STUDIES ON GRASS SILAGE FROM PREDOMINANTLY *PASPALUM DILATATUM* PASTURES IN SOUTH-EASTERN QUEENSLAND

1. A COMPARISON AND EVALUATION OF THE ADDITIVES METABISULPHITE AND MOLASSES

By M. S. LEVITT, B.Sc., V. J. TAYLOR, B.Sc., and A. HEGARTY*

SUMMARY

In one experiment, the silage treatments compared were untreated, metabisulphite at 8 lb/ton green matter and molasses at 40 lb/ton. In a second experiment, two additional treatments, metabisulphite at 12 lb/ton and molasses at 80 lb/ton, were included.

The experimental procedure of fine chopping, rapid filling and maximum compaction resulted in low-temperature silages. Fermentation losses were of the order of 10 per cent. in all treatments. Appreciable effluent resulted only in treatments involving the addition of sodium metabisulphite.

In both experiments the use of additives improved silage quality. The best quality, as indicated by lower pH and increased lactic acid concentration, resulted from the use of molasses. There was little further improvement in quality from the higher content of 80 lb molasses/ton.

In comparison with the control silage, both metabisulphite and molasses treatments showed a significantly greater digestibility of the nitrogen-free-extract, organic matter and dry matter, this effect being most marked with the greater concentration of additives used in the second experiment. In the first experiment there were no significant differences in digestibility between the products made with additives. In the second experiment some differences between additives attained significance, metabisulphite giving greater digestibility of dry matter, organic matter and fibre, and molasses giving greater digestibility of the nitrogen-free-extract.

Some loss of digestibility was apparent from the ensiling process, the digestibility of the nitrogen-free-extract, organic matter and dry matter being markedly greater in the pasture prior to ensiling than in any of the resultant silages.

The order of palatability of the silages in relation to additives used was molasses at 80 lb/ton, metabisulphite at 8 lb/ton, molasses at 40 lb/ton, metabisulphite at 12 lb/ton, untreated.

I. INTRODUCTION

In all countries grasslands provide the basic and most important single item in the diet of ruminants. Agricultural economy demands therefore that increasing attention be paid to grass production and utilization. Davies (1960)

* Queensland Department of Agriculture and Stock

stated that in a normal year no more than one half of the dry-matter grown on British grasslands passes through the grazing animal, the remainder being wasted in so far as feeding the animal is concerned. In tropical countries the rainfall is characteristically monsoonal, occurring in the summer months. This results in a quick flush of pasture growth, and without conservation wastage would certainly exceed the 50 per cent. quoted by Davies.

A further complication in the tropical or even subtropical environment is the large seasonal fluctuations which occur in the nutritional value of most pasture species. Growth is rapid during the hot wet summer and mature dry pasture is often the only feed available in the dry winter and early spring. This is reflected in the growth rate of beef cattle. Chester (1952) stated that in Queensland cattle usually gain in weight from November to June and lose weight from July to October. A similar seasonal variation in productivity is evident in dairy cattle in Queensland. Pegg (1955) stressed the need for seasonal calving for dairy cows to make greater use of seasonal fluctuations in pasture quality.

In the subtropical environment, pasture conservation as silage has a considerable advantage over hay making in that weather conditions at time of harvest are not so important.

Grass silage offers tremendous advantages to the dairying industry of Queensland, which at present depends on summer-growing subtropical pasture species as the main source of diet for the State's dairy herds. In the over-45 in. rainfall zone, *Paspalum dilatatum* is grown to the extent of 780,000 acres (Bureau of Census and Statistics 1960), and each summer a considerable bulk of surplus grass forage is available for conservation purposes.

No data would appear to be available on factors affecting the quality of grass silage made in a tropical or subtropical environment. Murdoch (1960) showed that in most cases silage quality was better at lower temperatures (70–80°F). However, in Queensland the shade temperature in summer, when pasture is available for conservation, usually exceeds 90°F. There was therefore a need to examine the quality of grass silage laid down under these conditions and at the same time to evaluate the need for additives to improve silage quality.

The use of additives to reduce losses and improve silage quality has been studied extensively in many countries. These additives include mineral acids, organic acids, chemicals such as formate-nitrite and sodium metabisulphite, and materials rich in readily available carbohydrate.

Additives used in the experiments reported here were molasses and sodium metabisulphite. The former was selected on the grounds of availability as a by-product of the extensive cane-sugar industry in Queensland. The latter was selected in view of the findings of Cowan and his associates (1952, 1956).

II. METHODS AND MATERIALS

Experimental Area.—An experimental area of approximately 2 ac was selected at the Animal Husbandry Research Farm at Rocklea, near Brisbane. The predominant pasture species was *Paspalum dilatatum,* and green couch (*Cynodon dactylon*) was present in limited quantities. The amount of white clover (*Trifolium repens*) was negligible at the time when the pasture was being ensiled.

Pasture Yield Measurements.—Pasture yield in the experimental area was determined from 10 quadrats, each of 1 sq. yd., cut to a height of approximately 2 in. above ground level. Yields were recorded as dry matter from a representative sample dried to constant weight in a hot-air oven at 105°C. Measurements were made during the period of maximum growth of pasture for 2–3 weeks prior to conservation.

Harvesting Procedure.—The pasture was harvested with a commercial harvester of the cutter-bar type, the blades of which were set to give a product chopped in lengths of approximately 1-2 in. The chopped product was blown into a trailer, as harvested, and transported a distance of about 2 miles from the experimental area to the experimental silos.

Experimental Silos.—These were cylindrical cement pipes 4 ft in diameter, sealed onto a concrete base. In the first experiment the pipes were 4 ft in height; this was increased to 5·5 ft to provide additional silage in the second experiment. An iron pipe of 1 in. diameter connected the centre of the base of the silo, through an air trap, to a vessel for the collection of effluent. The entrance to the effluent pipe was covered with a perforated plate, flush-fitted with the base of the silo. Before use, the inside of the silo was coated with a commercial silicate preparation and the bottom of the silo was covered with a layer of stones to a depth of about 3 in. to aid the drainage of effluent.

When filled, each silo was fitted with a hardwood lid, the external diameter of which was slightly less than the internal diameter of the silo. Each lid weighed about 100 lb. A number of concrete blocks were placed on each lid to give a total weight of about 1000 lb. This was designed to simulate the pressure that might be expected 2–6 ft below the surface in a trench silo.

A steel pipe, 6 ft in length and 1·5 in. in diameter, was sealed at one end and placed in the centre of each silo during the filling operation. The sealed end rested on the base of the silo and extended through a hole in the centre of the wooden lid. The pipe was filled with water to silo height. After stirring, the temperature of the water was determined at intervals during the fermentation process.

The experimental silos were provided with a common roof to ensure protection against weather. A gantry was attached to this roof and a block-and-tackle ensured ease of handling lids and weights.

Filling Procedure.—The chopped pasture was weighed into each silo in 25 lb lots, using a clock-face spring balance with an accuracy of $\pm 0 \cdot 2$ lb. After the addition of each 50 lb the material in each silo was well trampled. Where treatments involved the use of additives, the correct amount for 50 lb of chopped pasture was sprinkled on the exposed surface prior to trampling.

When the silo was full the contents were covered with a layer of plastic sheeting followed by a layer of fibreen sisalcraft and the lid and weights placed in position. A hole was cut in each covering to accommodate the steel pipe for temperature measurement.

Silage Quality Tests.—Fermentation losses were measured by recording the amount of dry matter ensiled and recovered.

pH was determined on a representative sample as described by Barnett (1954) and using a Cambridge pH meter. Total acidity, volatile acidity, amino acids and volatile bases were essentially those quoted by Barnett (1954). Lactic acid was calculated by difference.

The physical characteristics of colour and smell were used as additional aids in the determination of silage quality.

Methods of Analysis.—Proximate stock-food analyses were those of the Association of Official Agricultural Chemists (1955).

Dry matter was corrected for loss of volatile constituents after drying to constant weight in a hot-air oven at 105°C. Appropriate corrections were made for proximate constituents determined on dry matter.

Digestibility.—Apparent digestibility was assessed as described by Harvey (1952), using 2–3-year-old Merino wethers housed in metabolism crates. All sheep were penned and fed grass silage for at least 3 weeks before being housed in the metabolism crates and fed the experimental silage.

Palatability.—The comparative palatability was assessed for each silage from the dry-matter intake of sheep isolated in individual pens and given the choice of two silages. All test animals had been group-fed on grass silage for at least 3 weeks prior to the test period. Each animal was then offered 2000 g from each of two silos twice daily for three days. The positions of the feed troughs in each pen were reversed on alternate days.

III. EXPERIMENTAL

(a) Experiment 1

The first experiment was made in the summer of 1956-57. Pasture yield measurements commenced on December 24, 1956, and continued until January 30, 1957. Digestibility measurements on pasture cut daily from the experimental paddock commenced on January 16, 1957. After a 7-day preliminary period, the collection period was from January 24 to January 30 inclusive. Approximately 70 per cent. of the experimental area was harvested for silage on January 25, 1957. The remaining 30 per cent. was mown for hay on January 30, 1957.

Silage treatments were:—

Silo 1: Control—chopped pasture with no additive.

Silo 2: Chopped pasture plus sodium metabisulphite at the rate of 8 lb per ton green material.

Silo 3: Chopped pasture plus molasses at the rate of 40 lb per ton green material. To facilitate handling, the molasses was diluted with an equal volume of water just prior to use.

The experimental towers were opened for chemical evaluation, digestibility and palatability studies on August 9, 1957. The silage had then been laid down for 197 days.

(b) Experiment 2

The second experiment was made in the summer of 1958-59, the experimental area being the same as that used in Experiment 1. Pasture yield measurements commenced on January 20, 1959, and continued until February 13, 1959. Digestibility measurements on pasture cut daily from the experimental paddock commenced on February 1, 1959, the 7-day test period being from February 7 to February 13 inclusive. The pasture was harvested for silage on February 9, 10 and 11, 1959.

Silage treatments were:—

Silo 1: Control—chopped pasture with no additive (harvested February 11).

Silo 2: Chopped pasture plus sodium metabisulphite at the rate of 8 lb per ton green matter (harvested February 10).

Silo 3: Chopped pasture plus sodium metabisulphite at the rate of 12 lb per ton green matter (harvested February 10).

Silo 4: Chopped pasture plus molasses at the rate of 40 lb per ton green matter (harvested February 9).

Silo 5: Chopped pasture plus molasses at the rate of 80 lb per ton green matter (harvested February 9).

The experimental towers were opened for chemical evaluation, digestibility and palatability studies on July 20, 1959. The silage had then been laid down for approximately five months.

IV. RESULTS

(a) Experiment 1

Rainfall data and the yield and protein content of pasture on a dry-matter basis are shown in Figure 1. The rainfall data cover the period of 30 days prior to harvesting the pasture for silage. The yield was determined at intervals during the 30 days before pasture conservation. During this period the pasture yield showed a fourfold increase and the protein content fell to about half the initial value. There was little change in either yield or chemical composition from January 24 to January 30 when the digestibility of the pasture was being determined. The pasture was harvested for silage on January 25 and for hay on January 30.

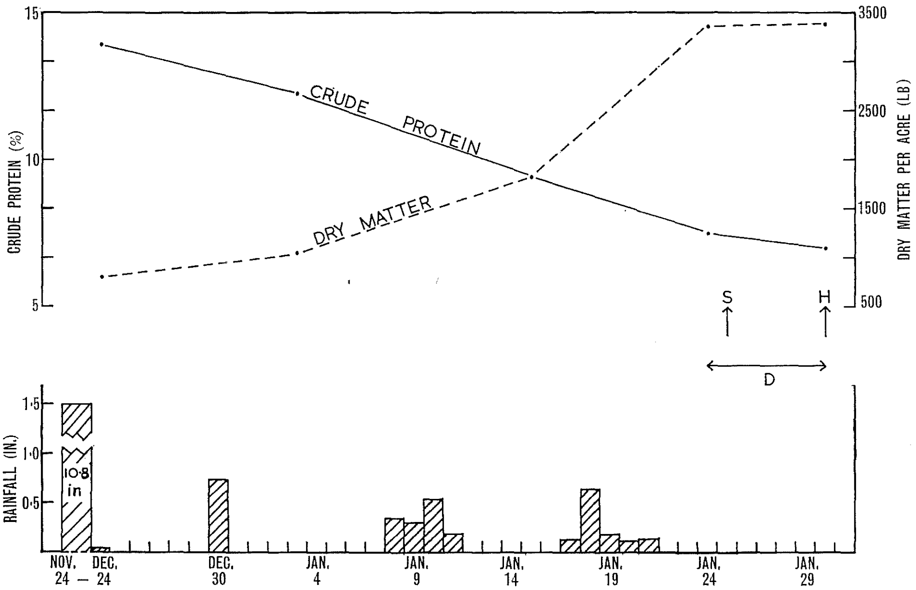

Fig. 1.—Dry-matter yield and protein content of pasture, and rainfall data—Experiment 1.

S ↑ Time of harvesting for silage

H ↑ Time of harvesting for hay

D ↔ Period of digestibility measurement.

Table 1 records the proximate analyses on pasture samples from quadrats cut at intervals prior to conservation. It is evident that as the protein level in the pasture falls there is an increase in fibre content. The mean composition of the pasture fed for digestibility measurements, the pasture harvested for ensiling, and the pasture harvested as hay is also shown in Table 1. It is evident that the pasture harvested for ensiling has a higher protein content

TABLE 1

Composition of Pasture from Experiment 1

Sample	Percentage on Dry Matter						
	Protein	Fat	Fibre	N.F.E.	Ash	Calcium (Ca)	Phos-phorus (P)
Quadrat cut 24.xii.56 ..	13·9	2·1	27·9	46·6	9·5	0·26	0·27
Quadrat cut 3.i.57	12·2	1·9	29·0	48·3	8·6	0·20	0·23
Quadrat cut 15.i.57	9·4	1·0	31·4	50·1	8·1	0·16	0·20
Quadrat cut 24.i.57	7·5	1·2	34·4	49·3	7·6	0·11	0·19
Quadrat cut 30.i.57	7·0	1·4	34·4	49·7	7·5	0·11	0·20
Representative sample from digestibility trial 24.i.57 to 30.i.57	7·0	1·5	33·6	49·5	8·4	0·11	0·20
Representative sample from pasture at ensiling on 25.i.57*	8·6	1·4	34·9	47·0	8·1	—	—
Representative sample of hay mown on 30.i.57 and harvested 2.ii.57	6·7	1·4	34·1	49·9	8·9	0·16	0·20

* The setting on the harvester was to cut at a height of 3–4 in., whereas quadrat cuts were to a height of about 2 in.

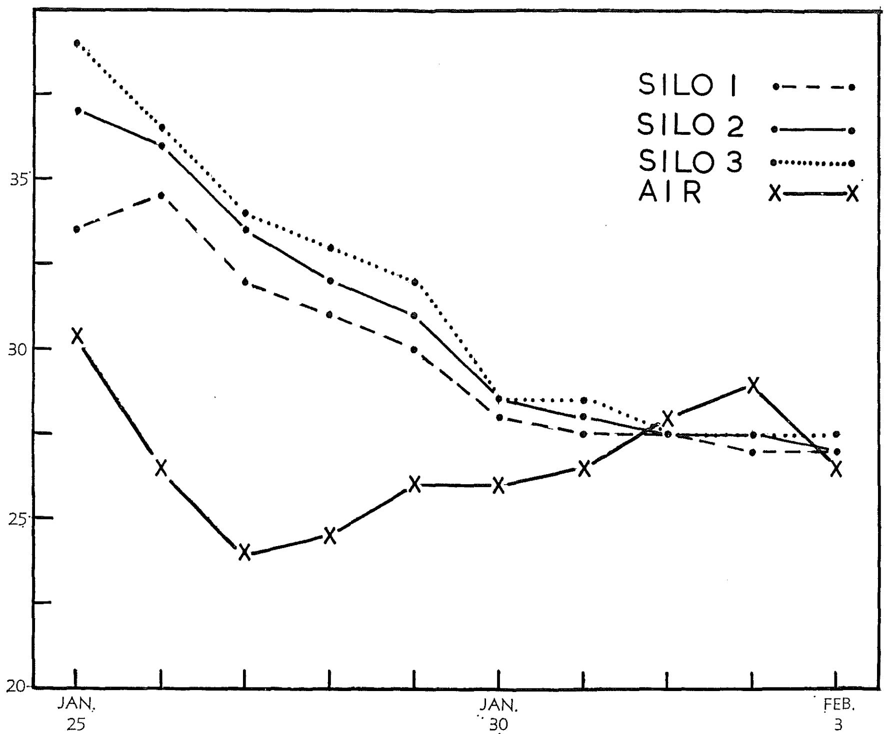

Fig. 2.—Changes in temperature of silage in Experiment 1.

than that fed in the digestibility measurements. A logical explanation is that these differences are due to the height above ground level at which pasture was cut. The quadrats and pasture fed for digestibility were cut at a height of approximately 2 in., whereas the forage harvester and mower cut at a height of 3–4 in.

The temperature changes in each silo and the air temperature readings are shown in Figure 2. All silage was made from one load of pasture. Silos were filled in the order Silo 1, Silo 2, Silo 3. Although the pasture was kept under cover, the mean temperature of the pasture at ensiling was greatest in Silo 3 and least in Silo 1. Subsequent measurements and all air temperatures were taken at 1 p.m. each day. In all silos the temperature had fallen to atmospheric temperature at about the sixth day after filling; thereafter daily changes in temperature did not exceed 0·5°C, although the diurnal variation in room temperature from maximum to minimum was of the order of 9°C.

TABLE 2

FERMENTATION LOSSES IN EXPERIMENT 1

Treatment	Amount Ensiled (lb)	Additive (lb)	Amount Recovered (lb)	Amount Effluent (lb)	Fermentation Loss (%)
Silo 1 (control)	1,200 (325)*	0	1,125 (282)	0	13
Silo 2 (8 lb metabisulphite)	1,200 (325)	4·5 (4·5)	1,130 (292)	6 (0·5)	12
Silo 3 (40 lb molasses) ..	1,300 (350)	23·0 (17·5)	1,245 (332)	0	10

* Values in parenthesis are expressed on a dry-matter basis.

Fermentation losses for each silage treatment are shown in Table 2. There was little difference between treatments, losses ranging from 10 to 13 per cent. Effluent occurred only in Silo 2, in which the addition of 8 lb sodium metabisulphite per ton of green matter was used. The amount and composition of this effluent are shown in Table 3.

TABLE 3

COMPOSITION OF EFFLUENT IN EXPERIMENT 1

Treatment	Total Volume (ml)	pH	Dry Matter (%)	Nitrogen (N) (%)	Volatile Acids (acetic) (%)	Residual Acids (lactic) (%)
Silo 1 (control)	0					
Silo 2 (8 lb metabisulphite) ..	2,740	6–6·9	8·9	0·037	0·34	0·49
Silo 3 (40 lb molasses)	0					

Silage quality findings are tabulated in Table 4. Measurements were made on representative samples of silage taken from the upper, middle and lower sections in each silo. For all treatments the silages tended to be of uniform quality in each section of the silo. The additive metabisulphite increased the concentration of lactic acid and the ratio of lactic to acetic acid. However, this silage showed a marked tendency to mould formation within 24 hr of exposure to the air. The addition of 40 lb molasses per ton of green matter (Silo 3) markedly increased the concentration of lactic acid and lowered the pH.

TABLE 4

SILAGE QUALITY TESTS IN EXPERIMENT 1

Treatment	Site	pH	Dry Matter (%)	Volatile Acidity (% acetic acid)	Residual Acidity (% lactic acid)	Nitrogen			Comments
						Total (%)	Volatile Base (%)	Amino Acid (%)	
Silo 1 (control)	Top ..	4·63	25·1	4·61	0·88	1·46	0·17	0·30	Light brown colour; strong acid smell
	Middle ..	4·66	24·9	4·86	0·80	1·50	0·21	0·31	
	Bottom ..	4·59	25·3	4·90	1·34	1·46	0·20	0·27	
	MEAN ..	4·63	25·1	4·79	1·01	1·47	0·19	0·29	
Silo 2 (8 lb metabisulphite)	Top ..	4·65	26·7	2·66	2·77	1·46	0·11	0·23	Olive green colour; appearance of preserved grass; sweet smell; marked tendency to mould on exposure to air
	Middle ..	4·60	25·9	3·56	2·13	1·39	0·16	0·30	
	Bottom ..	4·64	25·2	2·81	2·97	1·47	0·20	0·26	
	MEAN ..	4·63	25·9	3·01	2·62	1·44	0·16	0·26	
Silo 3 (40 lb molasses) ..	Top ..	4·36	27·2	1·95	3·68	1·42	0·17	0·28	Yellow to green colour; very sweet smell
	Middle ..	4·42	26·6	1·88	3·84	1·38	0·21	0·30	
	Bottom ..	4·46	26·2	1·99	3·51	1·48	0·21	0·27	
	MEAN ..	4·41	26·7	1·94	3·68	1·43	0·20	0·28	

Table 5 records the proximate analyses of the three silage treatments. Chemical composition tended to be uniform throughout each silage treatment and there were no marked differences between treatments.

TABLE 5

COMPOSITION OF SILAGES IN EXPERIMENT 1

Treatment	Site	Proximate Analyses on Dry Matter (%)				
		Protein	Fat	Fibre	N.F.E.	Ash
Silo 1 (control)	Top	9·2	2·6	36·0	42·8	9·4
	Middle	9·4	2·5	36·7	42·2	9·2
	Bottom	9·1	2·5	36·2	43·2	9·0
	MEAN	9·2	2·5	36·3	42·8	9·2
Silo 2 (8 lb metabisulphite)	Top	9·1	2·6	34·5	43·8	10·0
	Middle	8·7	2·3	35·5	43·5	10·0
	Bottom	9·2	2·5	34·9	43·5	9·9
	MEAN	9·0	2·5	35·0	43·6	9·9
Silo 3 (40 lb molasses)	Top	8·9	2·4	35·0	44·3	9·[illegible]
	Middle	8·6	2·4	35·1	44·5	9·4
	Bottom	9·3	2·4	34·4	44·6	9·3
	MEAN	8·9	2·4	34·8	44·5	9·4

Digestibility data on silages from each treatment are shown in Tables 6 and 7. These data showed:—

(1) Both the fresh pasture and the hay from this pasture had similar digestibilities on a dry-matter basis.

(2) Due to differences in protein levels, no valid comparisons could be made between the digestibility of the pasture and the three silages. However, in spite of the lower protein content of the pasture cut at a height of about 2 in. above ground level, the total digestible nutrients, metabolizable energy and starch were similar to the values obtained for the three silage products.

(3) The dry-matter and organic-matter digestibilities were significantly greater ($p<0{\cdot}05$) in the treated silages (Silos 2 and 3) than in the control (Silo 1).

(4) Both the metabisulphite (Silo 2) and the molasses treatment (Silo 3) resulted in a significantly greater digestibility for N.F.E. ($p<0{\cdot}01$ and $p<0{\cdot}001$) compared with the control (Silo 1).

(5) No other differences in digestibility attained significance.

The daily dry-matter intakes of each silage during palatability tests are shown in Table 8. The order of palatability was metabisulphite (Silo 2) > molasses (Silo 3) > control (Silo 1).

TABLE 6

MEAN DIGESTIBILITY COEFFICIENTS AND STANDARD ERRORS OF DIFFERENCES ON PASTURE, HAY AND SILAGE IN EXPERIMENT 1

Treatment	Dry Matter (%)	Organic Matter (%)	Crude Protein (%)	Fat (%)	Fibre (%)	N.F.E. (%)
Pasture	55·1	57·2	49·0	36·6	60·6	56·7
Hay	54·8	56·2	48·1	38·7	61·2	54·3
Silo 1 (control)	53·7	55·7	53·0	53·0	64·9	48·6
Silo 2 (8 lb metabisulphite)	56·5	58·2	54·4	51·7	66·5	52·7
Silo 3 (40 lb molasses) ..	56·9	58·5	53·5	54·3	65·9	54·0
S.E. differences, two silage treatments	±0·89	±0·90	±1·37	—	±1·19	±0·83
Significance	3,2>1*	3,2>1*	N.S.	—	N.S.	3 >1*** 2 >1**

Number of determinations per treatment = 6
N.S. = No significant differences among treatments
* = Significant at 5% level
** = Significant at 1% level
*** = Significant at 0·1% level

TABLE 7

DIGESTIBLE PROTEIN, TOTAL DIGESTIBLE NUTRIENTS, METABOLIZABLE ENERGY AND STARCH EQUIVALENT PER 100 LB OF MOISTURE-FREE MATERIAL IN EXPERIMENT 1

Sample	Digestible Protein (lb)	Total Digestible Nutrients (lb)	Metabolizable Energy (therms)	Starch Equivalent (lb)
Pasture	3·4	53·1	82·2	33·2
Hay	3·2	51·9	81·0	31·8
Silo 1 (control)	4·9	52·2	77·5	30·4
Silo 2 (8 lb metabisulphite) ..	4·9	53·7	80·3	32·7
Silo 3 (40 lb molasses)	4·8	54·6	81·7	33·7

TABLE 8

DAILY DRY-MATTER CONSUMPTION AS AN INDEX OF PALATABILITY IN EXPERIMENT 1

Sheep No.	Day	Daily Dry-matter Intake (g)					
		Silo 1 v Silo 2		Silo 2 v Silo 3		Silo 3 v Silo 1	
		1	2	2	3	3	1
1	1	251	660	671	90	502	172
	2	62	811			392	152
	3	24	716			248	176
2	1	10	666	562	163	684	137
	2	16	433	493	197	596	39
	3	22	409	434	23	478	144
3	1	35	405	408	32	385	126
	2			204	21	440	25
	3			206	25	222	29
Mean Ratio		1 :	10	5 :	1	4 :	1

Order of palatability: Silo 2 (metabisulphite) >Silo 3 (molasses) >Silo 1 (control).

(b) Experiment 2

Rainfall data and the yield and protein content of pasture on a dry-matter basis are shown in Figure 3. In a period of 20 days there was a threefold increase in pasture yield and the protein content fell from 11·2 to 7·6 per cent. on dry matter. There was little change in either yield or chemical composition from February 7 to February 13 when digestibility of the pasture was being determined. The remainder of the pasture was mown for conservation as hay on February 14 but was spoilt by rain and discarded. Table 9 records the proximate analyses on pasture from quadrat cuts, on a pasture sample representative of material fed during the digestibility trial from February 7 to February 13, and on representative samples of pasture ensiled on February 9 (Silos 4 and 5), 10 (Silos 2 and 3) and 11 (Silo 1). As in Experiment 1 the pasture harvested for ensiling had a higher protein content than that fed in the digestibility measurements. This has been attributed to the greater height above ground at which the commercial harvester operated.

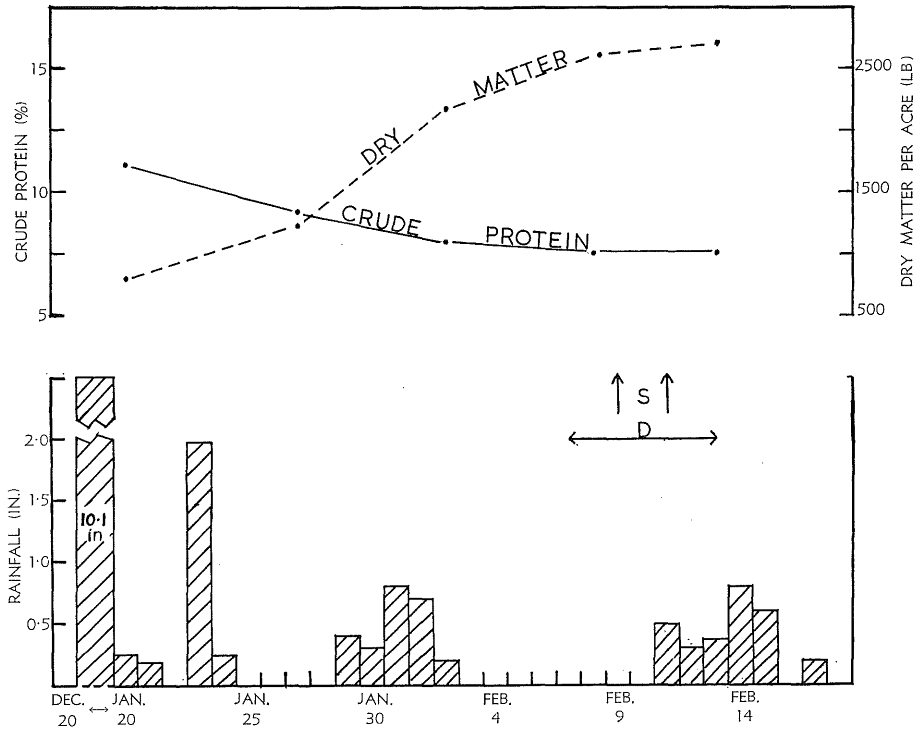

Fig. 3.—Dry-matter yield and protein content of pasture, and rainfall data—Experiment 2.

↑S↑ Time of harvesting for silage

D ←→ Period of digestibility measurement.

TABLE 9

COMPOSITION OF PASTURE IN EXPERIMENT 2

Sample	Percentage on Dry Matter						
	Protein	Fat	Fibre	N.F.E.	Ash	Calcium (Ca)	Phosphorus (P)
Quadrat cut 20.i.59	11·2	1·2	29·3	48·9	9·4	0·20	0·23
Quadrat cut 27.i.59	9·2	1·1	32·3	48·7	8·7	0·18	0·20
Quadrat cut 2.ii.59	8·1	1·1	33·3	48·8	8·7	0·16	0·22
Quadrat cut 8.ii.59	7·6	1·4	34·3	48·2	8·5	0·13	0·20
Representative sample from digestibility trial 7.ii.59 to 13.ii.59	7·6	1·5	35·0	47·0	8·9	0·14	0·19
Representative sample from pasture at ensiling on 9.ii.59*	8·5	1·2	34·3	47·2	8·8	0·18	0·22
Representative sample from pasture at ensiling on 10.ii.59*	8·3	1·0	34·3	47·7	8·7	0·15	0·22
Representative sample from pasture at ensiling on 11.ii.59*	8·1	1·0	34·9	47·4	8·6	0·16	0·21

* The setting of the harvester was to cut at a height of 3–4 in., whereas quadrat cuts were to a height of about 2 in.

Atmospheric temperature and changes in each silo are recorded in Figure 4. There was no further increase in temperature in any silo at 24 hr after filling and sealing. Temperatures had fallen to the atmospheric level at 4–5 days after filling, and thereafter remained relatively constant.

TABLE 10

FERMENTATION LOSSES IN EXPERIMENT 2

Treatment	Amount Ensiled (lb)	Additive (lb)	Amount Recovered (lb)	Amount Effluent (lb)	Fermentation Loss (%)
Silo 1 (control)	1,725 (410)*	0	1,610 (361)	11·0 (0·6)	12
Silo 2 (8 lb metabisulphite) ..	1,800 (414)	6·4	1,690 (373)	27·6 (1·4)	11
Silo 3 (12 lb metabisulphite)	1,800 (392)	9·6	1,660 (364)	43·7 (1·7)	10
Silo 4 (40 lb molasses) ..	1,750 (435)	31·2 (23·9)	1,725 (414)	2·3 (0·2)	10
Silo 5 (80 lb molasses) ..	1,800 (453)	64·3 (49·2)	1,825 (442)	2·4 (0·2)	13

* Values in parenthesis are expressed on a dry-matter basis.

TABLE 11

COMPOSITION OF EFFLUENT IN EXPERIMENT 2

Treatment	Total Volume (ml)	pH	Dry Matter (%)	Nitrogen (N) (%)	Volatile Acids (acetic) (%)	Residual Acids (lactic) (%)
Silo 1 (control)	5,000	5·8	5·9	0·028	0·29	0·34
Silo 2 (8 lb metabisulphite)	12,480	5·8	5·3	0·245	0·50	0·20
Silo 3 (12 lb metabisulphite)	19,810	6·2	4·0	0·308	0·58	0·30
Silo 4 (40 lb molasses) ..	1,030	5·9	8·0	0·014	0·29	0·42
Silo 5 (80 lb molasses) ..	1,080	5·7	8·4	0·018	0·49	0·52

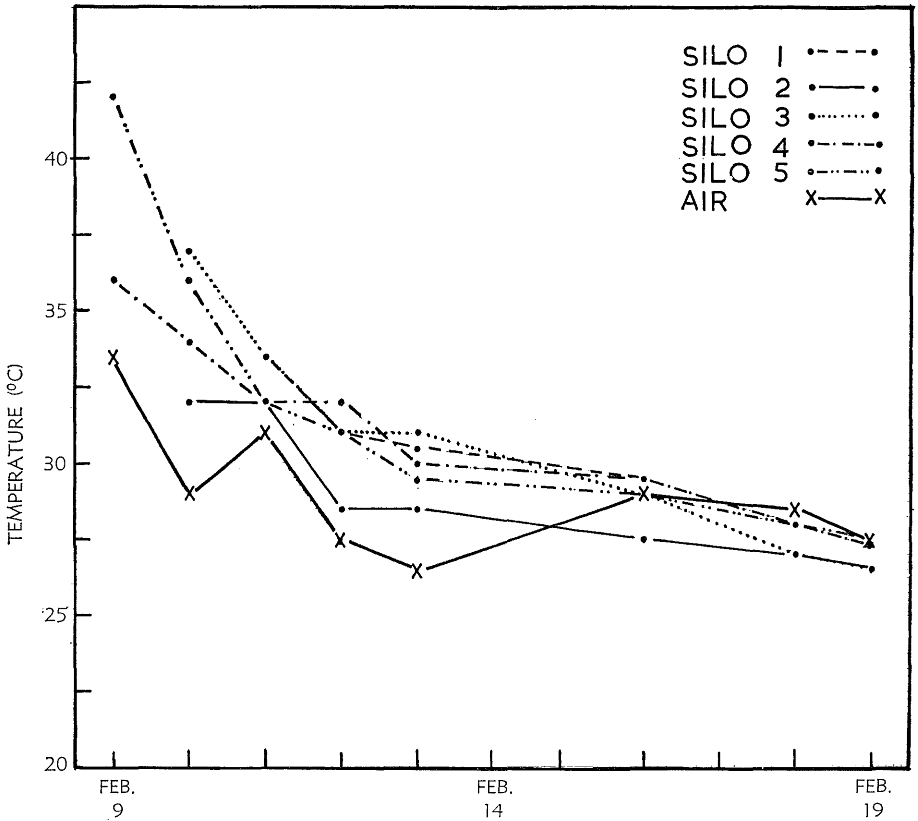

Fig. 4.—Changes in temperature of silage in Experiment 2.

Fermentation losses for each silage treatment are shown in Table 10. As in Experiment 1 there was little difference between treatments, losses ranging from 10 to 13 per cent. Effluent loss occurred in all silos but was most marked in the silages containing metabisulphite. The composition of the effluents from each silo is shown in Table 11.

Silage quality findings are tabulated in Table 12. In all silages quality was assessed on samples taken at different levels in the silo. There were some differences between samples taken at different levels, but they were least in the products containing molasses. The additive metabisulphite again increased the concentration of lactic acid and the ratio of lactic to acetic. This increase was most marked in the product from Silo 3, which contained the higher level of 12 lb sodium metabisulphite per ton. Both products containing metabisulphite showed a marked tendency to mould formation within 24 hr after exposure to air and the pH was higher than in the control silage from Silo 1. The addition of molasses also resulted in greater concentration of lactic acid, the level being greatest in Silo 5, which contained the highest level of 80 lb molasses per ton. The pH was lowest in the silages containing molasses.

TABLE 12

SILAGE QUALITY TESTS IN EXPERIMENT 2

Treatment	Site	pH	Dry Matter (%)	Volatile Acidity (% acetic acid)	Residual Acidity (% lactic acid)	Nitrogen			Comments
						Total (%N)	Volatile Base (%N)	Amino Acid (%N)	
Silo 1 (control)	Top ..	4·57	22·5	4·89	2·00	1·45	0·33	0·27	Light brown stems; dark brown leaves; strong acid smell
	Mid-upper	4·55	22·3	4·66	1·66	1·43	0·31	0·28	
	Mid-lower	4·52	22·4	4·43	0·85	1·44	0·30	0·27	
	Bottom ..	4·70	22·5	4·84	1·47	1·42	0·32	0·24	
	MEAN ..	4·59	22·4	4·71	1·50	1·44	0·32	0·27	
Silo 2 (8 lb metabisulphite)	Top ..	4·57	22·2	3·96	2·57	1·46	0·25	0·33	Yellow stems; olive green leaves; appearance of preserved grass; sweet smell; readily develops mould on exposure
	Mid-upper	4·75	21·7	3·82	1·89	1·44	0·29	0·29	
	Middle ..	4·72	21·9	3·46	1·46	1·48	0·31	0·31	
	Mid-lower	4·72	21·9	3·96	2·01	1·45	0·34	0·28	
	Bottom ..	4·55	22·9	3·62	2·62	1·48	0·29	0·28	
	MEAN ..	4·66	22·1	3·76	2·11	1·46	0·30	0·30	
Silo 3 (12 lb metabisulphite)	Top ..	4·72	21·6	2·69	3·33	1·44	0·23	0·28	Similar to 2 except for slightly sour smell
	Mid-upper	4·70	22·0	3·09	2·73	1·43	0·27	0·28	
	Mid-lower	5·16	21·6	2·27	1·39	1·45	0·28	0·17	
	Bottom ..	4·80	22·3	2·65	3·09	1·41	0·21	0·22	
	MEAN ..	4·85	21·9	2·68	2·64	1·43	0·25	0·24	
Silo 4 (40 lb molasses) ..	Top ..	4·45	24·5	3·19	2·94	1·52	0·22	0·29	Yellow to green colour; very sweet smell
	Mid-upper	4·52	24·0	3·45	3·17	1·51	0·25	0·24	
	Middle ..	4·44	23·5	4·13	2·38	1·57	0·29	0·21	
	Mid-lower	4·52	24·0	3·91	2·42	1·54	0·30	0·23	
	Bottom ..	4·33	24·0	4·29	2·67	1·46	0·27	0·28	
	MEAN ..	4·45	24·0	3·80	2·72	1·52	0·27	0·25	
Silo 5 (80 lb molasses) ..	Top ..	4·52	23·3	3·53	3·22	1·50	0·22	0·15	Similar to 4
	Mid-upper	4·54	24·4	3·32	3·24	1·50	0·28	0·22	
	Middle ..	4·46	23·9	3·35	2·93	1·55	0·25	0·20	
	Mid-lower	4·38	24·6	3·25	3·50	1·47	0·24	0·23	
	Bottom ..	4·42	24·9	3·13	2·85	1·50	0·27	0·27	
	MEAN ..	4·46	24·2	3·32	3·15	1·50	0·25	0·21	

The proximate analyses of the five silages are shown in Table 13. Samples for analysis were taken from a number of sites in each silo. There were some differences in composition at different sites in the silo and also between treatments. In all silages the protein on a dry-matter basis was higher than in the representative sample of pasture before ensiling. This was due to fermentation losses of carbohydrate.

TABLE 13

Composition of Silages in Experiment 2

Treatment	Site	Proximate Analyses on Dry Matter (%)				
		Protein	Fat	Fibre	N.F.E.	Ash
Silo 1 (control)	Top	9·1	1·9	37·9	41·8	9·3
	Mid-upper	9·0	1·9	35·9	44·5	8·7
	Mid-lower	9·0	2·0	38·7	41·2	9·1
	Bottom	8·9	1·9	39·1	40·9	9·2
	Mean	9·0	1·9	37·9	42·1	9·1
Silo 2 (8 lb metabisulphite)	Top	9·1	2·0	36·6	41·8	10·5
	Mid-upper	9·0	1·7	37·5	42·8	9·0
	Middle	9·3	1·8	37·9	41·4	9·6
	Mid-lower	9·1	1·6	37·3	41·5	10·5
	Bottom	9·3	2·2	37·4	40·3	10·8
	Mean	9·1	1·9	37·4	41·5	10·1
Silo 3 (12 lb metabisulphite)	Top	9·0	2·1	37·0	41·1	10·8
	Mid-upper	8·9	2·1	35·7	43·4	9·9
	Mid-lower	9·1	1·9	37·1	41·0	10·9
	Bottom	8·8	2·1	36·1	42·2	10·8
	Mean	9·0	2·0	36·5	41·9	10·6
Silo 4 (40 lb molasses)	Top	9·5	1·8	36·0	43·2	9·5
	Mid-upper	9·5	1·7	35·3	44·2	9·3
	Middle	9·8	1·8	35·6	43·3	9·5
	Mid-lower	9·7	1·7	35·9	43·0	9·7
	Bottom	9·1	1·9	35·8	43·7	9·5
	Mean	9·5	1·8	35·7	43·5	9·5
Silo 5 (80 lb molasses)	Top	9·4	1·7	34·7	43·9	10·3
	Mid-upper	9·4	2·0	34·3	44·3	10·0
	Middle	9·7	1·9	34·5	44·3	9·6
	Mid-lower	9·2	1·9	33·6	45·7	9·6
	Bottom	9·4	2·0	34·8	44·1	9·7
	Mean	9·4	1·9	34·4	44·5	9·8

Digestibility data on these five silages are shown in Tables 14 and 15. All means quoted in Table 14 have been adjusted to eliminate among-animals and among-periods differences. Exact methods were used in testing differences among the five silage treatments, but only approximate standard errors are given in this table. No tests of significance involving pasture digestibility were performed but approximate standard errors are given.

TABLE 14

Mean Digestibility Coefficients and Approximate Standard Errors of Differences on Pasture and Silage in Experiment 2§

Treatment and Number of Determinations	Dry Matter (%)	Organic Matter (%)	Crude Protein (%)	Fat (%)	Fibre (%)	N.F.E. (%)
Pasture (6)	60·1	63·2	54·5	33·7	69·2	61·5
Silo 1 (control) (8) ..	52·41	54·94	53·20	45·4	64·74	46·56
Silo 2 (8 lb metabisulphite) (10)	55·30	57·64	55·80	41·7	66·42	49·53
Silo 3 (12 lb metabisulphite) (8)	56·69	58·67	57·27	48·0	68·50	51·61
Silo 4 (40 lb molasses) (12)	54·06	56·43	55·31	40·7	64·08	51·25
Silo 5 (80 lb molasses) (10)	56·06	58·28	56·73	50·8	65·48	54·37
S.E. difference two silage treatments	0·51	0·54	1·51	—	1·09	1·10
S.E. difference pasture mean and a silage mean	1·8	1·8	2·0	—	2·4	1·4
Significance	3>4,1*** 3>2* 5>4,1*** 2>1*** 2>4* 4>1**	3>4,1*** 5>4,1*** 2>1*** 2>4* 4>1*	N.S.	—	3>1,4** 3>5* 2>4*	5>2,1*** 5>4** 5>3* 3>1*** 3>2* 4>1*** 2>1*

§ Means have been adjusted to eliminate differences among animals.
N.S. = no significant differences among treatments.
* = significant at 5% level.
** = significant at 1% level.
*** = significant at 0·1% level.

TABLE 15

Digestible Protein, Total Digestible Nutrients, Metabolizable Energy and Starch Equivalent per 100 lb of Moisture-free Material in Experiment 2

Sample	Digestible Protein (lb)	Total Digestible Nutrients (lb)	Metabolizable Energy (therms)	Starch Equivalent (lb)
Pasture	4·1	58·8	90·9	38·1
Silo 1 (control)	4·8	50·4	75·1	27·8
Silo 2 (8 lb metabisulphite)	5·1	52·4	78·6	30·2
Silo 3 (12 lb metabisulphite)	5·3	54·0	80·5	32·2
Silo 4 (40 lb molasses) ..	5·2	51·9	78·6	30·7
Silo 5 (80 lb molasses) ..	5·3	53·9	81·7	33·3

These data showed:—

(1) The pre-ensiling digestibility data are based on pasture showing a slightly lower protein level than that of the material ensiled. This is due to height above ground at which the pasture was harvested.

(2) In spite of this lower protein level, the digestibility of dry matter, organic matter and N.F.E. was markedly greater than that of any silage treatment.

(3) Both the metabisulphite treatments (Silos 2 and 3) resulted in a significantly greater digestibility for N.F.E., organic matter and dry matter compared with the control (Silo 1), these differences being greater with the increased level of metabisulphite (Silo 3).

(4) Both the molasses treatments (Silos 4 and 5) resulted in a significantly greater digestibility ($P<0\cdot05$) for N.F.E., organic matter and dry matter compared with the control (Silo 1), these differences being greater with the increased level of molasses (Silo 5).

(5) There were significant differences between the molasses and metabisulphite treatments. Metabisulphite favoured greater digestibility of fibre, organic matter and dry matter. Molasses favoured greater digestibility of the N.F.E.

The daily dry-matter intakes of each silage during palatability tests are shown in Table 16. The order of palatability was molasses at 80 lb/ton (Silo 5) > metabisulphite at 8 lb/ton (Silo 2) > molasses at 40 lb/ton (Silo 4) > metabisulphite at 12 lb/ton (Silo 3) > control (Silo 1).

V. DISCUSSION

In the first experiment good November/December rain in 1956 (10·83 in.) resulted in a rapid growth of pasture from December 24 to January 24. Dry-matter yield during this 31-day period increased from 800 to 3360 lb/ac. At the same time there was an equally marked fall in pasture quality, as shown by the fall in protein from 13·9 to 7·5 per cent. on a dry-matter basis. There was very little change during the test period from January 24 to January 30 when digestibility was measured and pastures conserved as silage and as hay. Inadequate summer rainfall resulted in poor growth of pasture in the summer of 1958 and the experiment had to be abandoned in that year.

A pasture growth pattern very similar to that obtained in 1957 was evident in the second experiment from January to February, 1959, although maximum yield was lower at 2700 lb dry matter per acre. As in 1957 there was little change during the test period from February 7 to February 13 when digestibility was measured and pasture conserved as hay and silage. Rain on February 13-14 during the critical period of haymaking, following mowing on the morning of February 12, necessitated the abandonment of the haymaking portion of this experiment.

TABLE 16

DAILY DRY-MATTER CONSUMPTION AS AN INDEX OF PALATABILITY IN EXPERIMENT 2

Sheep No.	Day	Daily Dry-Matter Intake (g)									
		Silo 1 v Silo 2		Silo 2 v Silo 4		Silo 3 v Silo 5		Silo 4 v Silo 3		Silo 5 v Silo 1	
		1	2	2	4	3	5	4	3	5	1
1	1	198	550							787	227
	2	166	724							730	233
	3	51	766							910	64
2	1	93	241	392	141						
	2	1	260	250	24						
	3	66	225	245	97						
3	1					72	903			848	95
	2					61	892			807	45
	3					105	961			849	109
4	1			480	63			278	241		
	2			349	37			256	218		
	3			216	218			244	253		
5	1					275	401	241	47		
	2					116	446	281	35		
	3					178	597	204	65		
Mean Ratio ..		1 :	5	3 :	1	1 :	5	2 :	1	6 :	1

Order of Palatability :—Silo 5 (80 lb molasses) > Silo 2 (8 lb metabisulphite) > Silo 4 (40 lb molasses) > Silo 3 (12 lb metabisulphite) > Silo 1 (control).

In the first experiment metabisulphite was added at the rate of 8 lb/ton green matter and molasses at 40 lb/ton. The level of metabisulphite was that used in the initial experiment reported by Bratzler, Cowan, and Swift (1956). Barnett (1954) stated that molasses should be added at the rate of 20–40 lb/ton of ensiled material. Two further treatments were included in the second experiment—metabisulphite at the rate of 12 lb/ton and molasses at the rate of 80 lb/ton. Cowan *et al.* (1956) noted that no further improvement was apparent in lucerne silage when the rate of application of metabisulphite was increased above 5 lb/ton and palatability was impaired slightly at the 18 lb/ton level. They also found no loss in palatability of high-protein, high-moisture forages ensiled with 12 lb metabisulphite/ton. The selection of 12 lb metabisulphite/ton in the second experiment was based on the assumption that, due to oxidation by entrapped air in this rather stemmy pasture, the amount of metasulphite used in the first experiment was insufficient to ensure adequate preservation. The higher level of molasses was to see if a product of lower pH could be produced from a pasture of this type.

All silages would be classed as low-temperature products (Watson and Ferguson 1937). The maximum temperature was 42°C (108°F) in Silo 5 (80 lb molasses/ton) in Experiment 2. The minimum temperature was 32°C (90°F) in Silo 2 (8 lb metabisulphite/ton) in Experiment 2. It is most improbable that grass silage could be made at lower temperatures in this subtropical environment, where paspalum pastures are available for harvesting in January/February when midday shade temperatures approximate 90°F. In all experimental silos there was a gradual fall in temperature, reaching room temperature about six days after filling. Thereafter the daily change in temperature in the silos was never greater than 0·5°C. It would appear that very little if any generation of heat took place after the silos had been filled.

In Experiment 1 the production of effluent occurred only in the product containing 8 lb metabisulphite/ton. In Experiment 2 effluent occurred in all silages, being greatest in the product containing 12 lb metabisulphite/ton and least in the product containing 40 lb molasses/ton. The moisture content of the pasture at ensiling was 73 per cent. in Experiment 1 and ranged from 75 to 78 per cent. in Experiment 2. These findings suggest two conclusions under the conditions obtaining in these experiments. The first is that 73 per cent. moisture is about the maximum at which well-consolidated paspalum silage without additives can be made without effluent. The second is that metabisulphite favours the production of effluent. In all cases the effluent contained appreciable quantities of soluble nitrogenous products and acids. It would be anticipated that the nutrients in these effluents would be highly digestible to ruminants.

Fermentation losses were low in all silages and do not appear to be influenced by the additives used. This is contrary to the findings of other workers. Cowan *et al.* (1956), using lucerne, recorded dry-matter losses ranging from 10 to 50 per cent., losses being minimized by the use of metabisulphite. Bratzler *et al.*

(1956) recorded losses ranging from 9 to 22 per cent. for orchard grass and 15 to 28 per cent. for lucerne, the losses being least in silages containing metabisulphite. Watson (1950-51) quoted losses of 20 per cent. dry-matter in low-temperature silages with and without molasses. It would appear that the low fermentation losses recorded and the small differences due to treatments may be a function of the pasture used and the experimental conditions involving good compaction in relatively small towers. In both experiments it is evident that the use of molasses as an additive enabled better compaction, as shown by the greater total amount of dry-matter content ensiled in Silo 3 in Experiment 1 and Silos 4 and 5 in Experiment 2.

In both experiments the use of additives improved silage quality, the improvement being greatest in the silages containing molasses. This is shown by the lower pH and higher percentage of lactic acid. However, in no product did the pH fall below 4·2, the level below which both the residual carbohydrate and the produced lactic acid are not readily subject to attack by the butyric-acid-producing organisms (Barnett 1954).

In our studies residual acidity is expressed as lactic acid. This is based on the findings of Watson and Ferguson (1937) for silage treatments which did not include mineral acids. These workers stated also that, in general, the lactic acid content should exceed the volatile acid level in a good-quality silage. In both experiments metabisulphite increased the concentration of lactic acid and decreased volatile acidity, but the ratio approached unity only in the product containing the higher level of 12 lb metabisulphite/ton. In both experiments molasses markedly increased the production of lactic acid. However, only in the first experiment did the ratio of residual to volatile acidity exceed unity. In the second experiment the highest residual acidity resulted in the silage containing the higher level of 80 lb molasses/ton, but even so the ratio did not quite attain unity.

Protein breakdown was not inhibited to any marked extent in the treated silages. The amino-acid concentration was of the same order for all treatments in both experiments. The content of volatile bases appeared to be unaffected by treatment but tended to be greater in Experiment 2. Watson (1939) used as an estimate of silage quality the ratio of amino-acid content to the volatile base content. This ratio was greater than unity in Experiment 1 and was of the order of unity in Experiment 2. The stemmy nature of the pasture used in both experiments may have prevented the additives from exerting their inhibiting effects on the plant's proteolytic enzymes for some time after ensiling.

The physical characteristics of all silages suggest fair-quality products. However, the tendency of all metabisulphite treatments to spoil by mould development on exposure to air could cause considerable wastage at any exposed face if the silage was not fed out continuously.

The proximate analyses indicate a higher protein level, a higher fibre content and a lower N.F.E. concentration in the silage than in the pasture prior to ensiling. These changes are due to fermentation losses of predominantly carbohydrate. The increase in fibre and decrease in N.F.E. were most evident in the control silages and least marked in the silages which included molasses. As fermentation losses were similar in all silage treatments, the differences in composition between the control and molasses silages are due mainly to the direct effects of the added molasses, which at the 40 and 80/lb ton levels was equivalent to approximately 5 and 10 per cent. on a dry-matter basis.

In both experiments the pasture harvested with the commercial cutter-bar type of equipment showed a protein level higher than that of pasture harvested by scythe or mowing equipment. This was most marked in Experiment 1 but was still evident in spite of the lowest practical adjustment on cutting height of the harvester used in Experiment 2. However, in other constituents—fat, fibre, N.F.E. and ash—there were little, if any, differences between the two products.

In both experiments additives resulted in significantly greater digestibility coefficients for N.F.E., dry-matter and organic matter, this effect being most marked with the higher concentration of additives used in Experiment 2. Some differences between additives were significant in Experiment 2, metabisulphite giving greater digestibility of fibre, organic matter and dry matter, and molasses giving greater digestibility of the N.F.E. A comparison of the digestibility data on the pasture at the time of ensiling in Experiment 2 with the digestibility data on the control silage (Silo 1) shows markedly greater digestibility coefficients for N.F.E., organic matter and dry matter. This is true in spite of the slightly lower protein in this pasture compared with that actually harvested for ensiling. Some loss of digestibility is evident during the ensiling process encountered in this experiment.

The use of additives increased the relative palatability of the silages in each experiment. The order of palatability was molasses at 80 lb/ton, metabisulphite at 8 lb/ton, molasses at 40 lb/ton, metabisulphite at 12 lb/ton, control without additives. These are relative palatability assessments only. No difficulty was encountered in getting sheep to consume any of the silages prepared in either experiment.

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