period, a sample of silage from each silo was taken for chemical analysis. Silage from the three silos within each treatment was then bulked for the assessment of rumen degradability by the *in sacco* incubation technique, using four rumen-fistulated heifers given silage only.

In experiment 1, a perennial ryegrass - white clover mixture was cut and ensiled without wilting on 7 August, 1980, and in experiment 2, perennial ryegrass was cut on 22 August, 1980, and wilted for 24 h before ensiling.

A summary of the analysis of the forage before ensiling and of the silages is shown in the table, with estimates of the proportion of true protein (determined by a dye-binding technique) degraded in the silo, and of the proportion of silage N degraded in the rumen at various incubation times.

In both experiments, "Sylade" was particularly effective in maintaining a high true protein content in the silage, while "Farmline", "Add-F" and (in experiment 2 only) "Farmos B15" additives resulted in true protein contents appreciably higher than that of the control silage.

The rumen degradability of silage N at short incubation times was lower for silages which had a high true protein content. However, no additive had any significant effect on the maximal degradability of the silages.

Treatment	Application Rate (ml kg^{-1})	DM (g kg^{-1})	pH	TN (g kg^{-1} DM)	Proportion of true protein degraded in silo	Proportionate rumen degradability of silage N after no. of h: 0	8	16	>50
Experiment 1									
Forage	-	129.3	-	26.7	-	-	-	-	-
Control	-	118.2	4.15	29.1	0.46	0.73	0.88	0.93	0.96
Add-F	2.0	121.7	4.02	28.4	0.34	0.75	0.87	0.93	0.97
Farmline	4.0	122.5	3.99	29.1	0.34	0.68	0.87	0.93	0.96
Sylade	4.0	118.0	4.43	30.0	0.23	0.71	0.87	0.93	0.95
SEM		1.8	0.026	0.34	0.015	0.010	0.004	0.004	0.018
Experiment 2									
Forage	-	303.0	-	21.9	-	-	-	-	-
Control	-	259.8	4.77	24.4	0.65	0.73	0.83	0.89	0.95
Add-F	2.0	257.7	4.78	22.2	0.57	0.69	0.83	0.90	0.95
Farmline	4.0	272.0	4.74	22.9	0.57	0.65	0.80	0.88	0.95
Sylade	4.0	278.3	5.49	22.4	0.47	0.62	0.76	0.85	0.96
Fodder-guard-S	2.0	265.3	4.60	23.7	0.62	0.70	0.81	0.87	0.95
Farmos B15	4.0	270.8	4.62	22.6	0.57	0.68	0.82	0.88	0.94
Silo-Action	0.15†	264.5	4.58	23.3	0.59	0.70	0.82	0.88	0.95
Foraform	2.0	273.4	4.61	22.6	0.61	0.71	0.83	0.89	0.96
SEM		0.80	0.024	0.13	0.009	0.007	0.003	0.004	0.007

† g kg^{-1}

Paper No. 12.

INTAKE, EATING PATTERN AND DIGESTION OF ACETIC ACID-TREATED SILAGES BY SHEEP AND HEIFERS

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The chemical composition and fermentation pattern of silages partially determine the level of voluntary intake. Acetic acid content was found to be negatively correlated with the voluntary intake. However the addition of acetic acid to well-preserved silage to act as a buffer did not decrease the voluntary intake. However, in more recent research, a significant negative relationship between acetic acid content and intake was found.

In micro-silos, acetic acid was found to have a similar effect to formic acid on fermentation, and thus, coupled with its potential fungicidal effect and its nutritive value for dairy cows, acetic acid appears to be a more attractive silage additive than formic acid.

The following two experiments were designed to test, in larger silos, the value of acetic acid as an additive and its possible influence on intake, digestion and eating behaviour in sheep and cattle.

In experiment 1, six 12-month-old and six 24-month-old Texel wethers and twelve 10-month-old Friesian heifers were fed *ad libitum* with either a control silage without added acetic acid or a silage with acetic acid. Both silages were pre-wilted and had a chop-length of 13.75 cm. The design was a two-period cross-over with periods of 28 d.

Dry matter and acetic acid content were 29.88%, 1.49% and 29.43%, 2.52% for the control and acetic acid-treated silages respectively. Both silages were well preserved.

No significant differences in intake, digestibility, eating and ruminating behaviour were found in the sheep and cattle. The N retention measured with six sheep was significantly higher with the acetic acid-added silage 5.40 g d^{-1} N, than with the control silage, at 3.24 g d^{-1} N.

In experiment 2 six 7-month-old Texel wethers were offered either a control silage with no additive or silage plus 0.34% formic acid or 0.32% acetic acid. The silages were pre-wilted and had a mean chop length of 1.74 cm. The design was a three-period cross-over design with periods of 21 d.

No significant differences in intake, digestibility, eating and ruminating behaviour were observed. The N retention with the acetic acid-treated silage was non-significantly higher than the control and formic acid-added silage by 12.8 and 34.9% respectively.

The nutritive value of the silage does not seem to be improved by the addition of either acetic or formic acid and the higher N retention with acetic acid-added silages will need further investigation.

SESSION 4 UTILISATION OF SILAGE (2)

PAPERS 13 - 15

CHAIRMAN - DR. M.E. CASTLE

Paper No. 13.

LACTIC ACID METABOLISM IN THE RUMEN OF ANIMALS GIVEN SILAGE DIETS

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Characteristically, with diets containing grass silage there are transient peaks in the molar percentage of propionic acid in the rumen after feeding although the average fermentation patterns throughout the day are rarely of a high-propionate type. Previous work suggested that there was a rapid fermentation of L(+) and D(-) lactic acid in the rumen of animals given silage and that the peak in propionic acid after feeding could arise from the ruminal breakdown of lactic acid in the silage. However, in sheep given grass silage, alone and in combination with barley, defaunation with dioctyl sodium sulphosuccinate led to a replacement of the peak in propionic acid 1 to 2 h after feeding by a peak in butyric acid 3 to 4 h after feeding, and this suggested that the production of propionic acid was related to the rumen protozoa.

To examine the effects of defaunation on the ruminal metabolism of lactic acid, two sheep receiving grass silage were given intra-ruminal doses (30 g) of DL lactic acid and the rumen fermentation pattern was monitored over the following 3.5 h. Samples of rumen liquor were taken every 20 min. for the first 2 hours and every 30 min. thereafter. The animals were then defaunated and 10 days later the experimental procedure was repeated. The results are summarised in Table 1.

Table 1. The fermentation pattern in faunated and defaunated sheep.

	Short chain fatty acids (molar %)					
	Sheep 1			Sheep 2		
	acetate	propionate	butyrate	acetate	propionate	butyrate
Faunated						
0	65.7	19.6	8.5	64.9	18.4	9.1
1	53.0	34.4	8.1	50.3	37.8	7.8
3	58.0	27.5	10.0	51.3	31.2	11.8
Defaunated						
0	64.6	23.1	7.5	67.6	21.6	7.2
1	50.9	22.4	21.8	45.0	24.6	26.7
3	45.7	22.7	27.4	39.8	24.5	31.7

Defaunation resulted in a change in the end products of lactic acid fermentation. Propionic acid was the major end product in faunated animals whilst butyric acid was the main end product in defaunated animals.

To investigate this effect further, incubations were conducted *in vitro* to study the metabolism of lactate by bacterial and protozoal fractions isolated from the rumen of a sheep receiving a diet of grass silage. Rumen contents were strained through two layers of muslin, and after the removal of small feed particles the protozoal fraction was obtained by centrifuging at 100 g for 5 min. Rumen liquor, free of feed particles and propozoa, was designated the bacterial fraction. For the incubations the protozoal fraction was resuspended in autoclaved cell-free rumen liquor and an antibiotic mixture was added to suppress the activity of any associated bacteria. L(+)-lithium lactate mg) was added to 25 ml aliquots of the bacterial and protozoal fractions and the disappearance of lactate measured during 3.5 h of incubation at 39^0 C. The rate of disappearance of lactate was expressed relative to the protein content of the respective fractions. The results in Table 2 suggest that lactate-metabolizing activity is predominantly in the protozoal fraction.

Table 2. The rates of disappearance of L-lactate during incubation with bacterial and protozoal fractions rumen of a sheep receiving a diet of grass silage Values are a mean and standard error for 5 incubations

Fraction of liquor	μg lactate disappearance (mg protein per h)
Bacterial	1.78 ± 0.28
Protozoal	23.58 ± 3.62**

** $p<0.01$

At this stage it is uncertain whether lactate metabolism observed in the protozoal fraction is either the result of protozoal metabolism *per se* or whether it originates in bacteria intimately associated with the protozoa. However, the inference is that with grass silage diets, protozoa play a central role in ruminal metabolism of lactic acid.

Paper No. 14.

RUMEN METABOLISM STUDIES WITH BIG BALE SILAGE

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Silage made in half tonne big round bales (A), was compared with the same baled silage precision chopped (85% < 100 mm) prior to feeding (B), and with conventional precision-chopped silage (C), made from the same crop of first cut, wilted, perennial ryegrass. Silages A and C were well preserved (Table 1) and of similar composition although the lower concentration of acids and higher concentration of water soluble carbohydrate (WSC) indicate a reduced fermentation in the big bale silage. The lower proportion of protein N suggests a delayed induction of fermentation.

Table 1. Compositions of the three silages.

	Silage		
	A	B	C
Toluene DM (g kg^{-1})	311	319	272
Total N (g kg^{-1} DM)	21.4	22.1	24.2
Volatile N (g kg^{-1} total N)	91	86	125
Protein N (g kg^{-1} total N)	295	278	398
WSC (g kg^{-1} DM)	42	43	3
Lactic acid (g kg^{-1} DM)	75	76	60
Acetic acid (g kg^{-1} DM)	13	13	40
Butyric acid (g kg^{-1} DM)	2	1	5

The three silages were compared in a metabolism trial using nine rumen fistulated sheep, in a cross over design. The sheep were given the silage once daily at 0900 h. DM intakes of the silages were 17.0, 16.7 and 16.5 g kg^{-1} W for treatments A, B and C respectively with no significant difference between treatments. Eating pattern was measured by weighing residues on 5 days in each of the three periods after 2½, 4½, 7½, 12 and 24 h access. Uneaten silage was immediately replaced, after each of the first four weighings. The pattern of eating was similar with all three silages.

DM and organic matter digestibilities were significantly lower for silage C than A and B (Table 2) but differences in nitrogen digestibility were not significant. ME values were significantly higher for silage B (11.8 MJ kg^{-1} DM) than A and C (11.3 MJ kg^{-1} DM).

Table 2. Digestibility values and rumen VFAs 2 h postfeeding (mmol mol^{-1} TVFA).

	Silage			
	A	B	C	SED
Dry matter	0.741^a	0.738^a	0.714^b	0.0061
Organic matter	0.759	0.759^a	0.731^b	0.0063
Nitrogen	0.699	0.716	0.690	0.0114
Acetate	604^a	622^a	662^b	14.7
Propionate	213	219	197	15.1
Butyrate	113^a	94^b	77^c	6.6

Means in the same row with different superscripts differ significantly ($P < 0.05$).

Samples of rumen contents taken 2 h after feeding are shown in Table 2. Differences between silages in rumen propionate, pH, TVFA and ammonia concentrations were not significant. The lower rumen acetate with silage A was compensated for by increased butyrate. Rumen butyrate was highest for silage A and lowest for silage C. Non-glucogenic ratios, at the time of maximum fermentation, were 3.4, 3.4 and 3.7, and acetate to propionate ratios were 2.8, 2.8 and 3.4 for silages A, B and C respectively.

Paper No. 15.

RATE OF PASSAGE MEASUREMENTS AS AFFECTED BY DOSING AT EITHER BEGINNING OR END OF A MEAL

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The voluntary intake of silage is related to its chemical composition and the physical structure of the ensiled forage. To further understand how silage is utilized, more information is needed on its physical fragmentation during digestion as such processes determine the rate of passage of undigested residues through the digestive tract. Measurement of rate of passage through the alimentary tract can be obtained by a single dose of marker applied to the consumed material. According to earlier studies on rumen motility and particle movement in the reticulo-rumen, especially during a meal, dosing time of the marked material could be of importance. The objective in this study was to determine if time of dosing relative to a meal could affect turnover rate estimates within the same animal. Silage feeding can be associated with the development of an interwoven particulate matt in the reticulo-rumen shortly after feeding which would restrain particle breakdown and flow as compared to particles ingested before feeding. Coastal Bermuda hay also produces such a matt in the reticulo-rumen and was used in preferance to silage in this study to test for any dose x meal interactions.

Two mature cows (Brahman x Jersey) each weighing 471 kg and one mature steer weighing 558 kg were given Coastal Bermuda *(Cynodon dactylon)* hay for 2 weeks and then individually offered two 3.5 h meals for 10 days before dosing. A masticated sample of the hay was obtained via oesophageal cannulae, extracted with boiling water for 2 h, thoroughly washed with water and dried. 100 g of the masticate was soaked in 800 ml of water containing $Tb(NO_3)$, equivalent to 6.9 g of Tb (Terbium). An additional 100 g was separately soaked in 900 ml of water containing 200 μ Ci ^{160}Tb overnight. The masticate was filtered, washed thoroughly with water and a total of 25 g of Tb-labelled masticate and 20 g of ^{160}Tb labelled masticate were placed in 10 gelatin capsules which were dosed via oesophageal cannulae to each animal. The ^{160}Tb was dosed at the beginning, and the Tb at the end of the AM meal. Samples of faeces were taken at 4 to 6 h intervals for 6 days. Specific activity of ^{160}Tb was detected with a Ge(Li) detector and the concentration of Tb was determined by neutron activation analysis. The specific activities were fitted to a 2-compartment time-dependent model, with K_1 representing the rate of passage from the rumen, and time delay the time between dosing and the first appearance of marker in the faeces. Rates of passage and time delay for the pre- and post-meal dosing are shown in Table 1.

Table 1. Rate of passage (K_2) and time delay (h)

Dose Time	K_2 (% per h)				time delay (h)			
Animal	1	2	3	Mean	1	2	3	Mean
Pre-meal	6.094	5.442	7.597	6.371	25.9	17.2	22.9	22.0
Post-meal	2.831	3.610	4.644	3.695	17.2	14.2	21.2	17.5

Passage estimates and time delay were reduced by 42% and 20% respectively when dosing occurred at the end of the meal. The dosing time is thus of real importance in estimating turnover rates, as well as a possible way for manipulating ruminal residence time.

SESSION 5 PRODUCTIVE VALUE OF SILAGE (1)

PAPERS 16 - 18

CHAIRMAN - MR. A. ADAMSON

Paper No. 16.

COLD-FLO[R] (NPN) AND NaOH ADDITIVES FOR MAIZE AND SORGHUM SILAGES

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Trials were conducted to evaluate ammonia and NaOH additions to whole-plant silages. Two maize silages, 36-38% DM at the dent stage, and three sorghum silages, [illegible] DM at the soft-dough stage, were made in concrete stave silos (3 x [illegible] m) in the autumn of 1979. Maize silage treatments were: no additive (C) and 4.55 kg of Cold-flo (Cf. 82% ammonia N). Sorghum silage treatments were: no additive (C); 5.52 kg of Cf; and 12.2 kg of NaOH per 1000 kg of fresh crop.

All loads were weighed and sampled, and five thermocouple wires were evenly spaced in the silos at filling. Maize silage silos were opened after 51 d; sorghum silos, after 41. All silos were emptied at a uniform rate and sampled weekly.

Visual appraisal indicated that all five silages were well preserved and with a few exceptions, chemical analyses were similar among the silages (Table 1). Of the Cold-flo nitrogen applied to the ensiled forages, 57.9% was recovered in the maize silages and 76.3% was recovered in the sorghum silage.

In maize silages, Cf increased average ensiling temperature by 6^0 C during the first 7 days but decreased average temperature by 3^0 C during the first 7 days in sorghum silage. In both trials fermentation, storage, and feedout losses were lowest for the control silages. Dry matter recovered and fed (% of the DM ensiled) was: maize silages C, 93.3 and Cf, 88.5; sorghum silages: C, 91.0; Cf, 94.9; and NaOH, 78.9.

Table 1. Analyses of maize and sorghum silages.

Silage	Dry matter (%)	Crude protein (% of DM)	pH	Lactic acid (% of DM)	Butyric acid (% of DM)	Ammonia N (% of total N)
Maize, control	36.4	8.6	3.6	3.1	0.01	5.0
Maize, Cold-flo	36.4	11.2	4.0	4.4	0.09	37.3
Sorghum, control	34.0	7.4	4.0	2.9	0.03	4.2
Sorghum, Cold-flo	31.1	13.0	4.6	3.2	3.99	39.3
Sorghum, NaOH	30.6	6.4	4.2	5.2	0.13	3.6

Table 2. Performance of steers offered the three maize silage rations for 78 d.

Daily gain/ feed intake	Control + soyabean	Control + urea	Cold-flo + sorghum grain
Gain, (kg d^{-1})	1.12	1.04	1.08
DM intake, (kg d^{-1})	8.57	8.70	8.74
DMI per kg gain	7.72^{a}	8.40^{b}	8.10^{a,b}

^{a,b}($P<.05$)

Three maize silage rations were given to 20 steers in 4 pens of 5 steers (292 kg initial wt): C + soyabean mean (SBM); C + urea (to supply 26% of CP in ration); and Cf + rolled sorghum grain. Three sorghum silage rations were given to 18 heifer calves in 3 pens of 6 calves (188 kg initial wt):C + SBM; Cf + sorghum grain; and NaOH + SBM. All supplements were fed at 0.91 kg d^{-1} $animal^{-1}$.

Table 3. Performance of heifers offered the three sorghum silages for 84 d.

Daily gain/ feed intake	Control + soyabean	Cold-flo + sorghum grain	NaOH + soyabean
Gain, (kg d^{-1})	.53^{a,b}	.49^{b}	.59^{a}
DM intake(kg d^{-1})	5.66^{b}	5.07^{c}	6.01^{a}
DMI per kg gain	10.66	10.34	10.19

^{a,b,c}($P<.05$)

Cattle performance results are shown in Tables 2 and 3. With the maize silages, steers fed C + SBM outperformed those fed C + urea. For sorghum silages, calves fed NaOH gained 12% faster, but calves fed Cf, 7.5% slower than those fed C. NaOH silage was consumed in the greatest amount, Cf silage, the least.

Silage aerobic stabilities were determined by loosely packing 12, 2.0 kg replicates of each silage in polystyrene bins and exposing them to air at an ambient temperature of 18.3^{0} C. Silage was taken from the bottom 1/3 of each silo and at a 1 m depth below the surface.

Aerobic stability results show initial temperature rise above ambient for sorghum silages occurred on day 5.2 and 9.6 for C and NaOH, respectively. Control maize silage heated on day 10, while both Cf silages did not heat during 14 days of air exposure.

Paper No. 17.

SILAGE DRY-MATTER CONTENT AND ANIMAL PERFORMANCE

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Previous work at Liscombe has shown the benefits of wilting grass in terms of silage fermentation and liveweight performance of young beef animals. More recent observations have demonstrated that good animal performance was possible from "wet" grass which had been well preserved with an additive. The overall efficiency of systems of silage making based on either unwilted or wilted grass was therefore considered.

In the trials reported two factors were considered. Firstly, the use of additives on wilted grass. At Liscombe there has never been a significant benefit from using acid based additives in the wilting situation, but there may be possibilities with the formalin based products particularly from the "protein protection" aspect. Secondly, with the rapidly growing interest in silage for sheep it was of some concern that most of the information available related mainly to adult wethers.

In 1980 cut 1 (June) and cut 2 (July) grass was ensiled separately. At each cut there were 3 treatments each ensiled in a 150 tonne covered bunker silo.

1. Unwilted - cut with a mower/conditioner and picked up with a precision-chop forage harvester immediately to simulate direct cutting. Formalin/ formic acid additive applied. (UNA).

2. Wilted - cut as above, wilted for 1 to 8 days, picked up as above. Formalin/formic acid additive applied. (WA)

3. Wilted - cut as above, wilted for 1 to 8 days, picked up as above. (W).

Field losses due to wilting averaged 3.1% of the dry matter but the results were difficult to interpret. In-silo losses as a % of DM ensiled averaged 15.9% for treatment UNA and 9.8% and 8.8% for treatments WA and N respectively. The analyses of the silages are given in Table 1.

Table 1/...

Table 1. Analyses of the six silages.

	UNA		WA		W	
	Cut 1	Cut 2	Cut 1	Cut 2	Cut 1	Cut 2
DM (%) (toluene)	22.3	21.4	30.9	29.5	29.0	30.4
NH_3N (% total N)	5	6	8	8	9	7
DOMD (%)	66	65	68	67	67	66
DCP (g kg^{-1})	110	119	110	118	108	120
ME (MJ kg^{-1})	10.6	10.4	10.8	10.7	10.7	10.6

Cut 1 silages were offered from October 1980 to January 1981 to the following classes of livestock:

Hereford x Friesian steers - 20 months old (3 replicates of 4 animals per treatment). Friesian steers - 12 months old (3 replicates of 4 animals per treatment). Store lambs - 7 months old (2 replicates of 20 lambs per treatment).

Cut 2 silages were offered from January 1981 to March 1981 to the following:

Friesian steers - 23 months old (3 replicates of 4 animals per treatment).
In-lamb ewes (2 replicates of 25 ewes per treatment).

Table 2. Silage intake and animal performance.

	Silage			SED
	UNA	WA	W	
Hereford x Friesian (Cut 1, silage only)				
DM intake (kg d^{-1})	7.51	7.78	8.40	± 0.062
Daily liveweight gain (kg)	1.02	1.01	0.95	(NS)
Friesian (Cut 2, silage only)				
DM intake (kg d^{-1})	6.77	7.53	7.56	± 0.054
Daily liveweight gain (kg)	0.92	0.81	0.82	(NS)
Friesian (Cut 2, silage + 3.6 kg DM barley)				
DM intake (kg d^{-1})	9.07	10.50	9.97	
Daily liveweight gain (kg)	1.11	1.09	1.08	
Store Lambs (Cut 1, silage only)				
DM intake (kg d^{-1})	0.67	0.70	0.70	
Daily liveweight gain (kg)	0.05	0.05	0.05	
In-lamb ewes (Cut 2, silage only)				
DM intake (kg d^{-1})	0.75	0.82	0.86	
Twin lamb birthweight (kg)	3.9	3.8	4.0	

Paper No. 18.

EQUATIONS FOR PREDICTING SILAGE INTAKE BY BEEF AND DAIRY CATTLE

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Effective ration formulation depends on supplying the animal's requirement within the complex limitations imposed by the nutritive value and intake potential of the foods available. Rations can be formulated effectively only when predictions of requirements and intake are of the same order of precision. This paper describes the approach adopted to derive equations for predicting the intake of dairy cows on silage-based diets.

The method was to apply multiple regression techniques to published data. A review of the literature up to 1979 yielded the results of 78 experiments in which cow weights, milk yield, silage and concentrate intakes and the DM, pH, DOMD, crude protein and fibre values for the silages were reported. The data had limitations and did not adequately span the range encountered in commercial dairy herds. Another limitation was that the silages were frequently not well characterised. In particular, pH was usually the only index of fermentation quality given. The data also precluded time after calving as an independent variable. Caution was exercised in interpreting the correlation coefficients relating silage intake, expressed as g kg^{-1} $W^{.75}$, with the independent variables owing to the high correlations which existed between some of these. For example the correlation coefficient between silage intake and milk yield was -0.50 suggesting a significant relationship between these two variables. This was, however, an indirect effect since the relationship was due to the large amount of concentrates given to cows of high milk yield.

A two-stage method was taken to derive the final equation. First an equation was derived to predict the intake potential of the silage when given alone, and this was then corrected for the substitution or replacement effect of concentrates when included in the diet.

The equations derived to predict the intake potential of silage (I) and the intake of silage in mixed diets (SDMI) are given below.

$$I = 0.103\ DM + 0.0516\ D - 0.05\ N + 45.0 \quad \text{.......(1)}$$

$$SDMI = 1.068\ I - 0.00247\ C \times I - 0.00337\ C^2 - 10.9 \quad \text{.......(2)}$$

(R^2 = 72.5, RSD ± 7.9)

Where I and SDMI expressed as g DM kg^{-1} $W^{.75}$

DM = Silage DM (max. 300 g kg^{-1})

D = Silage DOMD (g kg^{-1})

N = Ammonia-N in silage (max. 200 g kg^{-1} total N)

C = Concentrate DMI (g kg^{-1} $W^{.75}$)

Equation (2) proved unsatisfactory for the prediction of intake of high yielding dairy cows and it was decided to adjust the equation by incorporating a correction factor based on milk yield. The correction factor was + 0.00175 Y^2 where Y = milk yield in kg d^{-1}.

The final equation describes the effect of the major characteristics of a silage on its intake by dairy cows, and attempts to take into account the replacement effect of concentrates when included in the diet.

The accuracy of the final prediction equation was tested using 72 independent sets of observation published since 1979. The mean differences between actual and predicted intake was 4.9% ± 3.0 (range 0-12%) and the mean bias was -3.0% ± 5.2 (range -12.4 to +8.7%). Seventy six *per cent* of predictions were within ± 1.0 kg of the actual intakes.

Following a similar two-stage approach, equations were derived to predict silage intakes of growing and finishing beef cattle. These are given below.

Intake Potential of Silage I g kg^{-1} W

Weaned Suckled calves

$$I = 0.0105\ DM + 0.0156\ D + 0.0075\ W - 0.02\ N + 3.5 \quad \text{..........(3)}$$

Pail fed calves

$$I = 0.010\ DM + 0.0161\ D - 0.0154\ W - 0.02\ N + 13.6 \quad \text{..........(4)}$$

Silage intake in Mixed Rations (SDMI) as g kg^{-1} W

$$SDMI = 0.92\ I - 0.027\ I \times C - 0.0247\ C^2 + 1.0 \quad \text{..............(5)}$$

DM = Silage DM (max. 350 g kg^{-1})

D = Silage DOMD (g kg^{-1})

N = Ammonia-N in silage (max. 250 g kg^{-1})

C = Concentrate DMI (g kg^{-1} W)

W = Animal Weight (kg)

SESSION 6 POSTER PRESENTATIONS

SEE PAGES 61 - 88

SESSION 7 PRODUCTIVE VALUE OF SILAGE (2)

PAPERS 19 - 22

CHAIRMAN - DR. R.A. EDWARDS

Table 1. Yields and analyses of ensiled first-cut grass, 1977-1979, with animal intake and production data

	1977			1978			1979		
	Early		Late	Early		Late	Early		Late
Date of cut	23 May		14 June	22 May		8 June	5 June		15 June
DM yield (t ha^{-1})	4.66	0.184***[a]	8.50	4.32	0.137***	7.03	4.20	0.134***	6.00
Silage analysis									
pH	4.2		4.2	3.8		4.8	4.1		4.2
Dry Matter (g kg^{-1})	261		236	255		388	208		268
'D' Value (g kg^{-1})	710		637	716		637	690		663
M/D (MJ kg^{-1})	11.6		10.0	11.8		8.9	11.5		10.4
Intake and production									
Silage DM (kg cow d^{-1})	9.9	0.29**	8.9	9.8	0.14NS	9.5	9.3	0.12*	9.0
Concentrate DM (kg cow d^{-1})	6.9		6.9	7.1		7.1	6.9		6.9
Milk Yield (kg cow d^{-1})	21.0	0.504*	19.9	22.9	0.462***	20.7	20.7	0.585NS	20.6
Milk composition									
Fat %	4.03	0.071NS	4.09	4.09	0.059*	4.23	4.19	0.085NS	4.11
Protein %	3.39	0.039***	3.23	3.39	0.035*	3.30	3.31	0.043NS	3.29
Lactose %	4.86	0.028NS	4.83	4.87	0.024NS	4.83	4.95	0.034NS	4.93
Change in body weight (kg cow d^{-1})	+0.36	0.071**	+0.14	+0.35	0.066NS	+0.27	+0.16	0.046NS	+0.18
Cow days ha^{-1}	400[b]		812	374		704	384		567

a ± SED

b assuming 15% loss of DM during ensiling

Paper No. 20.

WHITE CLOVER SILAGE FOR MILK PRODUCTION

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The object of this study was to make silages from a ley with a high proportion of white clover *(Trifolium repens)* and to investigate the value of the silages for milk production.

The medium large-leaved white clover var. Blanca (RvP, Belgium) was sown alone at the rate of 6.5 kg ha^{-1} in May 1978 and harvested for silage twice per year in 1979 and 1980. The clover was grazed with sheep each Autumn, and the mean annual yield in the 3 years was 6 t ha^{-1}.

The herbage from the four harvests had a mean DM concentration of 136 g kg^{-1} as cut, with 68% white clover in the total DM. The other herbage was mainly *Poa annua, Agropyron repens* and broad-leaved weeds. The herbage was wilted for an average of 4.5 days and ensiled with a mean DM concentration of 244 g kg^{-1}. Formic acid ("Add-F", BP Nutrition Ltd.) was applied at the rate of 4.9 l t^{-1}. Harvests 1 and 2 in 1979 were ensiled separately and termed silages 1 and 2 respectively, but in 1980 the two harvests were ensiled in one silo and termed silage 3.

The silage analyses (Table 1) showed high concentrations of crude protein and ash, and low concentrations of crude fibre and low *in vitro* D-values. The pH values were low also. The silages were dark in colour, friable, had satisfactory fermentations and a pleasant odour.

Table 1. The composition of the three silages.

Silage no.	DM (g kg^{-1})	Crude protein (g kg^{-1} DM)	Crude fibre (g kg^{-1} DM)	Ash	D-value	pH
1	280	236	232	131	0.611	4.2
2	240	225	225	131	0.623	4.1
3	250	232	222	135	0.600	4.2

The three silages were offered to a total of 26 lactating Ayrshire cows in three separate feeding experiments with Latin Square designs. The main results were as follows:-

1. All the clover silages were highly acceptable to the cows;

2. When clover silage was the sole constituent of the diet, the daily intake of 15.2 kg DM per cow was high, and equivalent to 3.01% of liveweight;

3. Supplements of barley alone and barley plus soyabean meal reduced silage intakes by 0.78 and 0.66 kg per kg supplement DM respectively, and increased milk yields;

4. Clover silage of low D-value (0.600) mixed in increasing proportions with grass silage of high D-value (0.660) slightly increased total silage intake, and maintained milk yields.

In summary, silages containing over 70% white clover were made satisfactorily by wilting and applying formic acid at 5 l t^{-1}. These silages had excellent fermentations, low D-values and high intake characteristics. The clover silages replaced grass silages of higher D-value and maintained milk yields and composition. There are no major reasons why silages containing high proportions of white clover should not make a useful contribution towards the feeding of dairy cows.

Paper No. 21

THE FEEDING VALUE OF WHITE CLOVER SILAGE

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The inclusion of white clover in grass swards offers the possibilities of making savings in the use of fertilizer nitrogen and supplementary feed protein. At the Grassland Research Institute considerable research is being conducted into herbage production and the feeding value of grazed and ensiled grass/clover and pure white clover crops.

Previous research with legumes has shown that well preserved red clover and lucerne silages, when fed to young beef cattle, support higher intakes and liveweight gains than ryegrass silages of a similar or higher digestibility. Since white clover is generally higher in digestibility than red clover and lucerne, further improvements in animal performance might be anticipated.

Recent fermentation studies have demonstrated that white clover can be successfully ensiled alone with an additive, if wilted to 30% dry matter, and if ensiled with ryegrass. After the fermentation work, two calf feeding experiments were conducted using white clover and ryegrass silages.

Experiment 1. The objectives were to demonstrate that there were no associative effects of giving mixtures of ryegrass and white clover to young cattle compared to the silages given alone, and to produce guidelines for the management of grass/white clover mixtures for conservation as silage.

White clover, cv. Blanca, and perennial ryegrass, cv. Melle, cut at two digestibilities High D and Low D, were ensiled in separate bunker silos (8 tonnes DM) after wilting and with the addition of formic acid. Table 1 shows the analyses of the crops as ensiled.

Table 1. Dry matter, nitrogen content and *in vitro* D values of ensiled herbage.

	Blanca white clover	Melle ryegrass High D	Melle ryegrass Low D
Dry matter (%)	23.2	29.6	23.5
Nitrogen (% of DM)	3.92	3.16	1.70
In vitro D value (%)	67.6	70.8	58.6

The silages were fed, without supplementation, either alone or in mixtures containing 25 or 50 per cent clover (DM basis), to 3 month old Friesian calves for 70 days. Figures for silage intake, digestibility and liveweight gain by the calves are given in Table 2.

Table 2. Silage intake and liveweight gains.

	Clover alone	Clover plus ryegrass High-D	Clover plus ryegrass Low-D
Dry matter intake (g d^{-1} per kg LW)	30.3	27.9	23.0
Digestible DM intake (g d^{-1} per kg LW)	21.7	21.9	14.8
DM digestibility (%) *(in vitro)*	71.6	78.6	64.5
Liveweight gain (g d^{-1})	881	833	193

Intake of clover dry matter was >8% higher than clover plus ryegrass High-D and >30% higher than clover plus ryegrass Low-D. DDM intake was similar for clover and clover plus ryegrass though clover supported 5% higher liveweight gain. Animal performance on the grass/clover silage mixtures was in direct relationship to the percentage white clover in the feed.

Experiment 2. The aim was to measure the relative performance of cattle given either ryegrass or ryegrass/white clover silages, differing in crude protein content, to additional supplement, in order to establish whether white clover would have a 'protein sparing' effect.

Crops of S23 ryegrass and Blanca white clover (70% of DM) plus S23 were ensiled after wilting on 1-3 September 1980. Formic acid was applied at approx. 2.5 litres per tonne crop. Dry matter %, nitrogen content (% DM) and D-value of the ensiled crops were 32 and 28, 2.15 and 3.23, and 70 and 65 for the ryegrass and clover/ryegrass respectively. The silages were offered *ad libitum* to 3 month old calves for 70 days, either without supplementation, with fishmeal at 2.5 g DM per kg calf liveweight, or with fishmeal (2.5 g) plus barley (7.5 g DM per kg LW).

Paper No. 22.

PROCESSED HAY AS A SUPPLEMENT TO SILAGE

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This experiment was to assess whether grinding and pelleting of high quality hay, with or without treatment with formaldehyde, could produce a supplement of similar quality to dried grass but at a lower cost in terms of fuel energy. Four supplements were compared: chopped hay (CH); pelleted hay (PH); hay pelleted with the addition of formaldehyde (20 g kg^{-1} CP; PHF); and dried grass (DG). Supplements were offered at two levels, low and high, 6.5 and 13.0 g DM per kg LW respectively, with silage available *ad libitum*.

A primary growth of *L. perenne* was cut in early June and harvested with a metered-chop forager without wilting. Formic acid was applied at 2.5 l t^{-1} and the crop ensiled at a DM content of 162 g kg^{-1}. The regrowth was cut in mid-July. Grass from half the area was dried in a high temperature drum drier, ground through a 6 mm screen and pelleted through a 12 mm die. The remaining grass was dried in the field for 5 d, baled and stored. The hay was subsequently either chopped or ground and pelleted to provide the treatments described.

The silage and supplements were fed to 54 individually penned British Friesian steers (100 kg LW). Intake and live-weight gain were recorded over 91 d, and the cattle were weighed fortnightly. Digestibility was assessed by total collection of faeces over 10 d.

Total OMI increased with level of supplementation and silage OMI decreased and was lowest with chopped hay (Table 1). Total DOMI was highest with the high level of dried grass and this produced the highest live-weight gain. At the low level of supplementation pelleted hay produced a similar LWG to dried grass but both were markedly higher than chopped hay. DOMI was closely related to LWG ($r = 0.89$), indicating that the positive effects on production were mediated directly through increased intake of digestible nutrients. The addition of formaldehyde did not appear to influence the response.

It appeared that dried grass and pelleted hay were superior to chopped hay at the low level of inclusion and that dried grass appeared to be superior to both chopped and pelleted hay at the high level of inclusion.

Table 1. Chemical composition of feeds, organic matter intakes and liveweight gains.

	Silage	Chopped hay		Pelleted hay		Pelleted hay + formaldehyde		Dried grass	
		Low	High	Low	High	Low	High	Low	High
Dry matter (g kg^{-1} fresh)	193	839		919		913		877	
Organic matter (g kg^{-1} DM)	907	931		932		930		905	
Total-N (g kg^{-1} DM)	20.4	22.6		21.9		21.4		25.9	
OMI intake (g kg^{-1} LW)									
Silage	16.6	14.1	9.9	15.1	11.4	14.4	11.1	14.1	11.7
Supplements	-	5.8	10.6	6.0	10.7	6.0	11.7	5.8	11.2
Total	16.6	19.9	20.5	21.1	22.1	20.4	22.8	19.9	22.9
DOMI (g kg^{-1} LW)	11.1	13.7	14.5	14.0	14.4	13.4	14.6	13.3	15.8
Liveweight gain (kg d^{-1})	0.23	0.44	0.68	0.59	0.69	0.52	0.68	0.61	0.92

SESSION 8 SILAGE MECHANISATION

PAPERS 23 - 25

CHAIRMAN - MR. H.J.M. MESSER

Paper No. 23.

CROP CONDITIONING WITH PLASTIC ELEMENTS

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Compared with steel components used for conditioning forage crops, plastic elements have the advantages of being lighter, usually cheaper, more easily fashioned into different shapes, and more resilient - which gives improved shock absorbtion and damage protection. The lower density of plastics is both an advantage and a disadvantage. Whilst lost plastic components picked up by forage harvesters are much less likely to damage the chopping mechanism than steel components, the resistance to wear of plastic must be expected to be less. However, within the wide range of polymers available, some have particularly favourable wear and impact resistance, and post-forming treatments can be used to modify performance characteristics.

Plastic components for conditioning forage crops are being evaluated in laboratory and field experiments. Initially different plastic brush configurations were studied, and more recently conditioning rotors using sheet plastic elements were investigated.

To speed up the development, extensive use is made of the NIAE conditioning rig which consists of a 3.5 m long trolley on which a simulated reduced-width windrow is placed. The trolley is driven forward so that the crop is delivered into an equally reduced-width conditioning mechanism of variable form. This treats the crop and replaces it on to the trolley so that samples can be taken for drying alongside untreated material. By periodic weighing of the samples the drying curves for the material are determined. In Table 1 the maximum improvements in drying rate over untreated crop are given for crops dried to equilibrium moisture content. At first the four brush systems were used normally, that is at speeds and clearances which gave visible adequate conditioning, with tufted brushes at a lateral tuft spacing of at least twice the tuft width. At those settings the peripheral speeds of the primary brushes were usually in the region of 22 m s^{-1}. During work with differing crops at different stages of maturity it was noticed that relatively little fragmentation occurred. Thus the aggressiveness of the brushes was increased by reducing clearances to a minimum. With these settings the results given under "maximum effect" were obtained (Table 1).

Table 1/...

Table 1. Increases in drying rate relative to untreated crop (%).

Brush system	Normal use	Maximum effect
Rotary brush and concave	75	125
Counter-rotating twin brushes	103	115
Co-rotating twin brushes	152	499
Intermeshing twin brushes	143	160

In plot experiments in Italian and perennial ryegrass, comparisons were made between three of the experimental brush systems and two commercial mower-conditioners. One was the steel rotor developed at NIAE. The ranking order of the results is given in Table 2 in which the lowest values are the best results.

Table 2. Relative field drying rates to 60% m.c. (wet basis).

Brush system	Grass	
	Italian ryegrass	Perennial ryegrass
Single brush	1	1
Co-rotating twin brushes	2	4
Intermeshing twin brushes	4	2
Steel spoke rotor (NIAE)	5	3
Cleated rubber rollers	3	5

With both grasses the simplest brush system gave the fastest wilting rate, and the other two brush systems were second and third in the Italian and perennial ryegrass respectively.

Wear of the plastic crop-engaging components has been assessed on only two occasions with tufted brush units. On one occasion, using polypropylene filaments, wear amounted to 4.4% in the most heavily loaded central brush section after 42 h of work. However, the length of the filaments had not been reduced, and away from the central brush region wear was minimal. On the second occasion a brush was fitted with tufts of polypropylene and nylon 66. After approximately 300 h an average of 8.1% of material had worn from the polypropylene tufts and a significant percentage of filaments had fractured at the trailing edges of the excessively stiff supporting sleeves which have now been modified. Tufts of nylon 66 had lost 4.4% on average without fractures after 165 h. Wear of the supporting sleeves was negligible. Developments are in hand to increase the resistance of the elements to wear.

Development of conditioning rotors using sheet plastic elements is still in the preliminary stages, but first indications are that levels of effectiveness can be achieved which are similar to those of brushes.

Paper No. 24.

RESEARCH AND DEVELOPMENT IN FORAGE CHOPPING

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Present day precision-chop forage harvesters have the ability to produce material of short chop length at high throughput rates, but the inherent disadvantages of high susceptibility to damage by foreign objects and high power requirement can often make the machines unattractive to the small dairy farmer. The availability of self-loading forage wagons has resulted in an alternative forage harvesting system; however, this is only applicable where short crop length and high harvesting rates are not of prime importance.

The forage chopping research and development programme at NIAE has the objective to investigate alternative methods of comminuting forage and to reduce the disadvantages of present systems. Various alternatives are being considered, and initially the work is concentrated on slicing a pre-compacted column of forage with knives positioned in the path of the crop column. The chop performance objective of the project is to achieve a median (50%) particle length of 25 mm, with inter-quartile range (25-75%) of 20-25 mm, giving 90% of the crop shorter than 60 mm. As a means of creating the crop column a conventional pick-up baler has been used with the knotting and bale tension mechanisms being replaced by the cutting system.

Initially the compacted column was pushed through a series of static knives, in a similar manner to that employed by the Kidd Courier self-loading forage wagon. However, measurement of plunger forces indicated that a minimum knife spacing of only 75 mm was possible without excessively loading the compacting mechanism. Although this could be strengthened, it was considered impractical to position stationary knives at the close spacing required to achieve the desired chopping effect. The project has progressed to investigate a similar system with reciprocated knives where the column thrust force is greatly reduced and, hence, less baler and knife strength is required. This development uses thin section counter-reciprocated knives which are held in tension in the crop path. Experience with an experimental field rig has shown that the system has considerable potential (Table 1).

Table 1/...

Table 1. Specific power requirement for two harvesting systems ($kW\ t^{-1}\ h^{-1}$)

	Precision-chop forage harvester	NIAE baler slicing development
Pick-up and feed system	0.20	0.55
Crop comminution	0.80	0.30
Crop delivery to trailer	0.70	0.25
TOTAL	1.70	1.10

Many unknown parameters have been encountered with this development project, the most significant being the knife design and its operating conditions. In order to evaluate and optimise these, a laboratory rig has been used to measure the forces acting on knives when crop conditions are varied. Straight and wavy edged knives have been evaluated at various reciprocation speeds and stroke lengths; crop density and cutting rate have also been investigated.

The power requirement to comminute different forages can vary with maturity, moisture content and species, and experiments have established the degree of variation with reciprocated slicing knives. Power requirement increased by approximately 60% during the 30-d period commencing 6 d before ear emergence, and decreased by approximately 50% with increasing DM content from 25% to 70%. The perennial ryegrass variety S24 required approximately 20% more power than Italian ryegrass variety RvP when cut under the same conditions.

Some existing forage harvesters can require in excess of 30 kW solely to impel and convey the chopped crop into an accompanying trailer. As an addition to the chopping research the NIAE aims to investigate mechanical methods of elevating the chopped material, e.g. augers and rubber belt elevators. A chain and slat elevator system has been built experimentally for use with the baler slicing device.

Paper No. 25.

FACTORS AFFECTING THE DENSITY OF ENSILED PRE-WILTED GRASS

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In silage making the density of the forage is important for the efficient utilization of silo capacity, the load on the structure, the fermentation of the silage and the minimizing of the risk of air penetration. In the various silage storage systems compaction is achieved in different ways. The compression is continuous, intermittent and a combination of both.

In tower silos continuous pressure is exerted by the dead weight of the fodder column on top. In trench silos the forage is usually compressed intermittently by the tractor filling the silos and additional continuous pressure is exerted by the weight of the fodder on top. Laboratory tests have been performed to establish the factors affecting the density of pre-wilted grass. By continuous compression the dry density (pt) can be expressed by the formula:

$$pt = A_t + B_t \log^2 p \qquad \ldots\ldots\ldots(1)$$

where: $A_t = a_1 + a_2 \log t$ and $B_t = a_3 + a_4 \log t$

pt = forage dry density (kg/m^3) after t hours of compression with vertical pressure p (kN/m^2)

$a_1 - a_4$ are coefficients related to the type of forage, such as chop length and stage of maturity

A summary of the results of tests is given in Table 1. The effect of the stage of maturity indicated by the crude fibre content and the effect of chopping is clear.

The lab oratory tests on intermittent compaction started in 1979, and a test unit, in which load pressure, load time and interval time could be adjusted was developed. The load pressure at the top and at the bottom of the forage sample and the height of the forage column are recorded continuously.

Table 1. Dry density (kg/m^3) of grass (dm ≥ 30%) at time, t = 720 h, at pressures of 10 and 100 kN/m^2.

Grass treatment	Number samples	Crude fibre	Dry density (kg/m^3) 10 kN/m^2		100 kN/m^2	
			Mean	S.D.	Mean	S.D.
chopped	37	≤ 22	277	30.8	568	61.1
	47	22-26	244	23.0	517	46.2
	21	≥ 26	201	20.1	432	31.2
unchopped	7	≤ 22	243	25.5	514	60.8
	15	22-26	234	32.6	516	58.2
	10	≥ 26	183	24.6	418	47.1

By intermittent compaction the forage expands again during the intervals between compression and the first experiments showed an expansion of 30%, depending on moisture content and stage of maturity of the forage. The dry density at compression time and after expansion is affected by the number of times of compression, the load pressure, and the load time, but also by the physical properties of the grass such as stage of maturity, chop length and moisture content.

Because of the risk of air penetration, the porosity of the forage is important. It is anticipated that there is a correlation between the volume mass in the forage and the porosity of the volume (V) of gas in the forage can be calculated by the formula:

$$p = \frac{dm}{100} \times \frac{(1 - \frac{V}{100})\, p_s \,.\, p_w}{p_w \cdot \frac{dm}{100} + p_s\,(1 - \frac{dm}{100})} \quad \ldots\ldots\ldots (2)$$

By an estimated density of complete dry matter at zero percent pore volume (p_s) of 1600 kg/m^3, a water density (p_w) of 1000 kg/m^3 and disregarding the weight of the gas, this can be written as:

$$V = 100 + p\,(\frac{3}{80} - \frac{10}{dm}) \quad \ldots\ldots\ldots (3)$$

For measuring the porosity, a permability meter is being built and the first results will be available soon.

SESSION 9 SYSTEMS FOR SILAGE MAKING AND FEEDING

PAPERS 26 - 30

CHAIRMAN - DR. D. OSBOURN

Paper No. 26.

WILTING GRASS FOR SILAGE

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Wilting grass reduces the water content and in Bavaria on the first day of wilting in favourable weather, the water content is reduced from *circa* 85% to 65%. On the 2nd day the value is 45%. In unfavourable weather the duration of drying may be 4 to 8 days or more.

Two main factors influence energy losses in the field; weather conditions and degree of wilting. In favourable weather, wilting from 85 to 65% water content the losses are between 1 and 3% in 1 day. In unfavourable weather conditions the losses increase to 5 to 30% in 2 - 7 days. Thus, with the variable weather conditions in Bavaria the weather risk due to wilting increases after more than 2 days following cutting.

Losses in the silo are due to effluent, respiration and fermentation and finally surface deterioration, hence there is a close correlation between the losses, water content and ensiling methods (Table 1).

Table 1. Energy losses in silo (%)

	Dry-matter content (%)				
Silo	20	30	40	50	60
Tower	37 - 30	25 - 17	19 - 11	17 - 9	15 - 8
Bunker	45 - 32	33 - 18	29 - 14	29 - 13	31 - 14

In the quality evaluation of silages by the method of FLIEG, wilted silages with high DM-contents have normally a higher classification than wet silages, because the butyric acid content is usually lower. A grouping of more than 4,000 analyses of grass silages from Bavaria is shown in Table 2.

Table 2. Dry matter content and silage quality

DM %	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60
Flieg -P.	22	31	52	63	77	82	81	90	93

The losses of nutrients from harvesting to feeding occurs more with soluble nutrients than with less soluble nutrients. Thus the content of soluble N-free extracts and protein decrease whereas the less soluble crude fibre increases. On average, the net energy content of the DM decreases by 0.6% and the crude protein content by 0.4% when the losses increase by 1%.

The silage intake (Y) normally increases with increasing DM content (X). For cows, this can be expressed by the following regression equation:

$$Y = 0.594X - 0.00743X^2 - 1.9$$

Thus the intake increases at a decreasing rate with increasing DM content and reaches its peak value at about 40% DM. This is valid for grass silages with less than 26% crude fibre in this DM. At higher crude fibre values the intake increases only up to 30 - 35% DM content.

Wilting grass has both advantages and disadvantages. Balancing these, there is a optimum which lies at a DM content of about 30 to 40% depending on the ensiling management.

Paper No. 27.

A COMPARISON OF TWO-CUT AND THREE-CUT SILAGE SYSTEMS FOR BEEF CATTLE USING EARLY AND LATE-HEADING VARIETIES OF PERENNIAL RYEGRASS

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In previous experiments at Hillsborough, earlier and more frequent cutting of grass for silage increased silage DM intake and the live-weight gain of beef cattle. The work involved only early-heading varieties of ryegrass, and animal performance was assessed only in terms of live-weight gain. Two experiments were therefore conducted to evaluate two systems of silage making based on either two or three cuts annually from swards of early- and late-heading varieties of perennial ryegrass. Output was measured as carcass gain per animal and per ha.

In Experiment 1, early (Cropper) and late-heading (Talbot) varieties of ryegrass were harvested on 20 June and 22 August 1979 for the two-cut systems and on 1 June, 16 July and 24 August for the three-cut system. The four silages were offered *ad libitum* both unsupplemented and supplemented with 2.3 kg of concentrates head^{-1} d^{-1} to 88 steers with an mean initial live weight of 337 kg, for 133 d. In Experiment 2 the same swards were harvested on 5 June and 12 August 1980 for the two-cut system and on 19 May, 1 July and 19 August for the three-cut system. The silages were offered *ad libitum* and supplemented with 2.3 kg of concentrates head^{-1} d^{-1} to 32 steers and 24 heifers with a mean initial live weight of 348 kg, for 132 d. All the silages were unwilted, precision chopped and had formic acid applied at the rate of 2.5 l t^{-1}.

In Experiment 1 (Table 1), grass variety did not affect any of the parameters at either cutting frequency and the results are presented as means of the two varieties.

Table 1. Experiment 1, 1979-1980.

	Two-cut system		Three-cut system		SE of mean
Level of supplementation (kg)	0	2.3	0	2.3	
Silage DM intake (kg d^{-1})	5.70	4.60	6.20	5.05	0.124
Live-weight gain (kg d^{-1})	0.43	0.73	0.63	0.83	0.022
Dressing percentage	53.9	55.9	56.2	57.6	0.360
Carcass gain (kg d^{-1})	0.27	0.48	0.45	0.60	0.014
Carcass output (kg ha^{-1})	412	908	593	971	
Yield of grass (kg ha^{-1} DM)	11.6		10.9		

Table 2. Experiment 2, 1980-1981.

Grass variety	Two-cut system		Three-cut system		SE of mean
	Cropper	Talbot	Cropper	Talbot	
Silage DM intake (kg d^{-1})	4.96	5.00	5.60	5.36	0.314
Live-weight gain (kg d^{-1})	0.77	0.80	0.97	0.94	0.045
Dressing percentage	55.4	55.3	57.3	57.3	0.300
Carcass gain (kg d^{-1})	0.48	0.49	0.66	0.64	0.021
Carcass output (kg ha^{-1})	922	860	1043	1048	
Yield of grass (t ha^{-1} DM)	12.7	11.7	11.8	11.7	-

The results of both experiments were similar in that grass variety did not affect any of the parameters examined at either cutting frequency, whereas more frequent cutting significantly increased silage DM intake, live-weight gain, dressing percentage and carcass gain. The response in carcass gain to more frequent cutting was proportionally almost twice the response in live-weight gain and emphasizes the importance of assessing animal performance in terms of carcass gain.

It is concluded that earlier cutting of ryegrass for silage produced a large increase in carcass gain per animal without depressing carcass output per ha irrespective of grass variety.

Paper No. 29.

EFFECT OF CUTTING FREQUENCY ON YIELD AND QUALITY OF SEVERAL GRASS SPECIES AND VARIETIES

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Farm development work in the early 1970's demonstrated the practicability and improved animal performance from a multi-cutting system of silage production. It was impossible to evaluate on a farm scale which varieties were best suited for a multi-cutting system and to accurately assess the yield penalty associated with an increase in cutting frequency. To answer these questions a replicated randomised block trial of perennial herbage varieties was conducted at three centres from 1976 to 1979 and a similar trial with short term varieties at two centres from 1978 to 1979.

The following treatments were compared:

1. Cutting frequency:- 3,4 and 6 weeks
2. Perennial varieties:- perennial ryegrass - S24, Barlenna, S23; cocksfoot - Saborto; meadow fescue - S215; timothy - S51; perennial ryegrass S23+ white clover Sabeda.
3. Short term varieties:- Italian ryegrass - RVP, Sabalan; hybrid ryegrass - Sabrina.

All plots were cut in mid-April and at the relevant frequency thereafter until early October (24 weeks). Cutting height was 5 cm for perennial and 7 cm for short term varieties. Both trials received 422 kg/ha N, 125 kg/ha P_2O_5 and 211 kg/ha K_2O annually. Phosphate was applied in one spring dressing and the nitrogen and potash in equal amounts for each growth period.

Table 1 shows the mean annual yield and digestibility of perennial varieties over all sites and years. Compared with 6-week cutting, 4-week cutting gave 16% less yield but 3.2 units digestibility increase, giving an overall reduction in digestible organic matter (DOM) of only 11.7%. 3-week cutting gave 29% less yield but 4.5 unit digestibility increase, an overall reduction in DOM of 23.4%. Variety differences were relatively small at 4- and 6-week cutting but Barlenna and S23 showed some advantage at the 3-week frequency. Digestibility differences were significant between species. More frequent cutting increased mean crude protein content of all varieties from 16.6% at 6-week cutting to 21.3% at 3-weeks.

Table 1. Perennial varieties: DM yield (tonnes/ha) and digestibility (%)

Variety	3-week Yield	3-week D value	4-week Yield	4-week D value	6-week Yield	6-week D value
S24	8.4	71.7	9.5	69.8	11.7	65.7
Barlenna	9.3	70.7	9.9	70.1	11.7	67.3
S23	9.1	71.6	10.0	69.0	11.7	68.3
Saborto	7.9	69.2	9.8	67.6	12.4	63.7
S215 *	7.6	69.8	9.8	69.1	11.3	65.2
S51 *	7.5	69.2	9.2	68.5	10.9	64.2
S23 + Sabeda	8.6	71.8	10.3	70.3	12.3	67.9
Mean	8.3	70.5	9.8	69.2	11.7	66.0

* 3 years only

Table 2. Short term varieties: DM yield (tonnes/ha) and digestibility (%)

Variety	Year	3-week Yield	3-week D value	4-week Yield	4-week D value	6-week Yield	6-week D value
RVP	1	9.6	72.2	12.7	70.8	15.3	65.0
	2	7.9	72.5	9.5	71.7	12.5	65.7
Sabalan	1	8.6	72.9	11.0	71.8	13.1	66.7
	2	6.5	73.1	8.3	72.6	11.2	68.5
Sabrina	1	9.1	72.3	11.4	71.0	12.5	66.8
	2	7.7	73.1	7.9	73.3	10.7	68.4
Mean		8.2	72.7	10.1	71.8	12.6	66.9

Table 2 shows the annual data for the short term varieties. All yields declined in the second year. Compared with 6-week cutting, 4-week cutting reduced yield by 20%. However, digestibility increased by almost 5 units giving an overall reduction of 13% in yield of DOM. 3-week cutting reduced yield by 35% with an increase of almost 6 units of digestibility resulting in a 30% reduction in yield of DOM. Crude protein pattern was similar to the perennial varieties.

Under Welsh climatic conditions increasing cutting frequency from 6- to 4-weeks will improve digestibility with a relatively small loss of yield with perennial varieties. In practice there is often scope for increasing ferti-lizer input to make up this loss. For long term grass there is no advantage in growing any species other than perennial ryegrass with mid and late season varieties having a small advantage over early heading varieties when cutting more frequently. Botanical content of perennial varieties was improved by frequent cutting but had little effect on short term varieties.

Paper No. 30.

COMPLETE DIETS FOR DAIRY COWS

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During the last few years there has been considerable interest in complete diet feeding. On larger dairy units it has mainly been introduced to simplify management and control feeding, while with smaller herds more importance has been attached to possible improvements in milk yield and quality. Although the survey data have been collected relating to the effect of complete diets on intake and animal performance, there is only limited evidence from experimental feeding trials. The objective of this work was to investigate the effect of complete diet feeding on dry matter intake (DMI) and cow performance when compared with feeding the same ingredients separately.

For the first 20 weeks of lactation, 50 cows received the complete diet and 50 cows were offered the same ingredients separately. Within each group, half of the cows were fed *ad libitum* and half were fed at a restricted level: DMI was 2.5% of liveweight in week 2 of lactation. All animals were individually fed through Calan Electronic feeding gates.

The diet consisted of 60% concentrates and 40% forage, and contained 20, 20, 10 and 50% on a DM basis of maize silage, lucerne silage, sugar beet pulp and dairy concentrates, respectively. The energy concentration, crude protein, crude fibre and DM content of the whole-ration was 11.9 MJ ME/kg DM, 14.6%, 17.8% and 41% respectively.

Table 1 shows that feeding the complete diet *ad libitum* increased DMI by 2.2 kg day^{-1}, milk yield by 1.4 kg day^{-1} and milk fat and protein content by 4 and 2 g kg^{-1} milk, respectively, when compared to cows offered the ingredients separately.

Table 1. Mean daily DMI, milk yield and milk quality components during lactation weeks 4 - 20.

	Complete diet *Ad lib*	Complete diet Restricted	Separate ingredients *Ad lib*	Separate ingredients Restricted
DMI (kg d^{-1})	16.6	13.3	14.4	12.6
Milk yield (kg d^{-1})	23.0	22.2	21.6	19.9
Milk fat (g kg^{-1} milk)	39	36	35	36
Protein (g kg^{-1} milk)	34	31	32	31

Restricted access to the complete diet gave the most efficient response as cows on this treatment consumed 3.3 kg DM day^{-1} less but produced only 0.8 kg milk day^{-1} less than cows fed the complete diet *ad libitum*. This was probably due to the fact that liveweight loss was greatest (30 kg) and subsequent gain lowest (18 kg) with the cows fed the complete diet at the restricted level of feeding. On the other treatments, the initial loss was lower at 17 kg and the subsequent gain greater at 40 - 50 kg.

The higher milk fat content produced by the cows fed the complete diet *ad libitum* was due to improved rumen fermentation as measured by the ratio of lipogenic to non-lipogenic end products (Table 2).

Table 2. Ratio of rumen fermentation end products.

	Complete diets		Separate ingredients	
	Ad lib	Restricted	*Ad lib*	Restricted
Ratio (Acetate + butyrate) / proportionate	3.5	3.0	2.9	4.4

The DM digestibility was measured in three cows from each treatment group. The DM digestibility was depressed slightly by mixing and slightly raised in cows fed *ad libitum* (Table 3).

Table 3. Dry matter digestibility coefficients. (in vivo)

	Complete diets		Separate ingredients	
	Ad lib	Restricted	*Ad lib*	Restricted
DMD coefficient	0.69	0.67	0.71	0.69

In conclusion, although complete diets increased intake and milk yield, these results should be treated with caution, as animals given the separate ingredients consistently rejected some lucerne silage. Thus, in order to maintain the 40:60 forage to concentrate ratio, other ration ingredients were reduced. The results illustrate the fact that the intake of unpalatable feeds can be enhanced by mixing.

With the continued emphasis in the payment for milk being placed on milk fat production, the use of complete diets would seem to provide one method of obtaining both high yields and maintaining milk quality components.

POSTER PRESENTATIONS

1. BIOCHEMICAL AND MICROBIOLOGICAL STUDIES ON SILAGE
   PAPERS 31 - 35

2. UTILISATION OF SILAGE
   PAPERS 36 - 41

3. SYSTEMS FOR SILAGE MAKING
   PAPERS 42 - 44

Paper No. 32

DRY MATTER DETERMINATION IN SILAGE

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A sample of frozen silage was ground in a meat grinder to reduce particle size to 5-10 mm. Dry matter content was then assessed by six methods:

1. Drying in a forced-draught air oven for 16 h at 65° C.
2. After 1, the sample was ground to pass through a 1 mm screen then dried for 16 h at 105° C.
3. Distillation with toluene, gravimetric method.
4. Distillate then subjected to a Karl Fischer titration.
5. Distillate subjected to a Foreman titration (NaOH titration).
6. Index of refraction.

Methods 1 and 2 directly assess DM content but methods 3 - 6 determine water content and DM is calculated by difference.

Because the Karl Fischer titration technique is somewhat tedious, the water content of the distillate and pure water was determined by Foreman titration (ml 0.1 N NaOH per 10.0 g distillate) and the difference in Index of refraction (ΔnD). Results are presented in Table 1 and the Index of refraction is shown to be a useful technique when compared to the Karl Fischer method.

Table 1. Comparison of water content as assessed by different methods.

Method	Water Content (%)					Relationship to Karl Fischer method
						y
Karl Fischer	99.5	99.0	98.5	98.0	97.5	99.57 - 0.061 x ml NaOH†
ml NaOH	1.2	9.4	17.6	25.8	34.0	99.69 - 0.099 x ΔnD x 10^4††
ΔnD x 10^4	2	7	12	17	22	

† r^2, 0.64: C.V., 0.31: n, 304

†† r^2, 0.80: C.V., 0.23: n, 304

In Table 2, the dry matter content in silage as determined by the six methods and the relationship between the Karl Fischer technique (i.e. 3 + 4) and the other five methods are shown.

Table 2. The relationship between the Karl Fischer and other methods for determining the DM content of silages.

Method	Dry matter content (%)					Relationship to the Karl Fischer method			
						y	r^2	C.V.	n
3 + 4	15.0	20.0	30.0	40.0	50.0				
1	14.5	19.8	30.5	41.1	53.0	1.355 + 0.941 X	0.982	3.6	410
1 + 2	13.5	18.6	28.7	38.7	48.8	1.577 + 0.992 X	0.990	2.7	410
3	13.9	18.9	29.0	39.0	49.0	1.112 + 0.998 X	0.997	1.4	534
3 + 5*	14.9	20.0	30.1	40.2	50.3	0.231 + 0.990 x	0.999	1.0	308
3 + 6	15.0	20.0	30.0	40.0	50.0	0.042 + 0.999 X	0.999	0.7	530

* Calculated with the factor (0.0091) which was the mean value with which to multiply the volume of NaOH (for the whole distillate) to achieve the same corrected weight of distillate as after correction with Karl Fischer titration.

It is concluded that the best way to measure DM content of silage is to determine the water content and assume the remainder to be dry matter. In the Karl Fischer method the recovery of water is about 99.95% but since this is a time consuming method, an easier technique is to use the Index of refraction of the distillate compared to that of pure water. The two stage drying method (1 + 2) plus a correction factor of 1.4 percentage units also gave good results.

Paper No. 33.

ESTIMATION OF THE AEROBIC STABILITY OF SILAGES BY MEASURING THE BIOCHEMICAL OXYGEN DEMAND (B.O.D)

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A new method was used to investigate which micro-organisms initiate the aerobic processes in different silages. Fungi and bacteria were inhibited selectively by adding antibiotics with antimycotic and antibacterial effect to the fodder. The B.O.D. measured in the treated samples reflected the activity of the respective microbial group. The advantages of this method are, (1) The automatic measurement of the true oxygen demand instead of CO_2 production. (2) The direct reading of B.O.D. in mg O_2, facilitating the calculation of DM losses. (3) The ranges for B.O.D. were measured from 1 to over 2000 mg O_2 per sample. (4) No effect of barometric air-pressure fluctuations in the sealed measuring system. (5) High measuring accuracy.

The instrument consisted of a temperature-controlled water bath, which contained 12 identical measuring units, a recorder and a cooling unit for conditioning the water bath.

Each measuring unit consisted of a reaction vessel with a CO_2 absorber, an oxygen generator and a pressure indicator. The activity of the aerobic micro-organisms in the sample created a vacuum which was recorded by the pressure indicator.

Pressure conditions were balanced by electrolytic oxygen generation and a recorder plotted the respiration activity curves. The oxygen generators of the individual units were electrolytic cells, which supplied oxygen from a copper sulphate solution with sulphuric acid.

The equipment was used to determine the aerobic stability of grass and maize silage. Samples were analysed for pH and for fungal and bacterial counts for six days, according to the development of the respiration activity, recorded as B.O.D.

The results showed the characteristic differences between grass and maize silage under the influence of air (Table 1).

Table 1. Data from grass and maize silage incubated aerobically for six days.

	Grass silage				Maize silage			
Treatment	B.O.D.	pH	Log yeasts	Log bacteria	B.O.D.	pH	Log yeasts	Log bacteria
Control	100	8.2	7.9	5.7	100	7.3	8.6	8.2
Antimycotic	5	4.1	5.0	5.9	84	7.3	5.9	8.6
Antibacteria	74	8.3	7.8	4.3	71	7.2	8.5	4.4
Antimycotic and Antibacteria	4	4.0	4.7	4.5	14	3.9	5.5	6.2

In grass silage a good stability was achieved by the antimycotic treatment alone, which inhibited the yeasts. The stability was indicated also by the almost complete suppression of the respiration activity and the maintenance of a low pH.

In maize silage neither the antimycotic nor the antibacterial component improved the stability if added separately. In this type of forage a combined treatment was needed to control both groups of micro-organisms.

Paper No. 34.

PROTEOLYSIS DURING ENSILAGE

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When grass is ensiled directly extensive protein breakdown occurs; treatments with formaldehyde will protect the protein from degradation but over-protection may occur leading to a decrease in silage digestibility and intake. Rapid acidification of the ensiled crop to a pH of approximately 4 has been suggested as an alternative treatment. Four experiments were undertaken to study the effect on the protein N (PN) content of silages of various methods of lowering the pH in the silo.

In Experiment 1, a ryegrass mixture was ensiled chopped in test-tube silos with the addition of formalin (4.6 and 9.1 l t^{-1}), formic acid (4.9 and 9.8 l t^{-1}), sulphuric acid (5.4 and 10.9 l t^{-1}) and an inoculum of *L. plantarum* with glucose. The compositions of the grass and silages are shown in Table 1. All treatments resulted in significantly higher PN contents in the silages ($P < 0.001$) but the highest levels were in the silages treated with formalin.

Table 1. Experiment 1. Composition of grass and silages.

	Initial pH	Final pH	WSC (g kg^{-1} DM)	Lactic acid (g kg^{-1} DM)	PN (g kg^{-1} TN)	NH_3-N (g kg^{-1} TN)
Grass	5.81	-	91	0.0	824	-
Silage						
Control	5.81	4.90	0.0	21.7	260	127
Formalin						
Low	5.92	5.13	32.0	34.3	632	63
High	5.90	5.79	126.7	0.0	748	13
Formic ac.						
Low	4.04	4.20	34.0	8.3	472	25
High	3.60	3.75	119.7	0.0	522	29
Low H_2SO_4	4.54	4.51	3.7	31.0	345	111
High H_2SO_4	3.73	4.54	0.0	4.3	438	105
Inoc. + glucose	5.81	3.89	8.3	202	340	85

In Experiment 2, ryegrass was ensiled untreated or inoculated with *S. faecalis* + *L. plantarum* or with the commercial product, "H/M Inoculant" *(L. acidophilus)* applied at the recommended rate (0.5 kg t^{-1}). After 24 h the PN content of the material treated with H/M Inoculant (644 g kg^{-1} TN) was slightly higher than those of the other silages (Control - 578 g kg^{-1} TN, *S. faecalis* + *L. plantarum* - 532 g kg^{-1} TN). Addition of glucose to the grass at ensiling made no difference to the values. After 3 days the PN content was still highest in the H/M Inoculant-treated silage (507 g kg^{-1} TN) but after 290 days the PN values were similar in all the silages (approximately 295 g kg^{-1} TN).

To obtain a more rapid drop in pH and, it was hoped, an inhibition of proteolysis, in Experiment 3 the commercial product "Siloferm" (*L. plantarum* + *Pediococcus acidilacti)* was applied to ryegrass to give up to 10^8 lactic acid bacteria per g fresh grass. The grass was ensiled chopped, with and without glucose, or minced. The composition of the grasses and silages are given in Table 2. Despite a drop in the pH value in 24 h with 10^8 lactic acid bacteria per g to 4.03 and 4.19 in the chopped and minced materials respectively there was no obvious effect on the PN contents of the silages.

Table 2. Experiment 3. Composition of grass and silages.

	pH		WSC (g kg^{-1} DM)		PN (g kg^{-1} TN)		NH_3-N (g kg^{-1} TN)	
Grass (Chopped)	5.89		234		916		-	
Silages	24h	76d	24h	76d	24h	76d	24h	76d
Control	5.75	3.75	188	9	619	264	35	114
Control + glucose	5.70	3.76	267	45	649	254	30	108
Minced	5.75	3.77	215	0	604	349	32	104
+ 10^8 bacteria								
Control	4.03	3.56	185	51	596	301	21	48
Control + glucose	4.20	3.54	200	29	613	312	21	47
Minced	4.19	3.53	180	85	576	376	23	41

In Experiment 4, the effect on the PN content of an immediate drop in pH value of the grass to below 4 followed by ensilage was investigated. This was achieved by macerating the grass in ice cold water or in sufficient dilute formic acid to lower the pH value to 3.92. For comparison, chopped grass sprayed with a similar quantity of formic acid was ensiled in the usual manner. After 24 h the pH values of the silages were chopped A - 6.38, chopped + acid B - 4.12, macerated C - 5.24 and macerated + acid D - 3.93. The PN values had decreased from 916 g kg^{-1} TN in the grass to A - 675, B - 740, C - 629 and D - 799 g kg^{-1} TN. After 33 days the pH values were A - 4.38, B - 4.16, C - 3.58 and D - 3.83 and the PN contents (g kg^{-1} TN) A - 281, B - 484, C - 440, D - 620.

It appears from this work that even an immediate drop in pH value of grass to 4 will not halt proteolysis in the silo but it will slow down the rate at which it occurs. At this pH value, further degradation of amino acids by clostridia should not occur.

Paper No. 35.

THE MICROBIOLOGY OF "H/M INOCULANT" SILAGE ADDITIVE

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"H/M Inoculant" (HMI) is a commercial preparation which is stated to contain a selected strain of *Lactobacillus acidophilus* organisms. It is claimed that this homofermentative bacterium accelerates the rate of fermentation resulting in improved digestibility and preservation of nutrients, and also reduces heat production.

Lactic acid bacteria numbers are low on fresh grass but under modern conditions of forage harvesting, large numbers are present by the time of ensiling, for example *circa* 450,000 g^{-1} fresh grass. A.D.A.S. data suggest that those contributed by the addition of a fresh supply of HMI at the recommended rate are around 200 g^{-1} grass. If the product has been stored at 20^0 C for 1, 2 or 3 months the numbers of viable bacteria added fall to 100, 20 and 2 g^{-1} fresh grass respectively.

During early ensilage, oxygen is depleted by plant and microbial activity (coliforms, leuconostoc and streptococci). Organic acids are produced by a succession of bacteria and the lactobacilli are only significant in later stages when pH and oxygen levels are low. Thus the addition of relatively small numbers of lactobacilli at ensilage is unlikely to influence fermentation patterns. Fermentation losses are minimal if homofermentative bacteria are predominant.

Results of A.D.A.S. experiments with both laboratory and field silos are given in Table 1 and these are consistent with the chemical data presented in Paper No. 6 (page 9). DM content of the silages ranged from 170 to 370 g kg^{-1} and the additive was applied at the recommended rate of 0.5 kg t^{-1}. Although HMI proved to be safe and easy to handle, it did not appear to increase the numbers of lactic acid bacteria or the proportion of homofermentative bacteria. No effect on pH values was observed.

Table 1/...

Table 1. Microbiological data from laboratory and field silos.

ADAS centre†	Type of silo & DM content (g kg^{-1})	Time (d)	Treatment	Lactic acid bacteria (log 10)	Homo-ferm§ (%)	pH
1	Laboratory (370)	0	(control	4.6	10	6.2
			(HMI	5.1	40	6.3
		16	(control	8.4	88	4.6
			(HMI	8.5	84	4.7
	Field (180)	0	(control	3.4	88	6.0
			(HMI	3.8	94	6.1
		17	(control	7.4	80	4.1
			(HMI	8.9	88	4.2
2	Laboratory (280)	0	(control	4.6	65	6.4
			(HMI	4.4	33	6.4
		20	(control	8.4	61	4.0
			(HMI	8.1	41	4.0
	Field (280)	1	(HMI	7.7	67	5.1
			(Add F	6.9	46	5.6
		20	(HMI	7.4	50	4.0
			(Add F	6.9	85	4.0
3	Laboratory (190)	1	(control	8.4	-	5.9
			(HMI	7.8	-	5.9
			(Add F	7.6	-	4.8
		21	(control	9.2	-	4.2
			(HMI	9.5	-	4.3
			(Add F	6.8	-	4.3
	Field (180 - 196)	0	(control	6.6	-	6.0
			(HMI	6.6	-	5.9
			(Add F	5.9	-	4.8
		15	(control	7.7	-	3.9
			(HMI	8.2	-	4.0
			(Add F	7.3	-	3.7
4	Laboratory (280)	0	(control	7.5	-	5.3
			(HMI	5.3	1.0	4.7
		10	(control	8.5	14	4.1
			(HMI	8.4	62	4.0
	Laboratory (160)	0	(control	2.2	88	5.8
			(HMI	3.9	14	6.2
		13	(control	8.6	100	3.9
			(HMI	8.6	100	4.0

† 1 - Wolverhampton 2 - Leeds 3 - Trawsgoed
4 - Newcastle § homofermentative bacteria

Paper No. 36.

MINERAL BALANCE STUDIES WITH LAMBS

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In order to examine the effects of drying and ensiling on the availability of major mineral elements, grass was fed fresh, after oven drying and after ensiling to young wether lambs. A supplementary energy source was fed along with some of the ensiling treatments.

Trial I. Fresh versus dried grass; 4 lambs per treatment. a) grass cut in the afternoon and fed next day. b) oven dried grass - cut at the same time, dried overnight and fed next day.

Trial II. Effects of ensiling wilted silage with different additives; 6 lambs per treatment. a) no additive (control). b) Add F (2.5 l t^{-1}). c) Liquid Kylage (2.5 l t^{-1}). d) Silaform (3 l t^{-1}).

Trial III. Effects of mineral-low supplement of corn starch + urea on the availability of silage minerals; 6 lambs per treatment. a) control silage without additive. b) control silage with supplement. c) silage treated with Silaform. d) Silaform silage with supplement.

Trial 1. Dry matter intake was arranged to be closely similar in both treatments. Total water intake (herbage + trough water) was much higher in the lambs fed fresh grass although water was freely available.

Table 1. Apparent availability of minerals (Trial 1).

Treatment	Apparent availability (%) Ca	P	Mg
Fresh grass	26.59	3.50	22.56
Dried grass	19.25	16.77	14.06
Sign. of diff.	NS	P < 0.01	P < 0.01

The digestibility of DM was unaffected by drying, being 75.9% in the fresh grass and 75.2% after drying. Total mineral intakes were within acceptable limits (ARC 1980). However drying reduced the availability of Mg and increased that of P.

Trial II. Silage intakes were relatively low compared with fresh grass so lambs were fed *ad lib.* There were no significant differences between the intake of the minerals and their apparent availabilities (Table 2).

Table 2. Apparent availability of minerals (Trial II).

Treatment	Apparent availability (%)		
	Ca	P	Mg
Control	15.34	10.04	14.14[a]
Add-F	8.11	-10.94	20.55[b]
Kylage	9.92	- 8.02	25.88[bc]
Silaform	11.16	-11.56	24.72[bc]

There were large between-animal differences in the availability of Ca and P and no significant treatment differences for these elements. The availability of Mg was however lower in the control silage than in the silages treated with additives (Table 2).

Trial III. The starch-urea supplement fed at 300 g d^{-1} reduced the silage intake of the lambs but enhanced energy intakes.

Table 3. Apparent availability of minerals (Trial III).

Treatment	Apparent availability (%)		
	Ca	P	Mg
Control silages	2.15[a]	26.67	21.98[c]
Control silage + supplement	10.90[b]	28.22	-6.25[d]
Silaform silage	13.15[b]	24.22	21.52[c]
Silaform silage + supplement	-7.63[a]	25.31	39.00[e]

Again there was variation between animals. Ca availability was enhanced by supplementing the control silage but reduced in the supplemented Silaform silage. Mg availability was reduced with the supplemented control silage and increased with the supplemented Silaform silage. P availability was unaffected by type of diet.

In conclusion, differences in availability of herbage minerals may be attributed to the treatments imposed although there were appreciable differences between animals on the same treatment. The effect of drying may be attributed in part to the altered water intakes of the lambs. In ensiled grass, additives increased Mg availability but it is unclear if this was due to an alteration in the products of fermentation. Increasing the energy intakes of lambs fed silage did not show a consistent increase in the availability of minerals.

ARC (1980). The nutrient requirements of ruminant livestock. ARC London, 351 pp.

Paper No. 37.

THE EFFECT OF THE BROWN MIDRIB MUTANT GENE (BM_3) ON THE <u>IN VIVO</u> DIGESTIBILITY OF MAIZE SILAGE

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The discovery of maize genotypes with brown midribs was first reported in the early 1930's. Their existence went largely unnoticed for thirty years until it was shown that their lignin content was appreciably lower than that of normal plants. A further period of time elapsed before animal nutritionists investigated the effect of the lower lignin content of the brown midrib mutant genes on digestibility value, dry matter intake and levels of animal performance. This work showed that with high embient temperatures the bm_3 gene was successfully used in North America to reduce the lignin content and increase the digestibility value of maize crops.

The aim of the present work was to investigate the effect of the bm_3 gene on the *in vivo* digestibility values of crops grown under the relatively cool climatic conditions of the U.K. where lignin content is already low.

The normal and bm_3 forms of Inra 188, 240 and 258 were grown and ensiled at 139 days after plant emergence. The six silages were offered to wether sheep at a maintenance level of feeding in a 3 x 2 factorially designed trial, with four sheep for treatment.

The dry matter (DM) content of Inra 188 normal and bm_3, Inra 240 normal and bm_3 and Inra 258 normal and bm_3 silages were 30.4 and 24.6%, 28.3 and 25.6%, and 29.3 and 26.0%, respectively. The mean values for cell wall, acid-detergent fibre, cellulose, hemicellulose and lignin content for the normal and bm_3 silages were 54.8, 21.4, 20.5, 33.4 and 0.88% DM and 52.8, 22.2, 22.2, 30.6 and 0.05% DM, respectively.

The results of the *in vivo* digestibility trial showed that the apparent digestibility of cell walls, acid-detergent fibre, cellulose and hemicellulose was increased from 76.2 to 78.8%, 67.9 to 76.7%, 75.6 to 81.8% and 81.0 to 80.1% (decrease) for Inra 188 and from 72.2 to 78.3%, 63.6 to 74.1%, 71.3 to 78.7% and 77.8 to 81.3% for Inra 240 and from 75.8 to 80.6%, 70.3 to 76.8%, 75.8 to 81.9% and 79.6 to 83.2% for Inra 258, by inclusion of the bm_3 gene. The inclusion of bm_3 gene in Inra 188, 240 and 258 increased the digestible organic matter in the dry matter from 73.4 to 76.3%, 71.6 to 74.4% and 76.0 to 77.2%, respectively. With the exception of hemicellulose, where the differences were significant at the 5% level, the increase of digestibility values attributed to the bm_3 gene were all significant at the 0.1% level.

In conclusion, the bm_3 gene has been shown to decrease lignin content and significantly increase the digestibility values of maize genotypes grown under the cool climatic conditions of the U.K., where forage and not grain maize production is of primary concern. Further work should be done to compare normal and bm_3 silages at similar stages of maturity and to determine its effect on animal performance.

Paper No. 38.

THE ENERGY VALUE OF A RED CLOVER SILAGE

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In an experiment to determine the energy value of a silage made from second-harvest tetraploid red clover, four adult wether sheep were given two levels of intake, i.e. low and high. Using a value of 9.2 MJ kg^{-1} dry matter (DM) for the metabolizable energy (ME) the low level of 1041 g d^{-1} DM was calculated to provide maintenance, whilst the high level of 1532 d^{-1} was the mean *ad libitum* DM intake of the four sheep reduced by 10% to minimise refusals. Fasting metabolism was measured both before and after the experimental feeding periods, which lasted 28 days at each level of intake.

At the low level intake the daily ME intake was 455.3 kg per kg^{-1} $W^{0.75}$ and at the high level 684.3 kJ kg^{-1} $W^{0.75}$. The ME requirement for maintenance was 317 kJ kg^{-1} $W^{0.75}$. The daily DM intake at the high level was 61.3 g kg^{-1} $W^{0.75}$ which was similar to that of 67.0 g kg^{-1} $W^{0.75}$ for wether lambs fed *ad libitum* found by Wilkins *et al* (1978). These authors showed that this intake achieved with lucerne and red clover silage was higher than that achieved either with grass (56.2 g kg^{-1} $W^{0.75}$) or cereal (54.8 g kg^{-1} $W^{0.75}$) silages prepared without additives.

The metabolizability (q) of the silage at maintenance was 0.54 and the ME content was 10.1 MJ kg^{-1} DM. The efficiency of utilization of ME at maintenance (km) was 0.73 and at twice maintenance (kf) it was 0.55.

In Table 1 the data obtained with the red clover silage in this experiment is compared with that from a typical grass silage at the first harvest both given *ad libitum* less 10%.

The experiment confirmed that sheep may achieve high intakes of DM when offered red clover silage and showed that the ME value at maintenance of 10.1 MJ kg^{-1} DM of this sample was higher than the published values of 8.8 MJ kg^{-1} DM (Tech. Bull. No. 33, 1975) and 9.2 MJ kg^{-1} DM (ARC, 1965).

An unusual feature of the experiment was that when the intake was increased to the high level of just over twice maintenance, the energy losses in faeces, urine and as methane all declined in all four sheep resulting in a mean ME value of 11.2 MJ kg^{-1} DM.

Table 1. A comparison between a grass and red clover silage.

	Silage	
	Grass harvest 1	Red clover harvest 2
ME intake (kJ d^{-1})	604.9	684.3
ME intake x maintenance	1.57	2.16
Metabolizability (q)	0.57	0.54
Retention (kJ d^{-1})	+ 107.4	+ 198.7
Efficiency of utilization of ME above maintenance	0.49	0.54

References

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Paper No. 39.

ENERGY AND NITROGEN BALANCE STUDIES WITH GRASS SILAGES

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Relatively few energy balance studies with grass silages have been made. The present investigation evaluates the effects of an additive ("Farmline") on the energy utilisation of a grass silage.

The silages were prepared from a ryegrass-clover mixture cut in early June 1979, and harvested with a precision-chop forage harvester. The grass was ensiled directly into two 6 t capacity bunker silos either with or without the addition of "Farmline" additive (10% formaldehyde, 20% formic acid, 24% sulphuric acid, 15% stabiliser/corrosion inhibitor) applied at the rate of 4.5 l t^{-1}. The compositions of the grass and the resulting silages are given in Table 1.

Table 1. Composition of fresh grass and silages.

			Silage	
		Grass	Untreated	Treated
DM	(g kg^{-1})	167	176	184
GE	(MJ kg^{-1} DM)	19.0	18.8	19.0
Total N	(g kg^{-1} DM)	37.3	37.9	38.5
Protein N	(g kg^{-1} DM)	791	317	444
Ammonia	(g kg^{-1} TN)	-	166	122
pH		5.88	4.72	4.40

The silages were fed at maintenance and one and one half times maintenance to four crossbred wether lambs of 30 kg mean live weight. N, and energy balance studies by open circuit calorimetry were conducted and the efficiency of utilisation of metabolism energy (ME) for growth (k_g) determined. The results of the studies are shown in Tables 2 and 3.

The treated silage contained higher protein N and lower ammonia N contents than the untreated silage (Table 1) with greater faecal N and lower urine N losses. (Table 2). The faecal energy losses relative to the gross energy (GE) intake were unaffected by the additive treatment, and urinary energy losses were significantly lower with the treated silage given at the higher rate. Similar energy losses were observed for methane (5.5%) and for metabolic heat (55.6%) relative to GE intake, for both silages. The energy retention/...

retention was significantly higher for the treated silage at the high level. The k_g values were higher for the treated silage (0.40) compared with the untreated silage (0.34).

It is concluded that the additive "Farmline" significantly increased N and energy retention in wether lambs.

Table 2. Nitrogen balance.

Silage	Maintenance level	N intake (g d^{-1})	Faecal N loss (% N intake)	Urine N loss (% N intake)	N retained (% N intake)
Untreated	1	18.4	18.6	70.6	10.9
Untreated	1½	25.2	19.2	68.8	12.0
Treated	1	18.9	21.0	70.3	8.7
Treated	1½	27.4	22.3	59.0	18.7
Comparison between silages	1	*	***	NS	NS
	1½	NS	***	***	**

Table 3. Energy balance.

Silage	Maintenance level	GE intake (MJ d^{-1})	Faecal energy (% GE)	Urinary energy (% GE)	Energy retention (% GE)	ME (MJ kg^{-1} DM)
Untreated	1	9.18	20.02	8.29	7.69	12.52
Untreated	1½	12.36	21.35	8.56	10.52	11.94
Treated	1	9.37	20.44	7.82	9.04	12.76
Treated	1½	13.49	21.11	6.68	13.89	12.56
Comparison between silages	1	NS	NS	NS	NS	*
	1½	***	NS	***	*	***

Paper No. 40.

UTILISATION OF WILTED SILAGES BY HEIFERS

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The objective of this experiment was to compare three silage making techniques.

1. A direct-cut silage made with formic acid (3.5 l^{-1} t).
2. A wilted silage - wilted for 3 days.
3. A heavily-wilted silage (4 days) harvested by a round-baler.

Bales were stored either (a) individually in plastic bags (b) grouped with the others under an air-tight plastic sheet with injected NH_3 or (c) grouped with the others under an air-tight plastic sheet, without NH_3.

The silage was prepared from a first growth of natural grassland with a CP content of 17% and a CF content of 24% in the DM.

There were 3 groups of 10 heifers. After a common pre-experimental period, the different silages were given without concentrates for 105 d. The animals were offered silage individually. Intake was measured on 4 days each week. The liveweight was measured regularly. The results are shown in Table 1.

It is concluded that it is possible to use a round-baler for heavily-wilted silage but the feed efficiency of such silage is low, and is not compensated by the relatively low DM losses.

Table 1/...

Table 1. Silage analyses and animal performance.

	Silage				
	Direct cut	Wilted	Big bales		
DM content (%)	22	27	43		
			A	B	C
pH	4.14	4.45	5.17	4.98	5.41
N-NH (% total N)	7.6	12.4	7.7	9.4	15.3
Acid (g kg^{-1} DM)					
C_2	22	40	7	11	7
C_4	0.3	1.0	6	4	11
Mean liveweight (kg)	349	341	342		
DM intake (kg d^{-1})	6.76^a	6.96^a	7.75^b		
Liveweight gain (g d^{-1})	890^a	740^b	750^b		
DM intake (kg kg^{-1} gain)	7.6	9.4	10.3		
DM losses (%)	19	10	16		

Paper No. 41.

THE INFLUENCE OF FERMENTATION ON THE NUTRITIVE VALUE OF SILAGE

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During the fermentation of silage there are various decomposition processes which are measured by the content of fermentation acids and NH_3. Part of the decomposed products are found in the fermentation gases, especially CO_2. During these processes the nutrients which are decomposed are those which are fermented by silage micro-organisms. These are the more digestible nutrients, i.e. the N-free extracts and proteins. Therefore, compared to green fodder there are various changes as shown in Table 1.

Table 1. Changes in the nutrient content of grass silage DM compared to green fodder (=100%).

	Crude protein	Fat	Crude fibre	Ash	N-free extract
Mean	98.3	(173.8)	104.6	110.7	93.1
SD	8.9	(47.3)	9.8	12.5	9.5

The proportion of N-free extract in the silage decreases, whereas the crude fibre increases. The crude protein content is virtually unchanged, but the ash content is increased.

The changes in the digestibility of the nutrients are shown in Table 2.

Table 2. Changes in the digestibility of nutrients (green fodder = 100%).

	Crude protein	Fat	Crude fibre	Ash	N-free extract
Mean	94.1	(131.2)	103.0	95.8	97.7
SD	6.9	(70.5)	5.7	5.9	3.6

The fermentation losses, and the DM content of the silage, influence the changes of nutrients (Table 3).

Table 3. Changes in the nutrient content of silage compared to green fodder (= 100%) for different levels of silage DM content and DM losses.

Dry matter (%)	DM losses (%)	Digest. C.P.	Crude fibre	N-free extract	Net energy
10 - 20	35 - 20	-15 to -18	20 to 10	-27 to -13	-18 to -8
20 - 30	20 - 10	-7 to -4	9 to 5	-12 to -7	-8 to -4
30 - 40	8 - 6	-4 to -3	5 to -4	-5 to -4	-3 to -2
40 - 50	6	-3	4	-4	-2

No correlations were found between DM content and DM losses and the digestibility of nutrients.

Paper No. 42.

CHOP LENGTH CLASSIFICATION

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Length of chop is an important factor in many aspects of silage production, yet its determination has been one of the most time-consuming operations in experimental work with the only reliable method being tedious hand measurement of every particle in the sample.

Studies have shown that the main problem with mechanical methods of sorting are the classification of bent and tangled material. The apparatus described below is designed to completely sort dried chopped grass into eight fractions ranging in size from less than 4.5 mm to greater than 90 mm. Turbulent air in an aspirator column is used to untangle the mass of chopped particles and to deliver individual pieces to the sorter. A cascade of horizontal corrugated trays with transverse knife edges forms the vibrating conveyor through which the sample descends as it is sorted. This arrangement gives a sufficient number of small grooves to align straight material, and the downstream edges of the transverse sorting gates are positioned at a lower level than the upstream edges to allow the longer bent pieces to pass over without causing blockages. The longest pieces pass over the first gate and are collected while the remainder overbalance and fall through onto the next tray, where the next longest fraction is sorted. This continues down through to the bottom layer of the cascade. Comparisons have been made between classifications of length obtained by the machine and by hand sorting for forage samples of stalk material, stalk and leaf material, and leaf material alone. The results in Table 1 show that agreement between the length distributions obtained from the machine and hand sorting is good. The overall values deduced from the machine distribution agree with those obtained from hand sorting to within 5%. For example, for a stalk and leaf sample with median chop length of 20 mm the difference between the machine determination and the hand sorted value would be a maximum of 1 mm.

Table 1/...

Table 1. Comparison of distributions of forage lengths obtained from machine and by hand sorting.

Type of sample	Median (mm)		Inter-quartile range (mm)	
	Machine	Hand	Machine	Hand
Stalk	15.8	16.4	12.2	13.0
Stalk and leaf	17.9	17.4	10.5	9.0
Leaf	15.6	13.8	13.5	11.2

The degree of comminution of forage samples has often been described as short, medium and long; which only gives comparative assessment without quantitive description. The parameter "chop modulus" has been used in the past, but the main disadvantages are that its value is not unique to any one distribution, and considerable experience is required to appreciate the actual length of the sample. Accurate definition of the distribution has facilitated the use of more precise methods of data presentation. Since most distributions are skewed, the mean and standard deviation values do not give genuine representations of the distributions. The most comprehensive and readily comparable presentation is cumulative length distribution where the cumulative percent by weight is plotted against chop length, and comparison of two curves will explicitly indicate the differences in distribution. The best single figure parameter which can be used to describe the distribution is the median (50%). This can be supplemented with the inter-quartile range (25%-75%) for additional distribution description, and it is suggested that these values should be used as a standard chop length description method.

Paper No. 43.

A COMPARISON OF BIG BALE AND PRECISION-CHOP SILAGE; SILAGE QUALITY, LOSSES AND LIVESTOCK PERFORMANCE

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Baled silage in bags has grown in popularity as farmers see the advantage of changing from hay to silage with low capital investment. The lack of positive data on losses, silage quality and livestock performance prompted this investigation. The objective was to review the comparative quality of wilted baled and wilted-chopped silage made from the same crop, compare livestock intake and performance with these silages and to establish in-silo losses.

Grass was cut with a rotary mower and wilted to approximately 30% DM. Alternate swaths were harvested by a precision-chop harvester and with a New Holland 850 baler at the same time. One hundred and six big bales with a mean weight of 599 kg were prepared from three fields. The precision-chopped silage was harvested with and without additive giving three silage treatments. The additive was Silaform at a rate of 6.2 l t^{-1}. Concurrently the precision chopped material was ensiled in 100 t concrete silage clamps and the bales were ensiled within 500 gauge black polythene bags sealed at the neck.

The analyses of the silages (Table 1) show that the wilted-chopped and baled silages were generally similar. The pH was 0.5 higher in the baled silage, WSC was higher and the protein breakdown was slightly greater.

Table 1. Composition of the silages.

	Baled silage	Wilted chopped	Wilted chopped + additive
DM (g kg^{-1})	334	295	286
pH	4.6	4.09	4.03
WSC (g kg^{-1})	55	31	98
TN (g kg^{-1} DM)	21.7	20.9	21.6
CP (g kg^{-1} DM)	135	131	135
NH_3-N (g kg^{-1} TN)	103	99	81
PN (g kg^{-1} TN)	321	350	451
GE (MJ kg^{-1} DM)	19.2	19.3	19.1

To assess livestock performance, the silages were offered individually, to four groups of 16 suckler calves with an initial weight of 350 kg. The trial was conducted for 20 weeks and the silage was given *ad libitum* with controlled barley supplementation. Silage intakes and liveweight gains were monitored.

Silage intake was 5.6, 5.7 and 6.0 kg DM d^{-1} on the baled, wilted-chopped and wilted-chopped + additive silage respectively. Liveweight gain varied more significantly with 926, 990 and 994 g d^{-1} respectively. This indicates a 6% lower liveweight gain with baled silage than with wilted chopped silage. No differences were found in either the killing-out percentage or in the carcass classification (as undertaken by the MLC).

In a trial with sheep for 9 weeks there were no significant differences in intake, but there were significant differences in liveweight gain and feed efficiency between baled and chopped silages. The liveweight gain was -0.28, 1.4 and 3.03 kg for the baled, wilted-chopped and wilted-chopped + additive silages respectively.

Bale weights were recorded at ensilage and at feeding and a mean total weight loss of 3.5% was recorded. DM losses in the range 3.4 - 8.9% were recorded. Using the MAD-fibre contents, mean losses of DM were 1.7, 5.7 and 12.3% in the 3 fields.

Most of the bales showed signs of moulding. Some 30% showed deep mould patches greater than 50 mm in depth and half of these were identified as being extensively moulded on the outer surface. Moulding was most apparent at the open end of the bag indicating the difficulty in obtaining an effective seal. 17% of the bags were torn or split during ensilage and unloading the silo. A further 6% had extensive pin holes, although the condition of the bales suggest that up to 50% of the bags were damaged. For a second year of usage 23% of the bags would be rejected.

The trial showed the value of baled silage and indicated that the compositions of baled silage and wilted-chopped silage made from the same material were similar. The intake trial indicated a 6% lower liveweight gain with baled silage than the other wilted silages. Mean losses in the range of 1.6 - 12.3% were recorded in the ensilage of big bales. A more flexible and resilient plastic is needed for big bale bags than the agricultural grade black polythene currently used.

Paper No. 44.

AN ALTERNATIVE TO THE TINE-BAR PICK-UP

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The use of plastic tuft-studded rotors to collect forages from windrows and feed them into harvesting machines such as forage choppers and balers has been reported previously, together with a design proposal for simultaneously rejecting unwanted heavy objects. More recent work has compared pick-up losses in different grass swaths at varying ground clearances, throughput rates and crop lengths, and measured the power requirement of high-speed brush pick-ups and the silica contamination of the recovered crop. The responsiveness of the acoustic impact sensing and mechanical rejecting system has been assessed in relation to foreign objects of differing mass.

For the field work an experimental rig was used which placed the collected crop on to a continuous canvas sheet, so that it could be weighed and all material and objects which remained on the ground were isolated. For the comparison of pick-up performance a conventional tine-bar pick-up on a self-loading forage wagon was used.

Within the normal range of work rate and crop length, pick-up losses with the brush were usually low. The most important factor governing pick-up performance was crop alignment. Probably because a windrowed crop is randomly arranged and interlinked, it was picked up more efficiently by the conventional system than a crop left in mower swaths, particularly drum mower swaths. With the tine-bar pick-up, losses in mower swaths rose drastically with throughput to 6% and above. The brush pick-up appeared to be unaffected by crop alignment, and for a given loss level and clearance it could be set higher. Soil contamination was also less, and this fact has already proved to be of value in reducing the wear rate of pelleting dies in a commercial grass drying installation. The effect of pick-up height on silica contamination, measured in a grass mixture, is given in Table 1.

Table 1. Change in crop silica content after machine lifting (% of DM).

Type of pick-up	Ground clearance (mm)			Average
	25	35	50	
Tine-bar	+0.48	+0.24	+0.27	+0.33
Brush**	+0.15	-0.02	-0.01	+0.04

** all values significantly lower at the 0.1% level of probability

Power requirement was in the region of twice that of the conventional pick-up, but in practice it should rarely exceed 6 kW. The ability to recover short crops more effectively should make it possible to condition crops more severely without risking excessive dry matter losses as a result of fragmentation.

The detection and rejection system for heavy unwanted objects which can be picked up with the crop had an overall efficiency of over 70% when tested with six typical objects. Efficiency increased with increasing mass of the object. The effectiveness of the system was due in part either to the brush tufts passing over objects on the ground or displacing them laterally. If a signal was generated by an object being lifted the mechanical deflector reached its fully operative position within 0.22 s of the impact occurring. The dwell time of the deflector in the operative position was 0.5-0.6 s, and the total cycle time from signal generation on the deflector having returned to its rest position was marginally over 1 s. Crop presence and the rate of throughput tended to reduce cycle time.

The main reasons for failing to reject objects, which found their way into the crop stream were failure to register an impact, particularly small irregularly shaped objects, and the deflector missing the object at either the beginning or end of its cycle. The amount of crop rejected with individual objects by the deflector varied between 0.2 and 12.9 kg, and the average was 3.6 kg.

The experimental sensing and rejection system for foreign objects had the advantage that it was automatic, i.e. the harvesting process need not be interrupted, and that heavy metallic and non-metallic objects were removed. Additionally, the momentary thinning out of the swath or windrow by the high-speed brush provided a good opportunity for the introduction and thorough mixing with the crop of small quantities of chemical additives in liquid and solid form. The experimental system had the potential of being improved by the addition of more microphones and of metal detection means. The latter would be particularly effective if an all-plastic rotor could be developed, and this seems likely. The additional signals from an induction coil can be fed into the existing control circuit, so that all ferrous objects, including small pieces which are not harmful to harvesting machinery but to livestock, are also separated.

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