THE CONSEQUENCES OF ENSILING GRASS WITH ABSORBENT MATERIALS

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by

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ABBREVIATIONS

ADAS	Agricultural Development and Advisory Service
ARC	Agricultural Research Council
BOD	Biological or Biochemical Oxygen Demand
CP	Crude Protein
DE	Digestible Energy
DM	Dry Matter
DOM	Digestible Organic Matter
g	Gram
GE	Gross Energy
k_f	Efficiency of Utilisation of ME for gain
kg	Kilo Gram
kg/dm^2	Kilo Gram per Square Decimetre
L	Litre
LWG	Live Weight Gain
MAFF	Ministry of Agriculture, Fisheries and Food
ME	Metabolisable Energy
NH_3-N	Ammonia Nitrogen
NS	Not Significant
OMD	Organic Matter Digestibility
*	Significant at 5% level ($P < 0.05$)
**	Significant at 1% level ($P < 0.05$)
***	Significant at 0.1% level ($P < 0.05$)
RDP	Rumen Degradable Protein
SBP	Molassed Sugar Beet Shreds
SDMI	Silage Dry Matter Intake
t	Tonne
VFA	Volatile Fatty Acids

SUMMARY

1 The literature in the following areas is reviewed:

a) Factors affecting animal performance from silage based diets: Silage fermentation, Silage voluntary intake, Silage nutritive value and supplementation of silage diets.

b) Losses of nutrients in silage making

c) The chemistry of silage effluent

d) The control of silage effluent

2 Ensilage experiments using 200 l drum silos (experiments 1 and 2a) were carried out to compare the effluent-absorbing characteristics of a range of absorbent materials and to measure their effects on silage composition. The results showed that none of the absorbents tested markedly affected silage preservation. Chopped barley straw, Vitaferm (a dried distillery by-product) and molassed sugar beet shreds proved the most effective controllers of silage effluent.

3 Experiment 2b (also using drum silos) investigated the relationship between effluent volume, grass dry matter content and the concentration of molassed sugar beet shreds ensiled with the grass. An equation was derived which allows the prediction, for a particular grass dry matter, of the level of molassed beet shreds needed totally to prevent effluent loss:

$$SBP_{(o)} = 41.9 - 0.191\ DM$$

Where,

$SBP_{(o)}$ = level of molassed beet shreds (% grass FW) required to produce no effluent.

DM = grass dry matter gkg^{-1}.

4 The effects of adding chopped barley straw, Viton straw cubes (an alkali treated straw feed), barley straw bales and molassed sugar beet shreds to grass at ensiling on effluent volume and composition and on silage quality were investigated using "mini pit" silos holding up to 10 tonnes of grass. All absorbents were added at 60 kgt^{-1} FW to second cut grass of 148 gkg^{-1} dry matter content treated with 4.5 lt^{-1} of 85% formic acid solution. Addition of chopped straw in a series of layers reduced effluent volume by 61%, total organic matter loss in effluent by 68% and reduced the in vivo OMD of the silage from 0.683 to 0.625.

Addition of Viton straw cubes (as a bottom layer) reduced effluent volume by only 5% but increased total effluent OM loss by 53%. The same absorbent used as a series of layers in the clamp reduced effluent volume by 17%, increased the total effluent OM loss by 15% and reduced the in vivo silage OMD from 0.683 to 0.631.

Addition of straw bales to the bottom of the silo increased effluent volume by 7% and reduced total effluent OM loss by 10%.

Addition of layers of molassed sugar beet shreds reduced both effluent volume (by 48%) and total effluent OM loss (by 25%). Silage in vivo OMD increased from 0.683 to 0.717. None of the absorbents tested markedly affected silage preservation as assessed by pH, and concentrations of ammonia-N and butyric acid.

5 A second similar trial using the "mini pit" silos tested chopped barley straw (two silos), molassed sugar beet shreds (two silos) and barley straw bales added at approximately 75 kgt^{-1} grass FW to first cut grass of 123 gkg^{-1} dry matter content treated with 3 lt^{-1} of 85% formic acid solution. Sufficient silage was produced to carry out an intake and performance trial using growing calves. Addition of straw bales increased effluent volume by 17% and total OM loss in effluent by 19%.

Addition of chopped straw as a series of layers reduced effluent volume by 46% and 50% for the two silos giving reductions in total effluent OM loss of 45% and 38% respectively. Silage in vivo OMD was reduced from 0.775 to 0.634. Addition of layers of molassed sugar beet shreds

reduced effluent volume by 62% and 51% but, as in the previous trial, total effluent OM loss was reduced by only 29% and 24% respectively as the concentration of OM in effluent was increased. Unlike the previous trial, OMD measured in vivo was unaffected by inclusion of molassed sugar beet shreds, probably because of the higher OMD of the grass (0.753) in the second trial compared to the first (0.654).

6 A feeding trial lasting six weeks was conducted to measure the effects of chopped straw or molassed sugar beet shreds inclusion to grass at ensiling on animal performance and ad libitum silage intake. Silages were supplemented with 1.0 kg barley, 0.2 kg soya bean meal and 0.07 kg mineral mix per calf per day. Eighteen Friesian steer calves, average liveweight 129 kg at the start of the trial were allocated to the three experimental diets (control, chopped straw silage and molassed beet shred silage) in a randomised block design. Animals offered the control, chopped straw and molassed beet shred silages consumed on average 2.27, 2.14 and 2.62 kg DM silage per day giving average liveweight gains of 0.97, 0.86 and 1.11 kgd^{-1} respectively.

7 Of the absorbents tested in the "mini pit" silos, only chopped straw and molassed sugar beet shreds showed promise as effluent absorbents. Absorbents are best used as a series of layers within the clamp. Molassed sugar beet shreds inclusion improved silage intake and animal performance but may not greatly reduce nutrient losses in effluent (and therefore pollution risk) unless used in sufficient quantity totally to prevent effluent loss. For grass of 180 gkg^{-1} dry matter content an inclusion rate of 80 kgt^{-1} FW (or 250 kgt^{-1} dry matter basis) is needed to prevent effluent loss. Chopped straw inclusion reduced silage intake and animal performance but proved the most reliable absorbent for effluent control as nutrient concentration in effluent was unaffected. The silo space required for a given weight of grass was increased by 22% and 79% respectively for molassed sugar beet shreds and chopped straw added at approximately 75 kgt^{-1} grass FW.

INTRODUCTION

Silage is the product formed when grass is stored anaerobically. It is formed by the process referred to as ensilage which takes place in a vessel or structure called a silo. Grass and other materials of high moisture content are liable to spoilage by aerobic micro-organisms. The aim of ensilage is to maintain strict anaerobic conditions yielding a stable, well-preserved product with as little loss of nutrients or feeding value as possible. Normally during ensilage, the fodder undergoes an acid fermentation in which bacteria produce lactic, acetic and butyric acids from sugars present in the raw material. The net result is a reduction in pH which prevents the growth of spoilage micro-organisms, the majority of which are intolerant of acid conditions.

In the United Kingdom, silage making only gained widespread use after the second world war (1939-1945), although there is evidence that the procedure was in use in Egypt as long ago as 100-1500 BC (see Schukking, 1976). However, Goffart (1877) published the first book on ensilage which was based on his own experiences of ensiling green maize. The ensilage method he recommended involved rapid filling of the silo, with compaction and tight sealing of the surface to exclude air. Voelcker (1884) was probably the first person to give information on the chemistry of ensilage in his study for a large number of silage samples. It was not until 1882 that the subject of silage received general interest among British farmers. In 1883 it was reported that not more than half a dozen silos were in existence in the UK, but within the next few years interest increased dramatically so that by the year of 1886 there existed 1,605 silos in the country (Rew, 1888).

During the following 50 years, research work established the main chemical changes that occurred in the ensiled green crop and the role of the various micro-organisms. A restriction of the amount of air in the silo and the rapid increase in the acidity of the silo mass are the major requirements of good silage making. This early development and research work was reviewed by Watson (1939). Details of the designs of silos, the losses involved in silage making and the effects of stimulants and chemical additives on the preservation of crops were also discussed.

As late as 1968, only 12-15% of the total conserved grass dry matter (DM) in the UK was conserved as silage. However, during the following years the amount of silage made increased sharply and by 1973 it accounted for 28%, and by 1978 about 45% of the conserved forage DM (Wilkinson, 1981).

Each year, more and more grass is conserved as silage as a better understanding of the factors affecting the process allows farmers to produce silage of high quality even under adverse conditions. The main practical points which should be followed in silage making are:

Chop grass short
Roll Silage well
Fill Silo rapidly
Use an effective additive
Avoid soil contamination
Sheet silo well

The introduction of polythene sheeting to cover silage has led to more silage being made in open clamps rather than in roofed buildings or tower silos. The fertiliser rates applied to cutting areas continue to rise in an effort to produce more grass. At the same time, there is a general move towards cutting grass at a younger stage of growth in order to produce a higher quality product which will result in more animal production from the roughage part of the diet.

Perhaps the main disadvantage of the trend away from hay making towards ensilage is the problem of silage effluent. Effluent is the liquid or juice that runs from silage clamps in the weeks immediately following ensilage. Unfortunately, many of the modern trends in ensilage techniques, whilst improving silage quality and yield, increase the losses of effluent. Effluent from silage clamps has a high BOD (Biological Oxygen Demand) and there is currently much concern about pollution of watercourses by silage effluent. Furthermore, effluent contains valuable nutrients which should, if possible, be fed to stock to avoid wastage.

A number of strategies have been adopted to overcome the problem of silage

effluent. Firstly, grass may be wilted in the field to lower the moisture content to a point at which effluent loss is avoided. Secondly, leak-proof silage clamps may be constructed with storage tanks for all the effluent lost. Effluent could then be safely disposed of by controlled spreading on the land or by feeding to stock. A third strategy is to add absorbent material to grass as the clamp is filled.

The experimental work described in this thesis is focused on the control of effluent by the use of absorbents, although the advantages and disadvantages of the other control methods are discussed.

The scope of the work is to assess the consequences of adding various absorbents to grass during silage making on the following aspects:

1 Effluent Volume and Composition
2 Silage Fermentation and Composition
3 Silage Digestibility, Intake Potential and Feeding Value.
4 The Practicality of the Silage Making Process.

CHAPTER ONE

REVIEW OF LITERATURE

SECTION 1

ANIMAL PERFORMANCE FROM SILAGE

The level of performance achieved by a particular animal fed on a silage diet mainly depends on the amount of silage the animal will eat and on the nutritional value of the silage. For most food-stuffs, the limits of intake and nutritional value may be assessed from a knowledge of the food's content of the main classes of carbohydrate, lipid and protein components and the energy they provide (Agricultural Research Council, 1965, 1976 and 1980; Ministry of Agriculture, Fisheries and Food, 1975). This provides a basis for ration formulation and allows prediction of animal performance. With silages however, the intake and nutritional value may vary not only with the content of the main chemical components, but also with the characteristics of the silage fermentation.

FACTORS AFFECTING NUTRITIVE VALUE OF SILAGES

A Chemical Composition of the Raw Material

The chemical composition of forage crops is influenced by a large number of factors including type, species and strain of plant, weather, growth conditions, level of fertiliser applied and the maturity of the crop at harvesting. Under most circumstances, the major determinant of crop composition is the stage of maturity. As plants mature, the proportion of cell wall increases, while that of more digestible cell contents is reduced. Also, the increase in the degree of lignification of the cell wall with maturity reduces the digestibility of the crop and consequently its metabolizable energy (ME) value. Moreover, as the crop matures, its crude protein content falls, while soluble proteins of a relatively constant amino acid composition continue to make up 0.75-0.85 of the crude protein (Lyttleton, 1973). The water soluble carbohydrates (WSC) are important sources of energy for the micro-organisms which are responsible for silage fermentation. The principle WSC in forage crops are fructose, glucose, sucrose and fructosans (Axelrod, 1965; Macilory, 1967 and Smith, 1973). The abundance of non-structural and WSC in a

crop depends to some extent on the quantity of nitrogenous fertiliser applied during growth. The content of these carbohydrates and nitrate applications are negatively correlated (Waite, 1958; Jones, 1970). Reduction in light intensity reduces the WSC concentration (Melvin and Sutherland, 1961; Smith, 1973). Deinum (1966) showed that the WSC content of regrass grown at a day temperature of 15°C and a night temperature of 10°C was only 90 gkg^{-1} DM at a low light intensity compared with nearly four times this value when grown under high light intensity conditions. Henderson (1973) found a positive correlation between WSC content and the stage of growth.

After the plant have been cut, there is no longer a supply of water from the roots and, since water loss from the leaves and stems continues, the plant cells begin to dehydrate, lose their turgidity and wilt. Normal transpiration is inhibited but water is still lost through the stomata and to a lesser degree through the cuticle layer. The rate of loss under these conditions depends on the difference between the vapour pressure of the internal water near the surface of the plant cell and the vapour pressure of the water in the surrounding air (Sullivan, 1973). During the wilting period, changes in chemical composition take place. Kemble and MacPherson (1954) showed that during a three-day wilting period, more than 20% of protein-N in grass was degraded to non-protein N (NPN). Brady (1960) examined the nitrogenous fractions of ryegrass during a wilting period of 26.5 hours (hrs) and found that the main increase occurred in the amino-N fraction with only relatively small amounts of volatile-N and amide-N being formed.

Several workers have reported that sucrose is catabolized to carbon dioxide (CO_2) in wilting grass (Wylam, 1953; Melvin, 1963; Festenstein, 1966). Clark (1974) studied the changes in WSC during wilting of Italian ryegrass under controlled environmental conditions. He found that, in general, WSC tended to decrease over the 48 hour wilting period. However, the changes in the composition of the crop during the wilting period depended on the length of wilting period, humidity, temperature and movement of air in contact with cut crop and on the addition of surface water as dew or rain. Wilting for a short period, when the rate of moisture loss is high and changes in crop composition

are minimal, may be advantageous for ensilage mainly due to concentration of the sugar in the crop which may enhance fermentation. But when cut crops are wetted by dew or rain, losses of soluble constituents are increased and the effects of plant enzyme activity are exacerbated leading to large losses of nutrients and ultimately, reduction in the nutritive value of the silage.

B Fermentation in the Silo

The objective in silage making is to achieve preservation whilst minimising losses of nutrients and avoiding adverse changes in the chemical composition of the forage crop. This is achieved through enclosure of the crop in the silo under anaerobic conditions, which allow rapid proliferation of lactic acid bacteria that produce lactic acid alone (homofermentative types) or lactic acid in mixture with other products (heferofermentative types). The end-products of the fermentation of soluble sugars by these organisms, principally lactic acid, reduce the pH in the silo until a value of approximately 4 (typically 3.8-4.2) is achieved. At this pH, stable preservation is achieved as microbial activity ceases. However, should the pH reduction be too little or at too slow a rate, secondary fermentation may occur involving the proliferation of clostridial organisms. These convert lactic acid and other materials to butyric acid, causing a rise in pH thus enhancing the secondary activity. Much protein breakdown to ammonia and amines takes place under these conditions and the palatability of the silage is reduced. Thus the factors controlling the rate of acid production and the resulting fall in pH are critical in the avoidance of butyric fermentations and the resulting spoilage. However, crop moisture content per se and soil contamination also influence the risk of secondary fermentation, since clostridial species thrive in wet conditions and are found in large numbers in the soil. Following these general comments, the factors affecting silage fermentation are reviewed in detail.

1 Composition of the Crop

The WSC content in the crop may be considered the major factor influencing silage fermentation. A general recommendation to obtain

satisfactory fermentation is that the forage to be ensiled should contain 60-80 gWSC kg^{-1} DM (McCullough, 1977). Other workers reported that a WSC concentration of 25-30 gkg^{-1} in herbage is sufficient for unwilted silage to be made without additives (Dijkstra, 1957; Zimmer, 1971; Hastings, 1972; Wilkins, 1974 and ADAS, 1979), although more recently a value of 35 gkg^{-1} has been suggested (Parker and Crawshaw, 1982). Haigh and Parker (1985), on the basis of 22 clamp silages made with unwilted grass treated with formic acid, suggest a minimum WSC necessary to produce successful preservation is 24 gkg^{-1}. This conclusion represents a considerable extrapolation from their data since the mean ($\pm$ SE) WSC level they recorded in their trial was approximately 130 $\pm$ 10 gkg^{-1}. Indeed, WSC levels in grass are almost always higher than the 24 gkg^{-1} they reported as the minimum needed.

The rate of fall of pH in the silo depends not only on the rate of production of acid but also on the buffering capacity of the crop itself. This is related to its content of organic acid salts and phosphates and varies with the type and species of forage, and with growth conditions and stage of growth (McDonald and Henderson, 1962). Furthermore, the fall of pH required for stable preservation of the crop is dependent on crop DM content. The organisms that are responsible for undesirable fermentations require wet conditions and a larger and quicker fall in pH is therefore needed for a wet crop than a dry one. Thus baled silages made in large polythene bags at DM levels of 400 gkg^{-1} may be well preserved at a final pH of 5.5. The low moisture level restricts fermentation of all types. At a DM level of 200 gkg^{-1} a final pH of 5.5 would indicate extensive secondary fermentation and spoilage.

The moisture content of the crop has been shown to affect the total bacterial count and the rate of fermentation (Stone et al, 1944; Gouet et al, 1965). Stirling (1951) found wilting delays bacterial multiplication in grass silage. McDonald et al (1962) reported that adding water to herbage stimulates multiplication of bacteria, especially the lactobacilli and the gram-negative organisms. Morgan et al (1980) found that increasing the DM of crop from 175 gkg^{-1} to 360 gkg^{-1} decreased the lactic acid content of the silage from 165 gkg^{-1} to 34 gkg^{-1} DM and the crop was well preserved at a pH of 5.09 compared

with the unwilted silage which had a pH of 4.0. The effect of decreasing the moisture content on the activity of the lactic acid bacteria and other micro-organisms is reflected in the high residual amounts of WSC in the wilted silage. Other fermentation products, especially acetic and butyric acid, are also relatively low in the wilted silage (see Table 1.11). These conclusions are supported by the work of a number of authors (Murdoch, 1960; Jackson and Forbes, 1970 and Donaldson and Edwards, 1976). Wilkins (1984) found that wilting, on average, reduces the concentration of fermentation acids but also increases the proportion of lactic acid and reduces ammonia-N concentration. He concluded that wilting tends to reduce the digestibility of silage. This effect was reported by other workers (Harris et al, 1966; Alder et al, 1969 and Marsh, 1979).

Weissbach et al (1974) has attempted to combine the three critical factors of crop DM content, crop WSC content and crop buffering capacity into a single model. He proposed the relationship between DM content and sugar to buffering capacity ratio as an index of probable silage quality (see Figure 1.11). This approach has practical implications as it would assist in the decision making with regard to degree of wilting needed and use of additive in a particular situation. However, Wilkinson et al (1983) have recently found that variation in WSC alone is more important.

2 Mechanical Pre-treatment of the Crop

The effects of mechanical treatment of herbage (chopping, laceration, bruising) before ensiling on silage fermentation have been researched. Microbiological studies have shown that lactic acid bacteria occur in very small numbers on fresh growing herbage, being restricted to damaged parts and partially decayed material (Stirling and Whittenbury, 1963). The release of intracellular plant juices under anaerobic conditions is important for the onset of fermentation (Greenhill, 1964) and thus physical damage to the crop is advantageous. Murdoch et al (1955) suggested that laceration tended to provide a better fermentation than chopping, while Barry et al (1978) reported that chopping, as opposed to lacerating, improves silage fermentation quality. Castle et al (1979) found that fermentation can be further improved by fine rather than

coarse chopping. However, Marsh (1978) in a review concluded that type of forage harvester was unlikely to have major effects on fermentation, except in heavily wilted silages which are difficult to consolidate.

3 Application of Additives to the Crop

Several attempts have been made to improve fermentation by the use of additives applied to the crop before ensilage. There are three main types of additives: those which encourage fermentation by supplying extra WSC, enzymes or micro-organisms to improve acid production in the silo; those that act as sterilants and either prevent or severely restrict fermentation; and those, such as acids, that provide conditions which favour the acid-producing lactobacilli and inhibit clostridial activity.

Many experiments have examined the effects of addition of molasses on silage fermentation. This additive has been shown to increase the DM and lactic acid contents and to reduce the pH and ammonia-N level in silages (Archibald, 1953; Murdoch et al, 1955; Reaves and Brubaker, 1956 and Thomas, 1978).

The addition of cellulolytic enzymes to crops at the time of ensiling has been reported by a number of workers (Leatherwood et al, 1959; Owen, 1962; McCullough, 1966; Wilson, 1976; Henderson and McDonald, 1982). Leatherwood et al (1959) applied up to 4.5 gkg^{-1} (on a fresh weight basis) of a commercial cellulase preparation to alfalfa and immature barley at ensiling, and found that pH level and DM losses were higher in the treated compared with the untreated silages, but all silages were of good quality. McCullough (1966) applied cellulolytic enzymes to corn or ryegrass plus wheat silages and found that fermentation and digestibility of the silages were improved. Henderson et al (1982) reported an experiment with perennial ryegrass, lucerne and clover in which each was treated with formic acid (4.5 lt^{-1} crop) or a commercial cellulase (4 gkg^{-1}). All the silages were well preserved but treatment with cellulase reduced the cellulose contents of the silage - the effect being greatest for the grass compared to the legume silages. However,

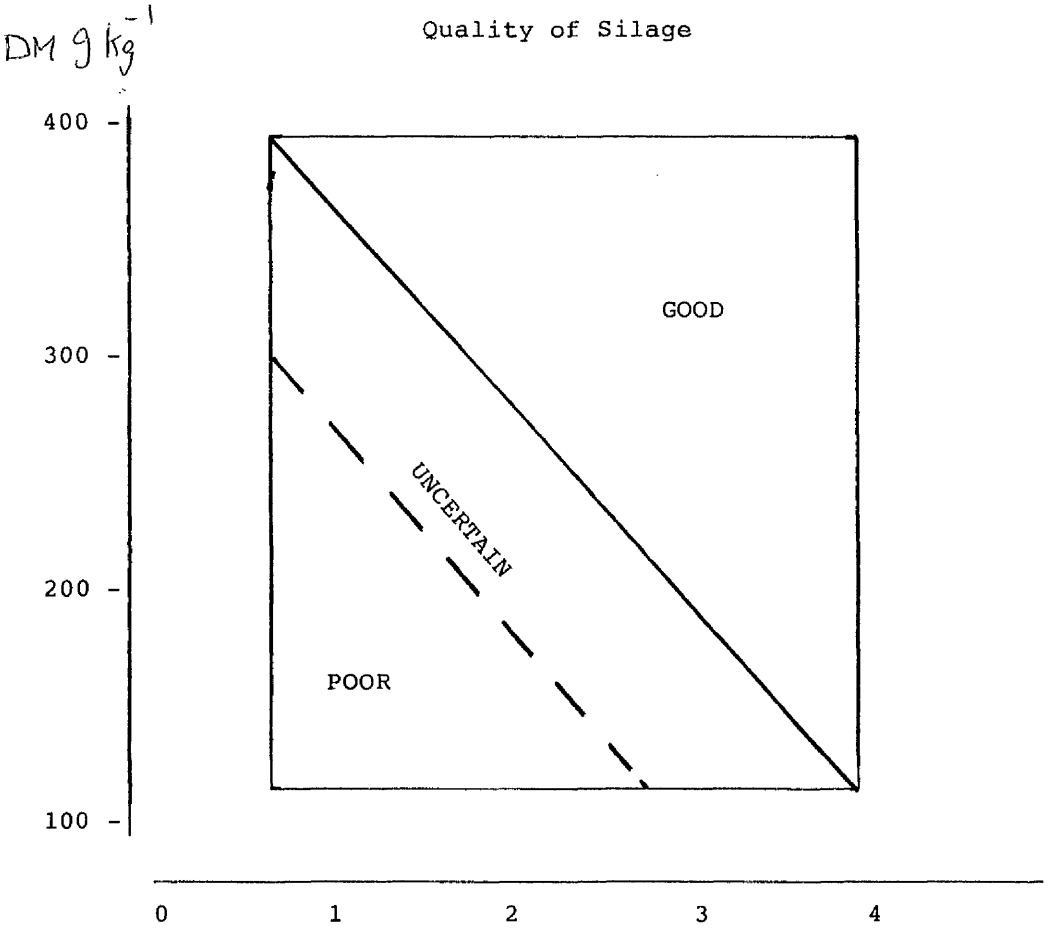
TABLE 1.11

Composition of two grass silages made from unwilted and wilted herbage (From Morgan et al, 1980)

Composition		Unwilted Silage	Wilted Silage
DM	(gkg^{-1})	169	359
pH		4.00	5.09
OM	(gkg^{-1} DM)	908	907
WSC	(gkg^{-1} DM)	11	185
Mod acid det fibre	(gkg^{-1} DM)	288	293
Total-N	(gkg^{-1} DM)	24.8	22.4
Protein-N	(gkg^{-1} DM)	286	286
Ammonia-N	(gkg^{-1} DM)	109	80
Nitrate-N	(gkg^{-1} DM)	12.1	8.9
Acetic Acid	(gkg^{-1} DM)	19.0	5.7
Propionic Acid	(gkg^{-1} DM)	0.54	0.24
Butyric Acid	(gkg^{-1} DM)	4.7	1.1
Caproic Acid	(gkg^{-1} DM)	0.21	trace
Lactic Acid	(gkg^{-1} DM)	165	34
Ethanol	(gkg^{-1} DM)	23	10

FIGURE 1.11

The Relationship between dry matter content and the sugar to buffering capacity ratio of a crop as it affects the ultimate quality of the silage. (From Weissbach et al, 1974).



in a recent study, Kennedy (1987) found no significant differences between enzyme-treated and untreated first cut grass silages in terms of pH, ammonia-N, lactic acid and total volatile fatty acids (VFA) content. However treatment with formic acid gave a lower pH, lower ammonia-N and total VFA and higher lactic acid content. In another experiment with third cut grass silage, he found that both silages were well preserved when treated with either enzyme or formic acid additives. Hemicellulase addition to silage showed no significant influence on the composition of sorghum silage (Owen, 1962). Wilson (1976) noted that hemicellulase was less effective than cellulase as a treatment for increasing the lactic acid and reducing the ammonia content of alfalfa silage.

In recent years a number of commercial inoculants have become available as silage additives. These inoculants contain freeze-dried preparations of homofermentative lactic acid bacteria and they are attractive to farmers because, unlike acid additives, they are safe to handle and are non-corrosive to machinery. Inoculation with Lactobacillus Plantarum alone (Moon, 1981; Seale and Henderson, 1984) or in combination with Pediococcus Acidilactici (Lindgren, 1984; Henderson and McDonald, 1984) has aided preservation in laboratory scale silos. In large scale experiments (MAFF 1981b, 1982a, 1982b) however, inoculated and control silages showed similarly poor preservation when compared to formic acid/formalin additives. DM intakes (beef cattle) and daily liveweight gains on the untreated and inoculated silages were similar and significantly lower than for the formic acid/formalin additive treated silages. Murphy (1981) similarly reported a slight improvement in preservation of the inoculum treated silage compared with the untreated control, but both silages were poorly preserved compared with the formic acid treated silage. Gordon (1987) prepared three silages with either formic acid at 2.3 lt^{-1}, inoculant at 3.2 lt^{-1} or no additive. He found only minor effects of additive treatment on fermentation characteristics, but a subsequent dairy cow trial revealed differences in performance. Cows offered the inoculant treated silage consumed 12 and 10% more silage DM and gave 2.1 and 2.3 kgd^{-1} more milk than those given the control and formic acid silages respectively.

Formaldehyde is a well-known sterilising agent and is commercially available as formalin (a 40% solution of formaldehyde in water). It has an ability firstly, to restrict fermentation (Wilkins et al, 1975) and secondly, to bind with plant proteins (Barry, 1976; Beever et al, 1977) which reduces protein degradation in the rumen so that the supply of amino acids to the animal may be increased. Wilkins et al (1975) examined a wide range of application rates of formalin and showed an almost total restriction of fermentation above 8 lt^{-1} fresh weight. However, there is evidence that at lower rates of application (4 lt^{-1} fresh weight) clostridial fermentation may be encouraged (Wilson and Wilkins, 1978). Beever et al (1977) have shown that the treatment of herbage with formaldehyde prior to ensilage markedly influenced the pattern of anaerobic fermentation and resulted in an increase in the WSC of the silage and in the flow of amino acids into the small intestine of sheep when compared to the control.

The use of mixtures containing mineral acid such as the AIV process (Virtanen, 1933) to control fermentation was not popular in UK, mainly because of difficulties in handling the corrosive acids (Watson and Nash, 1960). However, additives based on organic acids have become widely used to control fermentation. Formic acid in particular, has proved to be highly effective in reducing rapidly the pH of grass in the silo and in restriction of respiration. These conditions favour the development of lactobacilli. Formic acid is usually applied at a rate of 2.5 to 5 lt^{-1} of fresh herbage depending on the grass DM content; pH is lowered immediately (Wilson and Wilkins, 1973b) and respiration restricted. Application of formic acid to a grass of low WSC content resulted in a well preserved silage with lower ammonia-N content than that of silage made without addition of the acid (Wilson and Wilkins, 1973a). A further effect is that the content of fermentation acids is depressed in silage made with formic acid (Waldo et al, 1971). Waldo (1978) in a review showed that addition of formic acid resulted in a reduction in fermentation combined with a decrease in the proportion of total acids as acetic and butyric and a reduction in proteolysis. This is illustrated in the results of an experiment shown in Table 1.12 by Carpintero et al (1979).

4 Oxygen Level in the Silo

When herbage is cut and wilted, obligate aerobic micro-organisms and facultative anaerobes such as lactic acid bacteria may be expected to increase in numbers at the expense of the strict anaerobes such as clostridia (Whittenbury, 1968). If field wilting is prolonged, particularly when the crop has been lacerated thus releasing cell contents, the oxygen tolerant proportion of the micro-organisms can increase in numbers relative to the strict anaerobes (Henderson et al, 1972).

The effect of delayed sealing of a silo on the fermentation has been investigated. Yoder et al (1960) reported that a delay of 12 hrs in sealing lucerne in plastic laboratory silos effectively replaced lactic acid fermentation with a butyric acid fermentation. This conclusion has been supported by other workers (Van Ederen et al, 1972 and Ohyama et al, 1975). The effect of delayed sealing is to reduce the level of WSC available for fermentation and unless adequate amounts of WSC are present in the crop, inadequate lactic acid will be produced to inhibit clostridial growth (Ruxton et al, 1975; Ohyama et al, 1975 and Takano et al, 1977). Ruxton and McDonald (1974) reported that 16-49% of the fermentable sugar can be lost by continued respiration resulting from air trapped in the silo. Other studies show that infiltration of the silage by air lowers the content of lactic acid but produces relatively high levels of acetic and butyric acids and volatile nitrogen with a corresponding high pH (Langston et al, 1962; Ruxton et al, 1974 and Woolford et al, 1979). The effect of air in silage is to encourage the growth of undesirable aerobes which cause a depletion of substrate required by lactic acid bacteria, moreover, it delays the onset of the lactic fermentation (Woolford, 1984).

TABLE 1.12

The effect of different levels of formic acid on the composition of ryegrass-clover silages after a 50-day ensiling period. (From Carpintero et al, 1979).

Composition	Formic Acid Level lt^{-1}					
	0	0.4	1.0	2.0	4.1	7.7
pH	3.87	3.77	3.67	3.81	3.88	3.80
WSC (gkg^{-1} DM)	12	33	72	124	211	250
Total-N (gkg^{-1} DM)	18.2	17.8	18.5	19.3	19.2	18.6
Protein-N (gkg^{-1} TN)	265	285	325	358	401	462
Ammonia-N (gkg^{-1} TN)	95	79	59	46	12	12
Acetic Acid (gkg^{-1} DM)	28.8	24.1	18.9	13.3	4.5	3.1
Propionic Acid (gkg^{-1} DM)	0.18	0.27	0.22	0.36	0.28	0.19
Butyric Acid (gkg^{-1} DM)	0.19	0.04	0.04	0.16	0.23	0.03
Lactic Acid (gkg^{-1} DM)	122	153	115	117	66	5

VOLUNTARY INTAKE OF GRASS SILAGE

Voluntary food intake is controlled by centres in the hypothalamus. This small area is situated beneath the cerebrum in the brain and acts to integrate information on the animal's requirements for nutrients, in particular for energy, with information that the animal derives about its food. The latter is obtained through the action of central nervous system receptors sited in the mouth and nose, in the digestive tract, in liver, brain and elsewhere in the body. These receptors respond to the sensory qualities of foods (taste, smell, texture, etc), to the physical effects of food ingestion on the gut (stretch, pressure, etc), to chemical stimuli arising from the end-products of digestion before and after their absorption, and to any intake depressing compounds present in the food (Forbes, 1980).

The voluntary DM intake of forage crops is a major factor influencing their value for animal production. Intake is influenced by the characteristics of the animal and also the forage (Dulphy, 1980). The intake of forages is limited by the rate of removal of forage particles from the reticulo-rumen. This has been supported by Campling and Balch (1961). They found that when boluses of swallowed hay were removed from the reticulo-rumen, cows ate 70-85% more than their normal diet. This suggested that a major part of the intake regulation mechanism for hay could be due to the degree of gut-fill and reticulo-rumen distension. The rate of removal of forage from the reticulo-rumen is related to the chemical composition of the forage, to its particular size, to the digestion rate of its digestible constituents and to the reduction rate of its indigestible components (Dulphy, 1980).

However, the intake of silage DM by ruminants appears to be under the control of additional factors besides the digestibility of the material and it is well established that the voluntary intake of silage is lower than that of hay made from the same crop (Moore et al, 1960; Campling, 1964; Donaldson and Edwards, 1976; Demarquilly and Dulphy, 1977). It has been recognised that digestibility of a forage is a factor of major importance in determining its intake and nutritive value (McCullough, 1961; Balch and Campling, 1962, McCarrick, 1965; Castle and Watson, 1969). But higher digestibility in a silage has not always been associated with higher production (Tayler and Aston, 1967) due to the interaction of other factors (Wilkins, 1974; Wilkins,

1975). Thomas (1980) in an analysis of a restricted population of experiments which involved the feeding of well-fermented silages of different digestibilities to dairy cows, noted a positive response of intake to increased digestibility within experiments, but marked differences in intake between experiments. The results of individual studies showed that differences between silages in fermentation patterns had an important effect in modifying the response of intake to increased digestibility. However, Harris and Raymond (1963) and Wilkins et al (1971) reported that relatively little of the total variance in silage intake was associated with the digestibility and that intake was more closely related to the products of silage fermentation.

The relationship between the voluntary intake of silage and its chemical composition has been shown by Wilkins et al (1971). They found that intake of DM was positively correlated with the contents of silage DM, total N, and lactic acid as a percentage of total acid, and negatively correlated with the contents of acetic acid and ammonia-N expressed as a percentage of total-N. Wilson and Wilkins (1973) reported that intake is restricted by the products of protein degradation in silage or by high concentrations of free acid in well-preserved silage (McLeod et al, 1970). High contents of specific primary fermentation acids (eg lactic acid) can limit intake (McLeod et al, 1970; Wilkins et al, 1971; Wilkins and Wilson, 1971). However, when the acids were neutralised with sodium carbonate, increases in DM intake ranged from 9.7 to 20.7%, whilst the addition of lactic acid to silage decreased intake (McLeod et al, 1970).

The effect of wilting on DM intake has been reviewed by Marsh (1979) who reported a mean increase in the intake of silage DM due to wilting of 25% for dairy cows and 44% for sheep. Other workers have reported increases in voluntary intake of DM with increasing silage DM content (Jackson and Anderson, 1968; Forbes and Jackson, 1971; Donaldson and Edwards, 1976; McIlmmalle and Steen, 1980; Rohr and Thomas, 1984; Unsworth and Gordon, 1985). However, the effect is not a consequence of DM content per se but is attributed to appetite depressants such as organic acids and the products of protein degradation which are relatively more abundant in low DM silage (Harris et al, 1960; Neumark et al, 1964). The work of Gordon (1981) and Castle and Watson (1982) indicates that wilting should not always be an

accepted practice provided the use of additives enable the production of unwilted silages with a good fermentation and high voluntary intake. Although the stimulatory effect of wilting on DM intake is very clear (Gordon, 1981; Wilkins, 1984; Rohr and Thomas, 1984; Unsworth and Gordon, 1985) the increase in DM intake is generally not associated with increase in animal performance when compared with well preserved unwilted silage (Thomas et al, 1969; Gordon, 1984; Wilkins, 1984; Unsworth and Gordon, 1985). The effect of wilting on intake and in animal performance is discussed further in Section 4, page 41.

Chopping of grass prior to ensilage increases silage intake in two ways: firstly, through improving the fermentation quality and secondly, through increasing the rate of passage of the food through the rumen (McDonald, 1981). Deswysen (1980) found that the rate of intake of long silage was significantly lower than that of short, chopped silage. He explained that with long silage, the retention time of the digesta in the reticulo-rumen was longer than that of short, chopped silage, so that the voluntary intake of long silage was lower. Marsh (1978) reviewed the information available with dairy cows up to 1977 and showed that, in 5 out of the 6 experiments reported, a higher DM intake (mean increase 0.8 kg silage DM/day) was obtained with fine chopped than with flail harvested material. Castle et al (1979) compared three chop lengths through the same precision-chop harvester and also found that both intakes of silage and milk yields increased with decreasing chop length. England and Gill (1983) reported that short chopping produced no response in intake, but this may have been due to the poor fermentation quality of the silage. However, in a series of five comparisons between flail and precision-chop silage, Apolant and Chestnutt (1984) found, in each instance, considerably higher intakes with the precision-chop material. Hastings (1976) reported the results from a three year comparison between flail and precision-chop systems, and found that finer chopping increased the DM intake by growing cattle by 10% and liveweight gain (LWG) by 135 g/day. In these trials the flail harvested silages were poorly preserved. However, in later comparisons, he reported smaller responses in intake (5%) and performance (30 g carcass gain/day) with finer chopping when all the silages were well preserved. Apolant (1982) fed the same precision-chop and flail harvested silages to young calves and sheep. This showed precision chopping to increase silage intake by 10% for young calves and 36% for mature sheep and clearly indicated that young calves are not as sensitive as sheep to chop length.

Attempts at improving the intake of silage DM have included the use of additives which result in decreasing concentration of fermentation acids and increasing contents of WSC in silages. The beneficial effects of adding formic acid to herbage before ensiling is reflected in improved voluntary intake of DM and animal performance (Waldo et al, 1968; Castle and Watson, 1970; McIllmoyle and Murdoch, 1979). However, the beneficial effect of formic acid treatment depends on the type of forage. Addition of formic acid to difficult crops such as cocksfoot and lucerne, prevents the formation of clostridial silages and improvements in animal performance due to the use of an additive can be quite striking (McDonald, 1981). This is well illustrated in the experiments of Lancaster et al (1977) in which six lucerne silages made with formic acid (3.63-4.87 l/t) were compared in feeding trials with untreated silages. Addition of formic acid effectively inhibited the development of clostridia. Organic matter digestibility (OMD), DM intake and LWG in both cattle and sheep were significantly greater on the formic acid treated silages compared with untreated. Murphy and Gleeson (1984) ensiled perennial ryegrass immediately after mowing with and without 2.7 l/t formic acid and after 36 hrs wilting with and without 2.7 l/t formic acid. They concluded that silage DM intake was higher for wilted silages compared to unwilted irrespective of the application of additive. Milk production was lower for wilted treated silage compared to unwilted silage. The application of formic acid to either the unwilted or wilted material did not improve cow performance and this was probably as a result of the good preservation achieved on the untreated silage. Huber and Soejono (1976) in studies with maize silages fed to lactating cows, reported that formic acid increased silage DM intake slightly but had little effect on milk production. Murphy (1986) in a comparison between formic acid and sulphuric acid as silage additives, found that silage DM intake was significantly lower for sulphuric acid treatment than for formic acid treatment, but yields of milk and milk constituents were not significantly different.

EFFECT OF SUPPLEMENTATION ON VOLUNTARY INTAKE AND ANIMAL PERFORMANCE

It is often necessary to supplement forages with concentrate feed to obtain high rates of animal production. Generally, this supplementation leads to a

decrease of forage DM intake but increased total DM intake (Dulphy, 1980).

Oldham (1980) concluded that protein supplementation consistently increases the intake of silage DM by dairy cows but that the effects with beef cattle are much variable. Kirby and Chalmers (1981) found that supplementation of silage diets with fish meal and with either soya bean meal or fish meal (Kirby and Chalmers, 1982) did not significantly increase silage DM intake. This is in agreement with the results of Drennan (1973a, 1973b, 1983) and Kirby et al (1984). In other experiments, supplementation of silage-based diets with protein has resulted in increased intake (Waterhouse et al, 1983; Kirby et al, 1985).

The effects of protein supplementation on the performance of finishing cattle offered silage-based diets have been variable. Drennan (1973a, 1973b, 1976, 1983) obtained no response in the performance of finishing cattle when silage-based diets were supplemented with soya bean meal, while Drennan (1983) and Kirby et al (1984) obtained similar effects with fish meal. However, in the other experiments, substantial responses in both liveweight and carcass gains have been obtained when silage-based diets have been supplemented with either soya bean meal (Drennan, 1973a, 1973b; Thomas et al, 1982; Waterhouse et al, 1983) or fish meal (Kirby et al, 1983, 1985).

SECTION 2

LOSSES IN SILAGE MAKING

In a comprehensive review of the literature, Watson and Nash (1960) concluded that total DM losses during ensilage ranged from 1-40% with a mean value of 16.1%. Zimmer (1967) reported the DM losses from 504 experiments involving herbage with a range of DM contents and reported a mean value of 19.4%. Wilkins (1986) reviewed the total losses for unwilted and wilted silages in 'Eurowilt' and ADAS experiments and found mean total losses (% DM harvested) for unwilted silage of 18.6 and 24.7 for 'Eurowilt' and ADAS respectively, and corresponding values of 16.5 and 31.9% for wilted silages (see Table 1.21).

The sources of losses in silage making are:

a) Field Losses

Provided grass or other forage crops are cut and ensiled either the same day or after a short wilt (24-36 hrs), DM losses in the field are low (0-2%). When the crop is wilted for more than 48 hrs however, losses in DM are considerable (5-12%) [McDonald and Whittenbury, 1973]. Three causes of DM losses during field wilting have been identified by Gorden et al (1969): Mechanical, biochemical and leaching. Mechanical losses result from handling forage crops during field drying, and it is clearly related to the number of turning operations (Honig, 1980). Biochemical losses are due mainly to respiration and other enzymatic processes occurring in the plant after harvesting, whereas leaching losses are due to losses of soluble nutrients during periods of rainfall.

Field losses of DM associated with wilting per se in moderate to good conditions have been variable but are considered to be about 2-3% per day (Ruxton, et al, 1975), to which should be added an additional constant amount of 2-3% if the crop has been lacerated (Nash, 1959a; Kormos and Chestnutt, 1967). In recent studies, Bastiman and Altman (1985) found that for grass wilted to between 18-41% DM, field losses averaged 4.8%. Wilkins (1986) estimated that field losses average 2.5%

TABLE 1.21

Total losses (% of DM harvested) for unwilted and wilted silage in 'Eurowilt' and ADAS experiments. (From Wilkins, 1986).

	EUROWILT		ADAS	
	Unwilted Silage	Wilted Silage	Unwilted Silage	Wilted Silage
Number of comparisons	23		13	
DM at Ensiling (%)	19.3	35.9	22.4	32.7
Field Losses (% DM harvested)	2.5	8.0	0	4.5
In-silo Losses (% DM harvested)				
TOTAL	16.1	8.5	24.7	27.5
Effluent	3.2	0	1.4	0.2
Surface Waste	*	*	4.9	10.2
Other (respiration, fermentation)	12.9	8.5	18.4	17.1
Total Losses (% DM harvested)	18.6	16.5	24.7	31.9

* Included within 'other'.

for unwilted silage and 8% for crops ensiled at 35.9% DM.

b) Respiration and Fermentation Losses

When herbage is ensiled, plant enzymes and aerobic micro-organisms allow aerobic respiration to continue for a time and even when the residual oxygen is used up, the activities of the anaerobic bacteria result in further substrate losses. McDonald and Whittenbury (1973), by considering the biochemical pathways of the fermentation of the major nutrients of grass, have calculated the theoretical DM losses to be 3 and 5% for the homo and heterolactic fermentations respectively, but conclude that the losses due to clostridia, although difficult to predict, are probably much greater.

It is difficult, experimentally, to separate the DM losses due to respiration from those due to fermentation, but losses of up to 73% of the original herbage DM when the silo was inefficiently sealed have been reported (McDonald and Whittenbury, 1973). Some confirmation of the theoretical DM losses due to fermentation has been supplied by Brown and Kerr (1965) and Anderson and Jackson (1970) who ensiled grass in well sealed mini-silos and recorded DM losses of 2.7-10%. These studies showed that providing anaerobiosis is rapidly achieved and maintained and a lactic acid fermentation is dominant, the DM losses due to respiration and fermentation should not exceed 6% of crop DM (McDonald and Whittenbury, 1973). However, Wilkins (1986) reported a total in-silo loss (% DM harvested) for unwilted silage as 16.1 and 24.7% for 'Eurowilt' and ADAS respectively, and corresponding values of 8.5% and 27.5% for wilted silages.

Four aerobic phases occurring during the conservation of crops as silage have been identified: the field stage, the initial aerobic phase in the silo, the air infiltration phase and the secondary aerobic deterioration phase (McDonald, 1981). DM losses during the field stage have been discussed (see page 21).

As soon as forage has been ensiled, it is essential that anaerobiosis be achieved as rapidly as possible to avoid aerobic deterioration. This

may occur in silos that are filled slowly causing a delay in sealing. Henderson (1973) showed that total DM losses from delaying the sealing of silos for 72 hrs increased by about 3 times compared to the losses for the control silos which were sealed immediately after filling. Continued air infusion into the silage during storage due to poor consolidation or sealing, encouraged the development or persistence of aerobic micro-organisms. Brown and Kerr (1965) ensiled herbage of 50% DM in unsealed trench silos and reported DM losses of 69.5 and 71.1%, compared with 10.5-11.3% when the silos were sealed.

Secondary aerobic deterioration of silage occurs when opening the silo for feeding. Honig (1975) reported that losses of DM due to secondary aerobic deterioration can be as high as 30%. Woolford and Cook (1978) in their studies with maize silages, reported DM losses of 7.4% after 7 days and 12.7% after 13 days aerobic exposure. Henderson et al (1979) studied the DM losses in silages from 18 farms over a 7 day period of aerobic exposure. In 6 of the silages no DM losses occurred while in the remaining 12 silages, losses ranging from 0.8-20% were reported with a mean loss of 6.6%.

c) Effluent Losses

The volume of effluent produced during ensilage is inversely related to the DM content of the crop (Sutter, 1957; Moor and Walker, 1961; Miller and Clifton, 1965; Castle and Watson, 1973) but the degree of consolidation and the condition of the crop are also important factors (McDonald et al, 1960; McDonald and Whittenbury, 1973). The DM losses due to effluent may range between 1-10%, but are usually of the order of 6% (Sutter, 1957; Watson and Nash, 1960; McDonald et al, 1960; Bastiman, 1976; Woolford, 1978). Watson and Nash (1960) reported the mean DM losses in the form of effluent to be 60 gkg^{-1} DM ensiled. Bastiman (1976) reported that DM losses in effluent from 50 silages ranged from 7.2-2.5% of the DM ensiled, for silages ensiled with DM contents between 15-20% DM. The DM losses in the effluent from crops ranging in DM concentration from 100 gkg^{-1} to 327 gkg^{-1} DM have been calculated by McDonald (1981) and are shown in Table 1.22. It is clear that DM losses in effluent increased as the moisture content of the crop increased. However, DM content of the crops is not the only factor which affects

TABLE 1.22

Relationship between DM content of ensiled crop and DM losses in effluent. (From McDonald, 1981).

DM Contents of ensiled Crop gkg^{-1}	DM Loss (%)
100	12.2
150	9.5
200	6.9
250	4.2
300	1.5
327	0

silage effluent production.

FACTORS AFFECTING EFFLUENT PRODUCTION FROM GRASS SILAGE

1 The Dry Matter Content of Ensiled Crop

It is generally agreed that the DM content of the crop when ensiled is the most important factor governing the amount of effluent produced. Sutter (1957), Zimmer (1967) and Bastiman (1976) have proposed equations from which the volume of effluent produced can be predicted from a knowledge of the DM content of the ensiled crop (see Table 1.23). The relationship between crop DM and effluent production predicted using these equations are shown in Figure 1.21. The three equations showed that effluent production can be avoided when the ensiled crop has a dry matter content of 300 gkg^{-1}. However, ensiling crop with DM content of 160 gkg^{-1} gives predicted effluent volumes of 311 l of effluent t^{-1} of crop (Sutter equation) and 192 and 152 lt^{-1} of crop for Zimmer and Bastiman equations respectively. It is clear that the volume of effluent estimated by the Sutter equation is markedly higher than that estimated by the Zimmer or Bastiman equations. This could be due to the kind of silos which have been used since Sutter used tower silos, whereas Zimmer and Bastiman used bunker silos. Nevertheless, the use of these equations showed that approximately 20-30% of the original weight of the ensiled crop (at 16% DM) can be lost as effluent. The amount of effluent estimated by Stewart and McCullough (1974), Patterson and Walker (1980) and Lowman et al (1983) for crops ensiled at different DM content is in general agreement with those estimated by Zimmer (1967) and by Bastiman (1976).

Bastiman (1976) illustrated typical patterns of effluent production from grass ensiled at different moisture contents (see Figure 1.22). He found that both the peak flow rate and the quantity of effluent production in the first 21 days increased as the DM content of the grass decreased. Effluent production ceased approximately after 15 days of ensiling grass with 219 gkg^{-1} DM, and after 60 days when grass DM was 158 gkg^{-1}. However, effluent production continued for approximately 30 days when

TABLE 1.23

Equations to predicted volume of effluent

Equation	Reference
$V^* = 669.4 - 2.24D^+$	Sutter (1957)
$V = 832.5 - 5.418D + 0.00883\ D^2$	Zimmer (1967)
$V = 767 - 5.34\ D + 0.00936\ D^2$	Bastiman (1976)

* V is Volume of effluent (lt^{-1} fresh crop).

\+ D is dry matter content (gkg^{-1}) of the crop ensiled.

FIGURE 1.21

THE EFFECT OF GRASS DM CONTENT ON EFFLUENT LOSSES
FROM FARM-SCALE SILOS

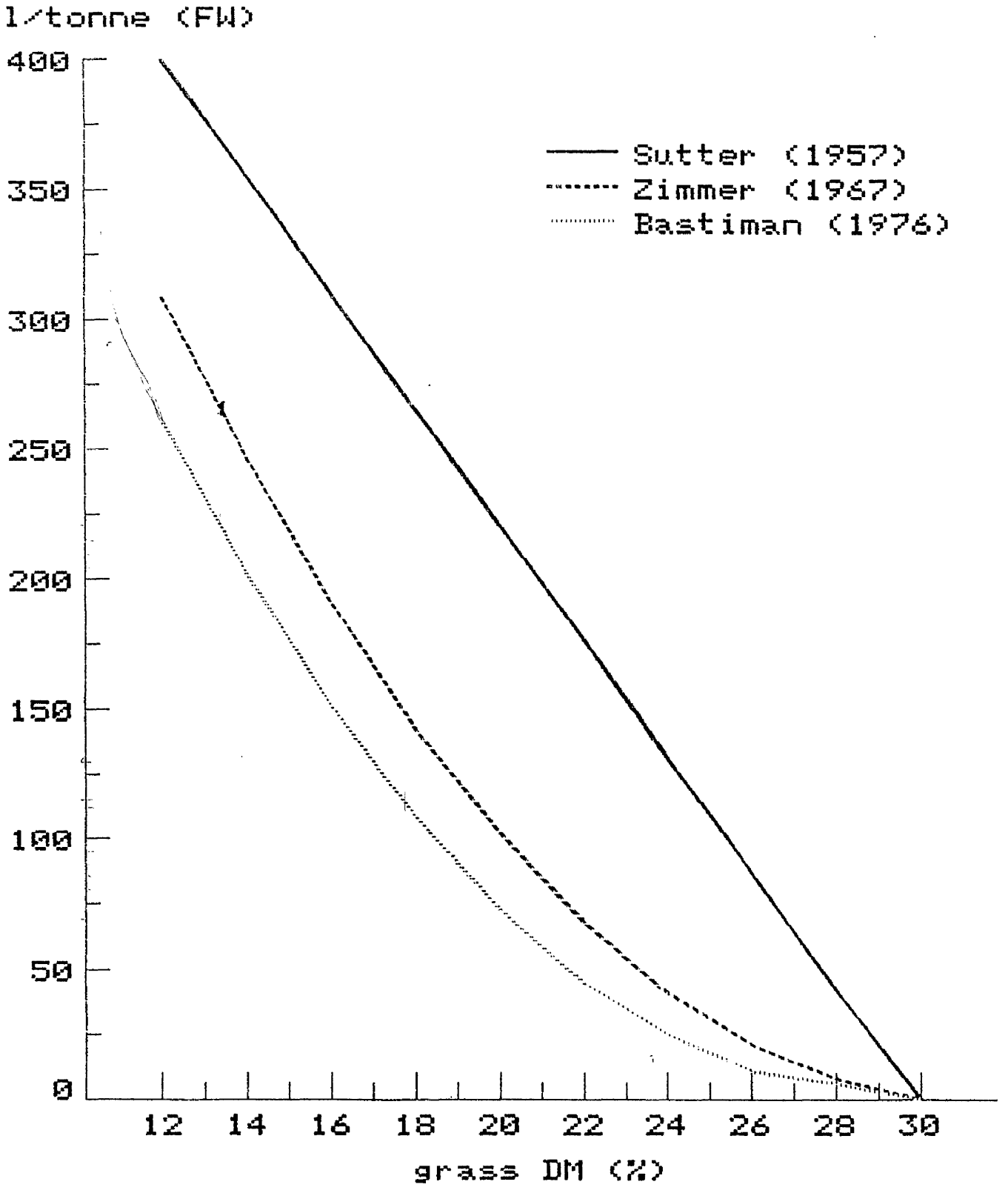
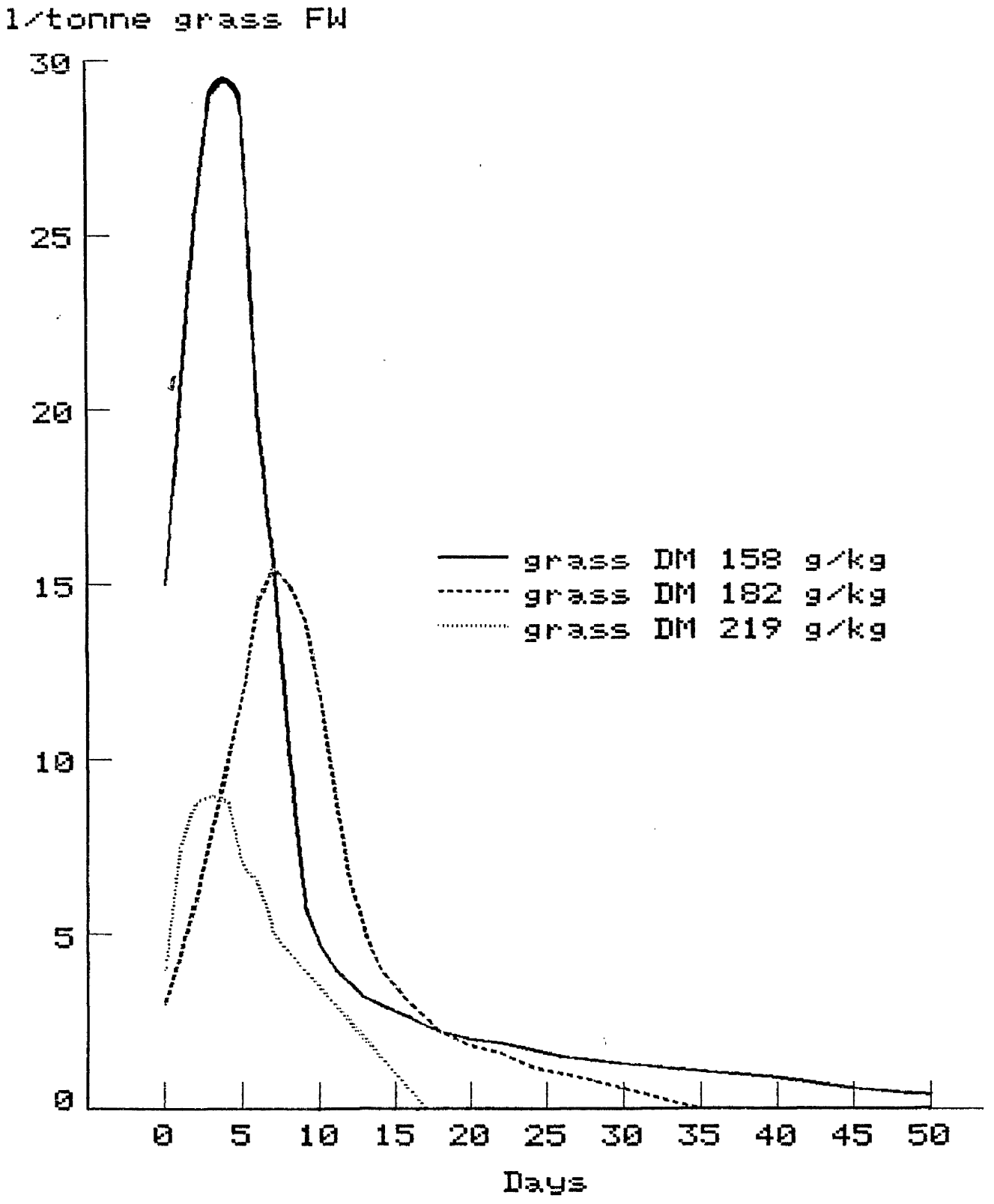


FIGURE 1.22

PATTERNS OF EFFLUENT PRODUCTION FOR SILAGES OF DIFFERENT MOISTURE CONTENTS (FROM BASTIMAN, 1976)



the ensiled grass was 182 gkg^{-1} DM.

2 Mechanical Pre-Treatments

Mechanical pre-treatment of crops before ensiling assists in consolidation and the rapid exclusion of air. However, it involves tissue laceration which might be expected to promote effluent production. Sutter (1957) propounded that mechanical treatment has little effect on effluent formation since only a small proportion of the cells are disrupted by such treatment. Jones and Murdoch (1954), in studies with silage made from a chopped mixture of grass and a legume at 180-190 gkg^{-1} DM, found that half as much effluent was produced as that made from the same unchopped crop. Brown (1961) reported that harvesting of grass by forage harvester effectively doubled the quantity of effluent compared with long cut material. McDonald et al (1964) observed that a similar increase in the amount of effluent resulted from bruising of herbage. Messure and Hawkins (1977) showed that whole crop maize silage ensiled at 20% DM produced 53 l effluent/t when the chop length was 6 mm, compared with 27 l/t for a 32 mm chop length.

3 Preservatives

The use of acids to preserve silage is widespread. These acids may alter the structural integrity of the plant cell and affect the moisture holding capacity, resulting in more effluent production from the herbage. Sutter (1957) compared the effects of formic acid and an unspecified mineral acid on effluent production and noted that the flow from the formic acid treatment was less rapid and more prolonged than from the mineral acid treatment. Henderson and McDonald (1971) reported that formic acid increases effluent flow. Pederson et al (1973) found that losses of effluent from silages treated with formic acid, formic acid-ammonium formate, and formic acid-formalin were greater than those from untreated silages. Bastiman (1976) has summarised the results of several investigations conducted mainly to evaluate formic acid, formalin and a mixture of formalin and sulphuric acid as preservatives. He found that herbage ensiled at 160 gkg^{-1} DM produced 154, 180 and 158 l of effluent per tonne of silage for untreated, formic acid treated and formalin treated silage respectively.

4 Consolidation

It is usual to consolidate silage in order to improve preservation by excluding air from the crop. Amos and Woodman (1922) observed that more effluent was produced from deep silos than from shallow silos and suggested that it is related to the greater pressure in the former. Greenhill (1964b) found that sustained pressure, rather than the pressure initially applied, had little effect on the consolidation of the silage mass, and therefore on the release of plant juice. However, the balance of evidence points strongly in favour of a direct effect of pressure on effluent production. In one study using small (1 tonne capacity) tower silos filled with grass, the effect of increasing the pressure applied to the surface of the grass from 1.4 m bar to 36.2 m bar increased the total effluent production from 55 gkg^{-1} to 123 gkg^{-1} ensiled grass (McDonald et al, 1960). Kirsch et al (1955) found the quantity of effluent produced with a surface pressure of 800 gcm^{-2} was ten times that at 80 gcm^{-2} and also that material of DM content 400 gkg^{-1} produced effluent when still greater pressure was applied.

SECTION 3

THE CHEMISTRY OF SILAGE EFFLUENT

The chemical composition of the DM in silage effluent will be affected by the composition of the sap, by the chemical changes resulting from fermentation and by changes in the effluent following its discharge. Generally, the main components of silage effluent are:

1 Plant constituents such as soluble sugars, amino acids and organic acids.

2 Fermentation products such as organic acids, alcohol and ammonia. Also, it may contain acids which have been applied to the crop in the form of silage additives.

3 Minerals, particularly P, K, Na, Ca and Mg.

4 Water, which ranges from 88-99% of the effluent.

The DM content of effluent ranges between 10 and 108 gkg^{-1}, but is usually of the order of 60 gkg^{-1} (Watson and Nash, 1960; McDonald *et al*, 1960; Bastiman, 1976; Woolford, 1978; Patterson and Walker, 1980; Fisher *et al*, 1981; Patterson and Steen, 1981-82). Effluent DM is typically composed of about 20% nitrogenous substances, 55% non-nitrogenous organic matter and 25% mineral matter (McDonald *et al*, 1960; Patterson and Walker, 1979a).

Patterson and Walker (1980), related the DM content of the ensiled grass to the DM content of the effluent as follows:

DM Content of Grass gkg^{-1}	DM Content of Effluent gkg^{-1}
150	45
200	65
250	85

Woolford (1978) found that DM content of effluent ranges between 10-100 gkg^{-1} and increased during the ensiling period. With the exception of soluble carbohydrate and possibly true protein, all major components of the effluent DM increase in concentration with time following ensilage. This conclusion is supported by the data of McDonald et al (1960), which shows the changes in the chemical composition of the effluent during the ensiling period (see table 1.31). In a recent study, Patterson and Steen (1981-1982) reported the DM content of effluent averaged 60 gkg^{-1} but ranged from 41-108 gkg^{-1}. The composition of effluent they collected is given in Table 1.32 together with the range of values obtained by Patterson and Walker (1979a) and by Patterson (1980).

THE POLLUTION EFFECT OF SILAGE EFFLUENT

Of the waste products of modern agriculture, silage effluent is among the most serious as a water pollutant. The highly polluting character of silage effluent derives from its high content of soluble organic nutrients released from the ruptured cells of the parent crop. When these nutrients contaminate a fresh water system, they stimulate rapid multiplication of its indigenous microbial population. The increased microbial growth removes dissolved oxygen from the water faster than it can enter into solution from the atmosphere. Thus effluent pollutes by the creation of a biological oxygen demand leading to depletion of dissolved oxygen (Woolford, 1978). The depletion of dissolved oxygen may cause the mortality of fish and other aquatic life.

Spillane and O'Shea (1973) compared the biological oxygen demand of various farm wastes and domestic sewage and found that the biological demand of silage effluent was 90,000 mgO_2l^{-1} compared to 35,000, 5,000 and 500 mgO_2l^{-1} for pig slurry, cow slurry and domestic sewage respectively. The quantity of effluent produced by 300 tonnes of silage of low DM content is equivalent in biological oxygen demand to the sewage produced in one day by a town with a population of 80,000 or in 27 years by a farmhouse with 8 occupants (Anon, 1976).

TABLE 1.31

Changes in the chemical composition of effluent during the ensiling period. (From McDonald et al, 1960).

Day*	pH	Component of Effluent gkg^{-1}					
		DM	Total-N	Ammonia-N	Acetic Acid	WSC	Ash
3	4.4	52.7	1.87	0.12	1.01	13.4	15.6
5	4.2	64.4	2.91	0.21	1.50	8.2	16.4
7	4.1	67.0	3.20	0.24	1.78	-	16.8
10	4.1	70.0	3.31	0.27	2.18	7.9	16.8
18	4.0	75.6	3.68	0.33	2.75	7.1	16.9
25	4.3	81.3	3.64	0.39	3.67	-	20.9
32	4.1	82.2	4.04	0.40	3.68	4.6	18.3
44	4.0	84.2	4.26	0.59	4.32	-	17.9
63	3.8	89.0	4.45	0.51	4.67	3.3	18.6

* After ensilage.

TABLE 1.32

Composition of silage effluent.

(From Patterson and Steen, 1981-82).

Composition	Mean	Range
DM (gkg^{-1})	60	41-108
Nitrogen x 6.25 (gkg^{-1} DM)	255	228-305
Lysine (gkg^{-1} DM)	10.4	6.6-16.5
Total amino acid N/total N (gkg^{-1})	594	539-746
Ammonia N/Total N (gkg^{-1})	125	27-406
Lactic Acid (gkg^{-1} DM)	285	211-382
Total Organic Acids (gkg^{-1} DM)	320	247-420
Carbohydrate (gkg^{-1} DM)	201	142-286
Ash (gkg^{-1} DM)	223	184-350
Calcium (gkg^{-1} DM)	21.9	16.1-28.6
Phosphorus (gkg^{-1} DM)	10.2	7.8-11.8
Magnesium (gkg^{-1} DM)	5.6	3.9-12.0
Sodium (gkg^{-1} DM)	12.1	5.7-17.8
Potassium (gkg^{-1} DM)	63.7	14.6-96.0

THE DISPOSAL OF SILAGE EFFLUENT

Most of the problems with silage effluent on farms arise from difficulties associated with the collection and retention of the effluent coming from silages. Clearly its direct discharge into water courses is highly undesirable. Moreover, all water authorities are extremely vigilant in monitoring water courses. Failure to prevent pollution results in heavy financial fines, which makes the provision of adequate collection and storage facilities cheap by comparison. However, most modern silos are arranged with a catchment system for collecting and storing silage effluent, although leakage of effluent is a very common problem. In many countries the currently advised method of effluent disposal is to spread it on the land. Recently, there have been some investigations into its potential as a feed.

a) Spreading on the Land

It is perhaps, not generally realised that silage effluent may contain a substantial proportion of the N and K originally presented in the crop ensiled (Moore et al, 1961) so that the economic loss can be considerable when nitrogenous and potassium fertilisers are regularly used. Studies have shown effluent to have a fertiliser value comparable to that of farmyard manure (Jensen, 1954; Purves and McDonald, 1963).

The most common means of effluent disposal is to spread it on the land. However this may scorch crops due to the acidic nature of the effluent, particularly during hot and dry weather. Another problem associated with this method of disposal is due to its very high biological oxygen demand. Effluent decomposition by soil microbes could deplete soil oxygen (Woolford, 1978), thus adversely affecting plant growth. However, scorch can be avoided or reduced by applying diluted effluent on days when the weather is overcast and the ground is wet. Woolford (1978) recommended the neutralisation of the excess acid with quicklime or limestone. However, dilution is currently the most favoured approach. Application rates of 25 $m^3 ha^{-1}$ for effluent diluted 1:1 water and 10 $m^3.ha^{-1}$ for undiluted effluent are advised (Anon, 1976).

b) Feeding to Animals

The contents of silage effluent represent the soluble fractions of the

ensiled forage. The nutritive value of these effluent constituents can be high, but the degree of dilution is also very high. Moreover, it is available at a time of year when other feeds are in relative abundance and can only be stored for about a week unless it is treated with formalin (3 l/tonne) [Patterson and Walker, 1980] which will increase the cost of using effluent as a feed. All these factors detract from the feeding value of effluent.

Experiments have shown that a daily allowance of 4.5 l of effluent with a dry matter content of 6.5% will replace 0.34 kg of meal when fed to pigs without loss of growth or grading (Patterson and Walker, 1980). Investigations have been carried out to examine the feasibility of feeding effluent to cattle. In a study in which 50 bullocks (liveweight 400 kg) were offered silage effluent as a supplement to unwilted grass silage, effluent was consumed in preference to fresh water, but the intake varied greatly between animals and the average intake being 14 $lday^{-1}$ (Patterson and Steen, 1981-82). The value of effluent relative to barley as a supplement to unwilted grass silage in the diet of finishing beef cattle has been examined by Patterson and Steen (1981-82). Unwilted grass silage was supplemented with 1.7 kgd^{-1} barley or 1.7 kgd^{-1} barley plus ad libitum effluent. They concluded that, responses of liveweight and carcass gain to supplementation with barley or barley plus effluent were similar. Clarke et al (1984) fed silage effluent to cattle receiving a diet of 3.5 kgd^{-1} concentrate and ad libitum ammonia treated straw. They found that silage effluent was consumed by the cattle but resulted in a reduction in straw intake. However, liveweight gain increased from 1.05 to 1.33 kgd^{-1} with effluent feeding. In a recent study, Steen (1986) evaluated effluent from grass silage as a feed for steers, in addition to a diet of grass silage given ad libitum and supplemented with 1.7 kg cereal-based concentrates. The results showed no significant differences in liveweight gain due to effluent intake. A frequent problem with effluent feeding is a large between-animal difference in intake of effluent. In addition, O'Kiely and Flynn (1987) have shown that intakes of effluent fell from 45 l/head/day to 4.5 l/head/day if the effluent was not well preserved.

SECTION 4

THE CONTROL OF SILAGE EFFLUENT

A) Pre-wilting of Crop before Ensiling

Effluent production from silage can be avoided by wilting the herbage which in dry weather, can lead to substantial reductions or the complete avoidance of the production of effluent. Wilting of herbage from 175-245 gkg^{-1} DM resulted in a decrease in effluent formed by approximately 70% (Brown, 1961). Effluent loss from silos is virtually stopped at a grass DM content of about 300 gkg^{-1} (Miller and Clifton, 1965; Castle and Watson, 1973; Bastiman, 1976; Fisher et al, 1981). However, even a modest wilt may often be difficult to achieve in regions of high rainfall.

The effect of wilting on dry matter losses, composition of herbage, fermentation in silo, digestibility of silage and intake and animal performance will be discussed.

1 Effect of Wilting on dry matter Losses

Field losses of dry matter associated with wilting per se in moderate to good conditions have been variable but are considered by reviewers to be about 2-3% per day (Ruxton et al, 1975). To this amount should be added an additional constant amount of 2-3% if the crop has been lacerated (Nash, 1959a; Kormos and Chestnut, 1967). Other experiments (Rucker and Knabe, 1980) clearly illustrate that field losses increase with length of the field periods, and are higher in bad than in good drying conditions. Wilkins (1984), in an analysis of the 'Eurowilt' experiments, reported that field losses averaged 2.5% for unwilted silage and 8% for wilted silage. This difference of 5.5% in field dry matter losses between the two systems agrees closely with the mean differences of 4.8% between unwilted (18% DM) and wilted (41% DM) silages for nine separate experiments by ADAS reported by Bastiman and Altman (1985).

The in-silo losses of dry matter reported by Bastiman and Altman (1985) were 24.7% for direct cut silage (22.4% DM) and 27.5% for wilted silage (32.7% DM). It is clear from this review that wilting caused a small increase in in-silo losses which might be because wilted silages, although potentially having better fermentation characteristics, might be more susceptible to aerobic losses (Ruxton et al, 1975). Increased susceptibility to aerobic spoilage in wilted silages may be due to factors other than DM content per se, including the possibility of wilting leading to the build up of aerobic micro-organisms which can remain latent in the silage and cause increased losses after opening (Honig and Woolford, 1979). In contrast, Wilkins (1986) found a large reduction in in-silo dry matter losses as DM of ensiled crop increased from 15% to 30%. He reported an in-silo loss for unwilted silage (19.3% DM) of 16.1% and 8.5% for wilted silage (35.9% DM).

Thus the increase in field losses caused by wilting are balanced to a variable extent by reduced effluent and fermentation losses in the silo. Hastings (1972) found that total DM losses in silage making decreased as the DM content of the ensiled crop increased to 400 gkg^{-1}. Waldo (1977), in a review, reported that average total DM losses from wilted silage made without additives were 13-15%, which compared favourably with the 17-20% losses from directly cut crops ensiled without additives and were similar at the 10-15% losses found in the unwilted additive-treated silage. Wilkins (1986) found that total DM losses for unwilted silages (19.3% DM) and wilted silage (35.9% DM) was 18.6 and 16.5% respectively. Bastiman and Altman (1985) from paired comparisons of silages made in bunker silos reported that total DM losses for unwilted silages made without additive (22.4% DM) was 24.64% and 32.34% for wilted silages (32.7% DM). The balance of evidence therefore suggests that wilting has no clear or consistent effect on total dry matter losses. However, should a practical method be established for feeding the effluent obtained from loss dry matter silages to stock (either by collection or by the use of absorbents), then total losses would be significantly less for unwilted silages.

2 Effect of Wilting on Composition of Herbage

The greatest change in the composition of herbage due to wilting is the

reduction in water content. The loss of water from herbage during the wilting period is related to a number of factors. Weather conditions (wind speed, temperature, humidity, radiation level) are important factors. Also mechanical treatment of the crop during harvesting is important. Rupture of cell by mower conditioning speed up the rate of drying by increasing the evaporating area (Sullivan, 1973).

Continuing respiration in cut crops during wilting leads to the oxidation of carbohydrate, though the changes in WSC content may be relatively small since the oxidation losses may be offset to an extent by sugars released by the hydrolysis of polysaccharide (Carpintero et al, 1979). Plant proteolysis also occurs during wilting, giving increases in the proportions of non-protein-N, amino-N, amide-N and ammonia-N (Brady, 1960). However, under adverse conditions and particularly where cut crops are wetted by dew or rain, losses of soluble constituents are increased and effects due to plant enzyme activity are exacerbated by the effects of leaching.

3 Effect of Wilting on Fermentation

Wilting herbages before ensiling affects the total bacteria count on the crop and the rate of fermentation (Stone et al, 1944). Wilting delays bacterial multiplication in grass silage (Stirling, 1951). Greenhill (1964a, b) shows that the release of intracellular plant juices is a prerequisite for the onset of a natural primary anaerobic fermentation and that, at a dry matter concentration above 330 gkg^{-1} DM, such a fermentation is delayed if not prevented. If the WSC levels are high in wet crops, then the lactic acid bacteria will be extremely active and the result will be a low pH silage of high lactic acid content. Wilkins et al (1971) reported that lactic acid content as a proportion of total acids, was positively ($P < 0.01$) related to DM content of silage. The effects of wilting on fermentation have also been discussed in section one of this chapter (page 7).

4 Effect of Wilting on Silage Digestibility

Silage digestibility is largely dependent on the digestibility of the parent material (Demarquilly and Jarrige, 1970) which in turn, is affected by the species of plant and its stage of maturity at harvest

(Harris and Raymond, 1963; McCarrick, 1965; Kormos, 1967 and Castle, 1975). Harris and Raymond (1963) found ensiling *per se* did not significantly alter digestibility of herbage, provided correction for volatiles was made. This conclusion has been supported by McDonald and Edwards (1976) and by Donaldson and Edwards (1976). However, other workers (Dijkstra, 1957; Watson and Nash, 1960; Harris *et al*, 1966; Alder *et al*, 1969; Demarquilly and Jarrige, 1970) have found the effect of ensiling on digestibility to be more variable with a tendency for digestibility to be reduced (range 0-0.13) by ensiling. In a comparison of the data from 20 different sources, Marsh (1979) obtained, for wilted and unwilted silages, mean DM digestibility values of 0.685 and 0.700 respectively, and from nine sources, corresponding N digestibility values of 0.629 and 0.658. Similarly, Wilkins (1984) in a review, reported that DM digestibility of unwilted and wilted silages were 0.698 and 0.681 respectively. He concluded that dry matter digestibility was higher in unwilted than wilted silages.

The effect of wilting on digestibility is likely to be influenced by weather conditions. If wilting is prolonged and carried out under poor weather conditions, losses of highly digestible nutrients through oxidation and leaching can be relatively high and this could reduce DM digestibility.

5 Effect of Wilting on Intake

Several workers have reported increases in voluntary intake of DM with increasing silage DM content (Murdoch *et al*, 1958; Moore *et al*, 1960; Brown, 1960; Jackson and Anderson, 1968; Forbes and Jackson, 1971). Marsh (1979) found in ten comparisons with sheep, that wilting increased DM intake by 44%. Demarquilly (1973) however, noted an increase due to wilting of only 12.6% in 14 comparisons with silages of 4-5 cm particle length. Wilkins *et al* (1979) and Demarquilly (1973), reported correlations between DM intake and DM content were not as high as those between DM intake and content of volatile fatty acids such as acetic acid, and it has been suggested that improvements in intake with increasing silage DM content may be associated with a reduction in the content of acetic acid in wilted silages (Wilkinson *et al*, 1976). Gordon (1981) reported that wilting increased silage dry matter intake,

but resulted in a significant depression in milk yield. Wilkins (1984) found the mean dry matter intake was higher for wilted than for unwilted silages by 4%, 9% and 6% for dairy cows, growing cattle and sheep respectively. Rohr and Thomas (1984) reported that dry matter intake was 9% higher for growing cattle fed wilted compared to unwilted silages. Unsworth and Gordon (1985) from 10 similar studies, reported an increase in dry matter intake of only 4.5% due to wilting and a reduction in milk yield of 6.8%.

6 Effect of Wilting on Animal Performance

Thomas et al (1969), in one comparison with lucerne, found wilting from 20.8 to 29.4% DM, reduced daily gain in sheep from 47g to -15g, despite an increase in DM intake of 2.6 gkg^{-1} liveweight. Marsh (1979) reported a mean increase in the intake of silage DM of 25%, but only a marginal increase in milk yield. Indeed, in some experiments wilted silage has produced significantly lower milk yields when compared with unwilted, formic acid treated silage (Derbyshire et al, 1976; Gordon, 1980a, 1980b, 1981; and Steen and Gordon, 1980). The results indicated that, on average, wilting increased silage DM intake by 4.8%, but milk yield was reduced by 4.3%. This effect of increased intake and lower milk output suggests that the dry matter from wilted silage was utilised less efficiently for milk production than that from unwilted material. Wilkins (1984), in a review of the effect of wilting on animal performance, reported that on average, milk yield was no higher with wilted than unwilted silage, but when the analysis was restricted to include only the unwilted silages made with additives, milk yield was 0.9 kg/day higher for the unwilted silages. Although liveweight gains by beef cattle were higher, on average, with wilted silages, these cattle consumed more silage DM but the gain per kg DM intake was higher with unwilted silages. In a subsequent analysis of the 'Eurowilt' experiments, Rohr and Thomas (1984) reported little differences in liveweight gains between unwilted and wilted silages, despite an increase in DM intake by 9% with wilted silages, indicating greater gross efficiencies with unwilted silages. Steen (1985) in a recent study concluded that field wilting for 36-80 hrs reduced animal performance by 0.08 and beef output per hectare by 0.11. Thus, although wilting has advantages unrelated to animal performance, silage should

not be wilted except during ideal weather, and period of wilting should not exceed 24 hrs. The major reduction in beef output per animal and per hectare (relative to well preserved, unwilted silage) which results from longer periods of wilting are likely to outweigh any practical advantages which result from achieving a higher DM concentration.

B) Absorption of Effluent in the Silo

This involves retaining the crop moisture in the silo by incorporation of a drier absorbent material into the crop at ensilage. This approach may be a more practical method than wilting for the prevention of effluent from silage in the wetter, western parts of the UK. Absorbents should be cheap, readily available, have a high moisture holding capacity and should occupy as small a volume as possible in the silo. Additionally, they should not reduce the nutritive value of the silage and, if possible, should enhance the silage fermentation.

Several materials, such as barley meal, barley straw, dried grass, dried beet pulp and newspapers have been tried. Everson et al (1971) investigated the ability of the colloidal clay sodium bentonite to retain water-soluble nitrogenous supplements during the ensilage of maize. It was noted that effluent production was initially eliminated by additions of sodium bentonite of up to 10 gkg^{-1} crop fresh weight. However, the elimination of effluent may have been due to the high dry matter content of the maize they used (290 gkg^{-1} or more). Woolford and Camp (1977), added sodium bentonite to wet grass at levels ranging from 0-5% of the crop fresh weight. They found that bentonite absorbed about six times its own weight of moisture and produced a marked reduction in both rate of effluent flow and total output, provided the level of addition was at least 1.0% of the crop fresh weight.

Incorporation of newspaper, straw and dried grass with sugar beet tops were investigated by Salo and Sormunen (1974). They reported that losses of effluent were markedly smaller and the retention of nutrients by the binding material was higher in the upper parts of the silos. The mean dry matter retention was 201, 202 and 50 gkg^{-1} DM for newspaper, straw and dried grass respectively.

The effect of adding milled straw to beet tops during ensilage in effluent production and silage fermentation has been investigated by Pederson (1980). He found that the addition of 150 g milled straw per kg fresh tops prevented the production of effluent and reduced the organic matter loss by 140 gkg^{-1} (see Table 1.41). The contents of lactic and acetic acids and alcohol were increased with increasing amounts of straw. Thus mixing with straw at ensiling in order to reduce effluent production appears a promising method. The principle may also be utilised in ensiling of crops other than beet tops.

Ensiling of forage crops mixed with dried beet pulp has also shown promising results. Dulphy and Demarquilly (1976) made silage from timothy/red clover mixed with 58.8 kg dried beet pulp per tonne at ensiling. They found that mixing with beet pulp at ensiling decreased effluent production from silage. When silage was fed to dairy cows, milk production was higher with pulp added at ensiling than feeding an equivalent amount of beet pulp as a supplement to the control silage. They also found that, when pulp was added at feeding, there was a loss of liveweight of 49 g per day per cow compared with an increase of 140 g per cow per day when pulp was added at ensiling. In another experiment with perennial ryegrass, silage mixed with 60 kg per tonne pelleted beet pulp, Dulphy and Andrieu (1978) reported a reduction in effluent production. They also found that addition of pulp at ensiling increased daily fat corrected milk production by 0.7 kg per cow and increased liveweight gain by 154 gd^{-1} compared with addition of pulp at feeding. Similarly, Jones and Jones (1987) made silage from grass (18% DM) mixed with 50 kg dried sugar beet pulp pellets per tonne of grass at ensiling. They found that effluent production over 20 days was 15 lt^{-1} from the sugar beet pulp treatment compared to 31 lt^{-1} from the control. These workers also reported an advantage in liveweight gain in beef cattle by the inclusion of sugar beet in the grass at ensiling compared to feeding an equivalent amount as a supplement to grass silage.

The effect of adding rolled barley to grass silage at ensiling on effluent production and animal performance has been tested by Jones and Jones (1987). They made silage from an autumn cut of hybrid ryegrass (16% DM) in 50 tonne clamp silos with:

TABLE 1.41

The effect of adding milled straw to beet tops on effluent losses and silage composition. (From Pederson, 1980).

Composition	Quantity of Straw Added (gkg^{-1})						
	0	30	60	90	120	150	200
DM Content (gkg^{-1})	136	157	179	201	230	252	282
Straw DM (gkg^{-1} total DM)	0	162	287	382	485	550	614
Effluent (gkg^{-1} fresh ensiled tops)	435	289	185	108	45	0	0
Organic matter loss (% of tops OM)							
Seepage	22	14.2	9.5	5.6	2.5	0	0
Fermentation	-1.5	2.7	3.9	3.7	(17.3)	8.4	0.5
Total	20.5	17.5	13.5	9.3	(19.9)	8.4	0.5
Composite of Silage pH	4.32	4.17	4.14	4.15	4.26	4.3	4.33
Ammonia-N (gkg^{-1} TN)*	64	74	63	66	71	75	69
Lactic Acid (gkg^{-1} DM)*	56	74	100	96	124	114	124
Acetic Acid (gkg^{-1} DM)*	16	27	29	28	40	36	37
Butyric Acid (gkg^{-1} DM)*	0	0	0.7	1.5	0.8	0.9	1.8
Ethanol (gkg^{-1} DM)*	4	5	5	5	5	7	10
WSC (gkg^{-1} DM)*	66	52	49	45	61	65	51
Organic Matter Digestibility	0.75	0.63	0.69	0.68	0.64	0.56	0.62

* Composition of tops DM (ie Total DM in silage - DM in added straw)

a) No-additive (control)

b) Formic Acid applied at 5 lt^{-1} of grass

c) 50 kg rolled barley mixed with each tonne of grass at ensiling

They found that total effluent production was 50, 60, 26 lt^{-1} of grass for control, formic acid treatment and barley treatment respectively. Barley silage was lower in ammonia-N than the control, but higher than for the formic acid treatment. The three silages were fed ad libitum to steers (liveweight 400 kg) for a period of 8 weeks. The barley silage was fed unsupplemented and the other groups supplemented with 1.5 kg rolled barley per head per day. They reported that, total DM intake was 8.8, 8.6, 9.0 kg per head per day for the control, formic acid and barley silage respectively. Liveweight gain was 0.82, 0.96, 1.00 kgd^{-1} for the control, formic acid and barley silages respectively. These results suggested an improvement in efficiency of energy utilisation as a result of mixing barley with the grass at ensiling compared to separate feeding of barley and grass silage.

CHAPTER TWO

MATERIALS AND METHODS

PRODUCTION OF SILAGE

The silage used in all the experiments was made from herbage of perennial ryegrass. The crops were cut with a disc mower and lifted with a maximum wilting time of three hours using a precision-chop forage harvester which chopped to a length of approximately 35 mm. An additive containing 85% formic acid ("Add-F", BP Nutrition Limited) was applied (when required) as the crop was chopped. The grass was transported from the field using tractors and trailers, weighed, temporarily stored covered on a concrete floor and ensiled within four hours of chopping.

Types of Silo Used

Two types of silo were used as follows:-

1 Drum Silos

Plastic drums, capacity 200 l, were used as silos. A large polythene bag was fitted inside each drum and a perforated false wooden bottom was fitted within the polythene bag to provide a space for accumulation of effluent (see Figure 2.1). This space was purged with CO_2 prior to filling the silo.

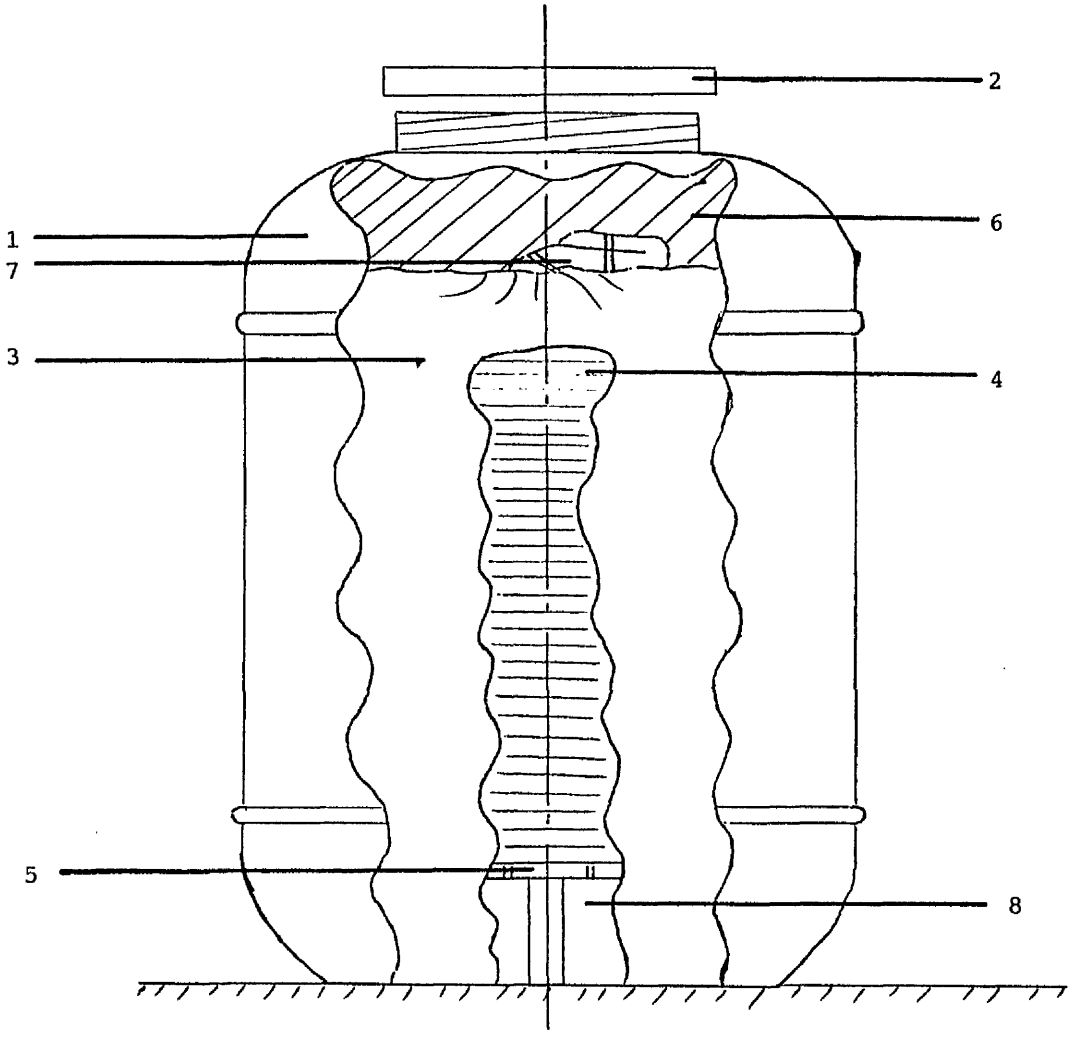
Grass for each drum was weighed, well mixed and a representative sample was taken. An appropriate amount of absorbent was then well mixed with the grass. The grass or grass + absorbent mixture (approx 60-80 kg FW) was tightly packed into each drum and compacted by repeated treading as the drum was filled. The silage was well sealed in the polythene bag within the drum by twisting the top of the bag and binding tightly in two places. Sand (40 kg) was then added to the free space above the silage to provide a loading pressure.

2 Mini Pit Silos

Six mini pit silos, constructed of railway sleepers, each of approx $1 m^3$ volume, were used. Each silo allows for total individual collection of effluent (see Figure 2.2).

FIGURE 2.1

DIAGRAM SHOWING CONSTRUCTION OF DRUM SILO



1 200 l plastic drum
2 Screw top
3 Polythene bag
4 Silage
5 False base (10 mm plywood/8 mm holes)
6 Sand
7 Bag ties
8 Effluent collection space

Polythene silage sheeting, which covered the silage surface, was continued down the sides of the pits and extended along the floor to a length of 0.5 m on all sides. A hole was made in the sheeting at the centre of the lowest point of the floor to allow effluent to drain out.

Each silo was filled with grass using a tractor foreloader. The silos were filled simultaneously from the weighed heaps of grass so as to equalise any effects of delayed filling.

Adding the Absorbent

Two systems for distributing absorbents within the mini pit silos were used as follows:

a) Bottom Layer System

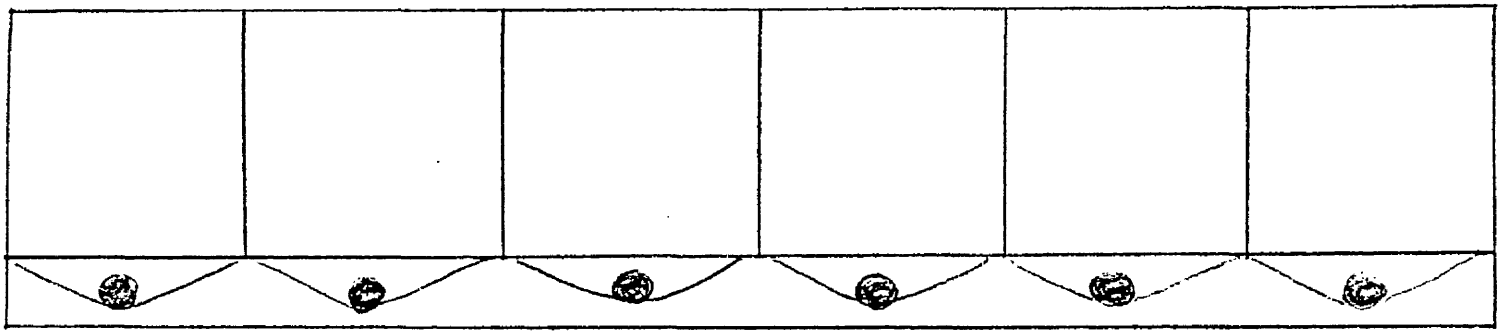
In this system, the absorbent was placed on the concrete floor of the silo and spread evenly before filling the silo. In the case of straw bale treatments, the silo base was tightly packed with straw bales placed on edge with cut ends of the straw uppermost.

b) Multi-Layer System

Approximately 0.1 of the total absorbent to be added was placed on the bottom of the silo and distributed evenly. Two loads of the grass were transferred to the silo with a foreloader tractor, spread by hand over the absorbent and compacted by treading. This process was repeated until the silo was filled giving approximately 10 absorbent layers distributed up the height of the silo. The layers of grass separating adjacent absorbent layers were typically of width 12-15 cm. Plates 2.1a and 2.1b show this system.

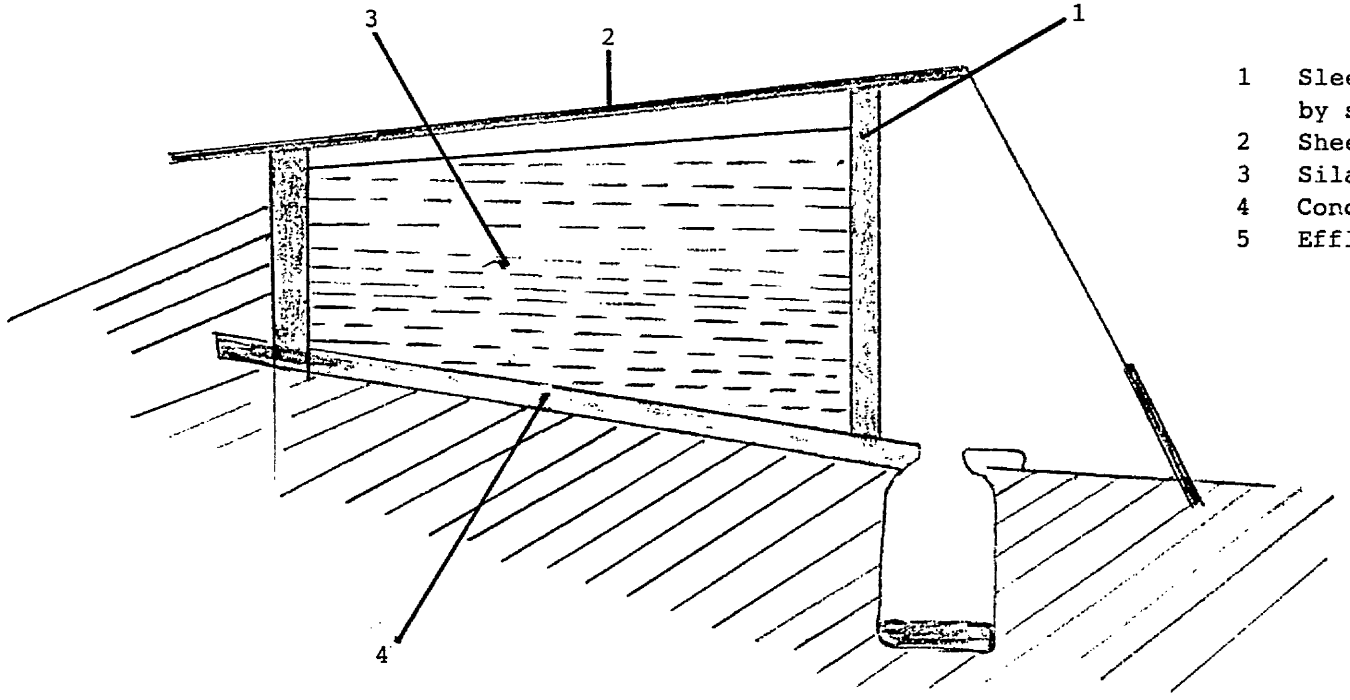
Consolidation

Grass was transferred to the silo by using a foreloader tractor. After each two loads of grass, compaction was achieved by treading with four persons working in each silo. Once the silo was filled to 0.75 capacity, a horticultural tractor was used to complete the consolidation (see Plate 2.2). The silo was then immediately covered with two black polythene sheets which



PLAN

SECTION



1 Sleeper wall supported by steel
2 Sheeted roof
3 Silage
4 Concrete slab
5 Effluent

FIGURE 2.2

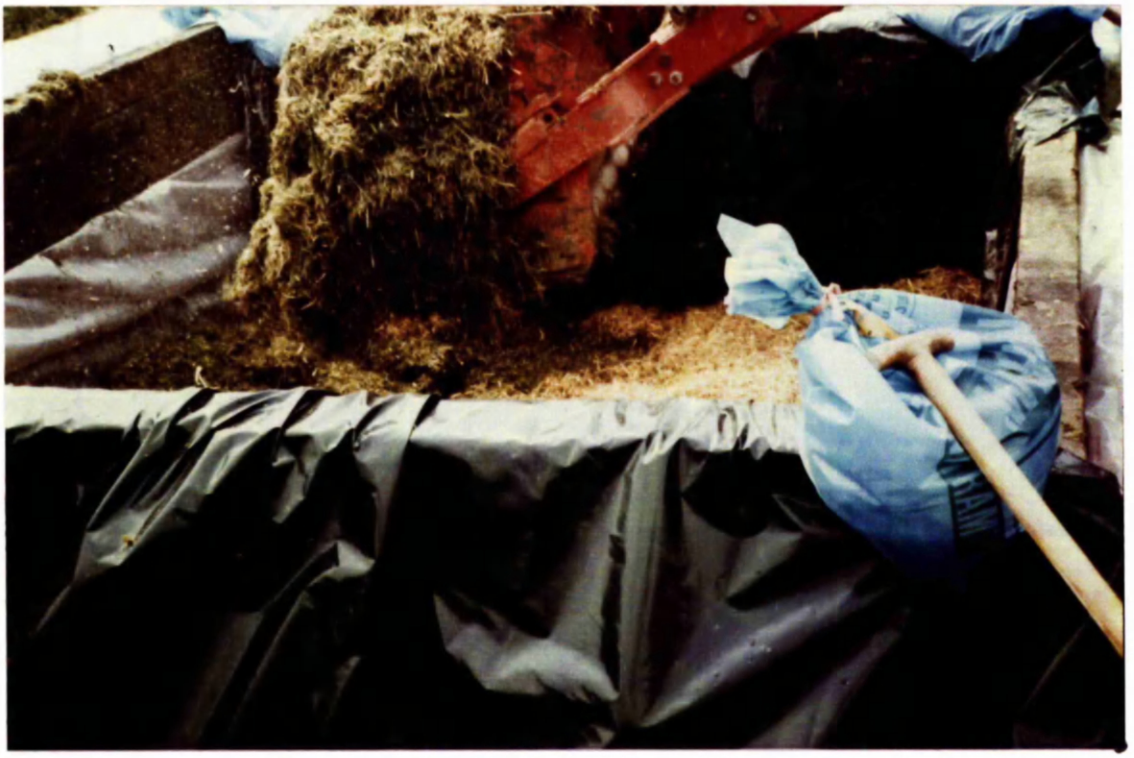
DIAGRAM SHOWING CONSTRUCTION OF "MINI PIT" SILOS

PLATE 2.1a

APPEARANCE OF SILAGE SURFACE AFTER ADDITION OF A LAYER OF MOLASSED SUGAR BEET SHREDS

PLATE 2.1b

THE FIRST LOAD OF GRASS BEING ADDED AFTER THE ADDITION OF A LAYER OF CHOPPED STRAW



were weighed down using tightly packed sand bags and well-sealed plastic containers filled with water (see Plate 2.3). Silage densities for control silages made with grass only were 1.18 m^3/tonne which compares with a typical value for farm scale silos of 1.20 for silages of comparable dry matter content.

Covering the Clamps

A roof which protected the silos from rain was then constructed. It was big enough to cover all the silos and effluent containers, and to ensure that rain did not enter the effluent containers (see Plate 2.4).

Effluent Collection

A continuous observation of effluent flow was made during the first day of ensiling in order to avoid overflow from the collection drums. A hand pump was used to empty the collection drums sited at the front of each silo into above ground storage drums (see Plate 2.5). Formalin (0.6 l) was added to each 200 litre of effluent on transfer to act as a preservative.

Sampling the Effluent

At the end of effluent collection, a representative sample was taken from each drum. Samples for each treatment were mixed well and further subsampled into small plastic containers (volume 3 l) which were stored in a deep freeze at -20°C.

PLATE 2.2

Final Compaction of Silage Using a Horticultural Tractor

PLATE 2.3

Method of Weighting the Covering Polythene Sheet

PLATE 2.4

End View of Silo Showing Roof

PLATE 2.5

Water Pump Used for Effluent Transfer

METHODS OF CHEMICAL ANALYSIS

OVEN DRY MATTER DETERMINATION

A known weight of sample was oven-dried at 100°C to constant weight and the dry matter expressed as a percentage of fresh weight.

TOLUENE DRY MATTER DETERMINATION

The toluene dry matter content of silage was determined by distillation of minced silage samples with toluene following the procedure of Dewar and McDonald (1961).

An accurately known weight of silage (average 65g) was placed in a one litre round bottom flask. 400 cm^3 of toluene was added, heated to boiling point and allowed to reflux for eight hours. Then a fine jet of toluene was directed down the condenser to remove the last traces of water and the distillation continued for a further 15 minutes. The volume occupied by the volatiles was estimated from the acidity of the water distillate.

The acidity of the water distillate was measured by titrating with 0.1M NaOH using phenolphthalein indicator. If W was the weight of silage (g), V was the observed volume of distillate (cm^3) and T was the titre of 0.1M NaOH (cm^3), then the percentage toluene DM (TDM%) was calculated as follows:

$$TDM\% = \frac{100 - 99.8\,(V - 0.0055T)}{W}$$

TOTAL NITROGEN DETERMINATION

Total nitrogen was determined by the Kjeldhal method based on the technique described by Egan et al (1981). Samples were digested with sulphuric acid using selenium oxide as a catalyst. Hydrogen peroxide was added to help to oxidise the organic matter in the sample. The second step was the colorimetric estimation of ammonia released by adding alkali to the digest.

Reagents

1 Digestion mixture was made up by mixing slowly with cooling the following:

a 40 g selenium oxide in 100 cm^3 distilled water

b 2 l concentrated H_2SO_4

2 Buffer - 5 g NaOH + 3.74 g anhydrous Na_2HPO_4 + 31.8g Na_3PO_4 $12H_2O$ + 10 cm^3 sodium hypochlorite (10-14% av Cl) in 2 litres distilled water.

3 Caustic phenol - 2.4g NaOH + 0.1g sodium-nitroprusside + 20g phenol in 1.6 litres distilled water.

4 Ammonia standards - ranging from 0.05-0.25g.l^{-1} ammonia nitrogen were made from a stock solution containing 4.7168g $(NH_4)_2$ in 1 litre 10% H_2SO_4 (1g $l^{-1}N$).

The different ammonia-N concentrations were made by appropriate dilution in 10% H_2SO_4.

Method

a Digestion

About 0.2 to 0.5g of test material (depending on N content) was weighed accurately into a 75 cm^3 graduated digestion tube. 8.0 cm^3 of digestion mixture was added to each tube using an automatic dispenser, followed by three 1 cm^3 volumes of hydrogen peroxide (100 vol) and two pieces of

sintered glass. The tubes were transferred to a block digester* and heated progressively to 350 for 2 hrs. The tubes were then allowed to cool for 1 hour after which the contents were made up to the 75 cm^3 mark with distilled water. The contents were mixed thoroughly and allowed to settle and cool for one hour before samples were taken for analysis.

b Ammonia Analysis

Ammonia was measured using the Indo-Phenol colorimetric method.

Samples of constant volume (about 0.1 cm^3) either standards or digests were dispensed into 50 cm^3 test tubes. 8.0 cm^3 of caustic phenol and 20.0 cm^3 of buffer solution were then added. The tubes were swirled and left to stand at room temperature for 1 hour for colour development. Absorption at 585 mm was then measured using a spectrophotometer (model SP8-500 PYE**). The measurement for the blanks and standards were used to draw a graph of nitrogen concentration against absorbence from which the nitrogen content of the sample was calculated.

WATER SOLUBLE CARBOHYDRATE DETERMINATION

The water soluble carbohydrates were determined by the method of McDonald and Henderson (1964).

APPARATUS

- Bottles - 250 ml, with screw tops
- Shaking machine

* Tecator Limited, Cooper Road, Thornbury, Bristol, BS12 2UP, UK

** PYE Unican Limited, York Street, Cambridge, CB1 2PX, UK

REAGENTS

a Anthrone reagent - 760 cm^3 of sulphuric acid (approx 98% W/V H_2SO_4) was added with stirring to 330 cm^3 of cold distilled water. After cooling, one gram of thiourea and one gram of anthrone were added and stirred until dissolved. Then reagent was stored in the refrigerator.

b Glucose stock solution, 0.8 mg/cm^3 of glucose - 0.4g of anhydrous D (+) glucose was dissolved in distilled water and diluted to 500 cm^3. The solution was used immediately after preparation.

c Glucose working standard solutions containing 0-0.16 mg/cm^3 glucose were prepared by transfer of 0, 5, 10, 15 and 20 cm^3 of glucose stock solution to five 100 ml graduated flasks and diluted to 100 cm^3. The standards were used immediately after preparation.

Procedure

0.2g of oven dried sample, ground to pass a 1 mm mesh sieve, was transferred to a bottle and 200 cm^3 of distilled water was added. The bottle was capped and shaken on a shaking machine for one hour. The contents of the bottle were filtered through a 12.5 cm Whatman No 1 filter paper. The first few cm^3 of filtrate was rejected and the remainder was retained for immediate analysis. 2 cm^3 of each glucose working standard solution or 2 cm^3 of extracted sample were pipetted into 200 x 25 mm pyrex glass test tubes. 10 cm^3 of anthrone reagent was added to each tube and mixed well by shaking. The tubes were placed in a boiling water bath for 20 minutes, then removed and left to cool. Absorption at 620 mm was measured using a spectrophotometer. The measurement for the blanks and standards were used to draw a graph of glucose concentration against absorbence from which the WSC of the sample was calculated.

LACTIC ACID DETERMINATION

Lactic acid was determined by the method of Barker and Summerson as outlined by Barnett (1951).

Reagents

1 20% copper sulphate solution.

2 4% copper sulphate solution.

3 Concentrated sulphuric acid (Analar)

4 Colour reagent. This was prepared by dissolving 0.5g of NaOH in 10 cm^3 hot water. Then 1.5g 4-hydroxybiphenyl was added and dissolved and made up to 100 cm^3 with hot distilled water.

5 Lactic acid standard (10 mM)

A molar solution of lactic acid was prepared by refluxing an approximate molar solution of lactic acid for 24 hours. The solution was then adjusted by precise further dilution following standardisation by titration using a standard solution of 0.1M NaOH with phenolphthalein as indicator. 5 cm^3 M lactic acid was then added to 5 cm M NaOH and made up to 500 cm^3 with distilled water.

Then four working lactic acid standards were prepared as follows:

a) 2 cm^3 distilled water (Blank)
b) 0.5 cm^3 lactic acid standard + 1.5 cm^3 distilled water (2.5 mM)
c) 1.0 cm^3 lactic acid standard + 1 cm^3 distilled water (5 mM)
d) 2.0 cm^3 lactic acid standard (10 mM)

Silage Extraction

A 20g sample of fresh minced silage was transferred into a bottle. 40 cm^3 of 0.3 M H_2SO_4 was added to cover the silage and the bottle was capped and stored in a refrigerator for one week at 4°C. The sample was then squeezed through linen and the filtrate was centrifuged and then stored in a deep freeze at -20°C.

Clarification

2 cm^3 of the silage sample filtrate and lactic acid standard solution were treated with 1 cm^3 of 20% copper sulphate solution, 1g of $Ca(OH)_2$ and 17 cm^3 of distilled water in 50 cm^3 test-tubes. the sample was mixed well and filtered through Whatman NO 1 Filter Paper. A 10 cm^3 aliquot of the filtrate was then made up to 100 cm^3 with distilled water.

Colorimetric Procedure

A one ml aliquot of each filtrate (either standard or sample extract) was added slowly with swirling to 9 cm^3 of ice cold H_2SO_4 in boiling tubes. The tubes were placed in a boiling water bath for 5 minutes, then taken out and left to cool for 5 minutes. The tubes were then placed in an ice bath, 0.05 cm^3 of 4% $CuSO_4$ and 0.1 cm^3 of 4-hydroxybiphenyl reagent was added. Samples were then left in an ice bath (deep freeze) for one hour, then plunged into a boiling water bath for 90 seconds. The tubes were left to cool for 5 minutes, transferred to an ice bath for 5 minutes and then left at room temperature for 15 minutes. Absorption at 560 mm was then measured using a spectrophotometer. The measurement for the blanks and standards were used to draw a graph of lactic acid concentration against absorbence from which the lactic acid content of the sample was calculated.

ASH CONTENT DETERMINATION

Approximately 20g of oven dried sample was transferred into pre-weighed dry crucibles, then heated in a muffle furnace for 24 hrs at 500°C. The crucibles were cooled in a dessicator for 1 hr then re-weighed and the ash content calculated.

DETERMINATION OF **IN VITRO** DIGESTIBILITY OF FEEDS

The in vitro digestibility of the feed was determined according to the method of Alexander and McGowan (1966, 1969).

For silage, 12.5 cm^3 (about 0.50g DM) of a homogenate prepared from the fresh minced silage was measured in triplicate into 100 cm^3 glass tubes. For other feeds, exactly 0.500g DM of the ground sample (1 mm mesh) was weighed directly into tubes.

One litre of rumen liquor from each of the three rumen-fistulated sheep was filtered through muslin and saturated with CO_2. The liquor was added to four times its volume of McDougall's buffer (McDougall, 1948) and 1 cm^3 of molar ammonium sulphate solution per 50 ml of rumen liquor buffer mixture was added. Inoculations were made by adding 50 cm^3 of this mixture (rumen liquor buffer mixture) to each tube. The tubes were then swept with CO_2, closed with stoppers, fitted with Bunsen valves and placed in a water bath at 38.5°C. The digests were adjusted electrometrically to pH 6.9 at 24 hrs and the rumen liquor stage was terminated at 48 hrs by injections of 1.5 cm^3 6M HCl followed by 2.5 cm^3 of 6M HCl into each tube. Aqueous pepsin solution was then added to each tube after electrometric adjustment of pH to 1.2. After a further 48 hrs digestion the residues were recovered in the presence of inert filter-aid (hyflo supercel) by filtration through a fibreglass paper. The residues were then dried at 100°C, weighed, ignited at 480°C and weighed again. A parallel determination of the total DM enabled the digestibility coefficient of the OM to be calculated, after allowing for the residual OM in the control tubes rising from the rumen liquor. Then OMD% =

$$\frac{\text{Original OM in sample} - (\text{OM of sample residue} - \text{OM of control residue})}{\text{Original OM in sample}} \times 100$$

The DOMD% <u>in vitro</u> was calculated as = OMD% x $\frac{\text{OM gkg}^{-1}}{1000}$

GROSS ENERGY DETERMINATION

Gross energy values of feed were determined by combustion in Oxygen in an adiabatic bomb calorimeter*.

Energy values of feed and faeces were carried out on the dried samples. The samples were first milled, and triplicate homogeneous samples were pelleted and weighed. At the same time, duplicate samples were taken for dry matter determination. Energy determination was carried out on the weighed pellets.

Silage gross energy determinations were carried out on fresh samples. The procedures involved fine mincing of the sample, then about 1g of silage was accurately weighed into a pre-weighed bag (weight about 0.420g and GE 46.4 kJ/g). The sample was carefully distributed within the polythene bag which was then rolled up and folded into the calorimeter crucible. The heat production from the polythene and silage was then measured using the adiabatic bomb calorimeter. After correction for the energy value of the polythene used, the GE of the silage was calculated.

* Parr Instrument Company, 211 Fifty-third Street, Moline, Illinois 61225, USA

BIOCHEMICAL OXYGEN DEMAND DETERMINATION

The biochemical oxygen demand (BOD_5) of effluent was determined by a modified version of the Standard Method (1971) [dilution method].

Reagents

1 5% sodium sulphate solution.

2 0.0625g $FeCl_3$ in 250 cm^3 distilled water.

3 6.875g $CaCl_2$ in 250 cm^3 distilled water.

4 5.625g $MgSO_4.7H_2O$ in 250 cm^3 distilled water.

5 Phosphatic solution, 2.125g KH_2PO_4, 5.44g K_2HPO_4, 8.74g $Na_2HPO_4.12H_2O$ and 0.43g NH_4Cl, diluted to 250 cm^3 with distilled water.

6 Dilution water:
For each sample, one litre of distilled water was transferred into a flask and aerated in a water bath at 20°C for 30 minutes, then allowed to settle for at least an hour before use. This procedure prevents water being super saturated at the start of the test.

To each litre of dilution water, 1 cm^3 of reagents 2, 3, 4 and 5 and 2 ml of seed were added. The seed consisted of activated sludge and garden soil plus pig and cattle slurry. The purpose of seeding is to introduce a biological population which will oxidise any organic matter present in the sample.

Method

1 20 cm^3 of effluent sample was transferred into a 100 cm^3 volumetric flask and made up to the mark with dilution water. A 500 cm^3 volumetric flask was filled to the mark with dilution water.

2 Both volumetric flasks were emptied into a large beaker and mixed well.

3 Two BOD bottles were filled with diluted sample and allowed to stand for 5 minutes.

4 All air bubbles were expelled by gently tapping the bottle with a stopper. The bottles were then tightly stoppered.

5 Two BOD bottles were filled with dilution water to serve as seeded blanks.

6 All BOD bottles were placed in a 20°C incubator and incubated in the dark at 20°C for 5 days.

Oxygen levels were then measured using an oxygen electrode* which was immersed into each sample and the two blanks. The calculation is as follows:

$$\text{BOD } (mgO_2/l) = \text{blank reading} - \text{sample reading} \times \frac{20}{600}$$

* EIL (8012-100 model), Hanworth Lane, Cherstsey, Surrey, UK

CHAPTER THREE

EVALUATION OF ABSORBENTS IN DRUM SILOS AND THE EFFECT OF PROLONGED SOAKING IN SILAGE EFFLUENT ON THE DIGESTIBILITY OF STRAW

CHAPTER THREE

EVALUATION OF ABSORBENTS IN DRUM SILOS AND THE EFFECT OF PROLONGED SOAKING IN SILAGE EFFLUENT ON THE DIGESTIBILITY OF STRAW

Introduction

Drum silo experiments were conducted in 1984 (experiment 1) and 1986 (experiments 2a and 2b).

The objectives of these experiments were as follows:

1 To compare the effluent-absorbing characteristics of a range of materials (experiments 1 and 2a).

2 To measure the affects of adding absorbents on silage composition (experiments 1 and 2a).

3 To measure the relationship between volume of effluent produced, the dry matter content of the grass and the level of molassed sugar beet shreds added at ensiling (experiment 2b).

Upgrading of poor quality feedstuffs such as straw by chemical treatment is a widespread agricultural practice. Treatment of straw with either alkalis such as sodium hydroxide or ammonia is the most common method for nutritional improvement of straw, but there is evidence that acids may also have beneficial effect. There is therefore the possibility that prolonged soaking of straw in acidic silage effluent may improve straw digestibility. Experiment 3 was designed to test the effects of silage effluent on straw degradability measured *in sacco* using sheep.

EXPERIMENT ONE

Experiment 1 was a preliminary experiment which aimed to develop the drum technique and to provide an initial comparison of a number of potential absorbents.

Experimental

Absorbents

Four absorbents were tested as follows:

1 Chopped barley straw
2 Whole barley
3 Rolled barley
4 Shredded newspaper

Grass

A second cut perennial ryegrass was cut during the second week of September 1984 with a disc mower fitted with a conditioner and was picked up immediately by a precision-chop forage harvester which chopped to a length of approximately 35 mm. An additive containing 85% formic acid was applied at a rate of 3.4 lt^{-1}.

Preparation of Experimental Silages

Grass was weighed and hand mixed with each absorbent at either 4% or 8% (fresh weight basis) and then ensiled in plastic drums (see Chapter 2 for details of the method). The amounts of grass and absorbent for each treatment are showing in Table 3.11.

RESULTS

Composition of Grass and Absorbents

Table 3.12 shows the composition of grass and absorbents. The grass has a DM content of 140 gkg^{-1} and a WSC of 102 gkg^{-1} DM. CP content of the grass was

206 gkg^{-1} DM.

The DM content of the absorbents ranged from 836 gkg^{-1} for rolled barley to 892 gkg^{-1} for shredded newspaper (see Table 3.12). CP content of barley was 129 and 132 gkg^{-1} DM for whole barley and rolled barley respectively.

Composition of Silages

The composition of silage is shown in Table 3.13. Oven DM content of control silage (treatment C) was 152 gkg^{-1}. The low level of absorbents produced silages with DM content of 168, 182, 182 and 182 gkg^{-1} for treatments LS, LWB, LRB and LP respectively, whereas corresponding values for high levels were 189, 193, 188 and 192 gkg^{-1} for HS, HWB, HRB and HP respectively. Addition of absorbent to grass at ensilage did not adversely affect silage preservation as indicated by ammonia-N contents and pH values. There were no clear trends in volatile N as a proportion of total-N. The overall mean of 85.2 gkg^{-1} total-N indicated that the silages were well preserved. The *in vitro* D-values of the silages were however, affected by addition of absorbent. Addition of barley increased the D-value by 7.4% units compared to the control, whereas addition of chopped straw or shredded paper reduced the D-values by 2.2% and 8.7% units respectively.

Lactic acid content of the control silage was 25.2 gkg^{-1} DM and for the other treatments it is ranged from 6.5 gkg^{-1} DM for LP and HP treatments (shredded paper) to 15.2 gkg^{-1} DM for the LS treatment (low straw).

Effluent Production

The total effluent volumes collected from each drum are shown in Table 3.14, together with the calculated volume of effluent produced per tonne of grass. Effluent produced from the control silage was 116 lt^{-1}. Treatments LWB, LRB and HRB showed no effect on effluent production. Effluent production by these three treatments were similar to that produced by the control silage (see Table 3.14). With the exception of the HWB, none of the barley treatments reduced effluent production. Straw however, proved the most effective absorbent followed by newspaper in terms of effluent reduction. At 8%, straw prevented effluent production completely and at the 4% level the effluent

TABLE 3.11

Amounts of grass and absorbents ensiled in each drum
(fresh weight basis)

Treatment	Grass Wt (kg)	Absorbent		Code
		Wt (kg)	%	
Control	100	0	0	C
Low Straw	95	3.8	4	LS
High Straw	79	6.3	8	HS
Low Whole Barley	100	4	4	LWB
High Whole Barley	100	8	8	HWB
Low Rolled Barley	100	4	4	LRB
High Rolled Barley	100	8	8	HRB
Low Paper	100	4	4	LP
High Paper	100	8	8	HP

TABLE 3.12

Composition of grass and absorbent

Composition	Grass	Chopped Straw	Whole Barley	Rolled Barley	Shredded Paper
DM (gkg^{-1})	140	846	864	836	892
OM (gkg^{-1} DM)	896	953	980	980	994
CP (gkg^{-1} DM)	206	61	129	132	2.0
WSC (gkg^{-1} DM)	102	20.9	47.6	44.1	7.2
In Vitro D-value (%)	63.7	45.2	83.8	83.8	16.0
ME ($MJkg^{-1}$ DM)	10.8	6.7	13.4	13.4	2.6
Ash (gkg^{-1} DM)	104	47	20	20	6

TABLE 3.13

Composition of Silages

Composition*	Treatment								
	C	LS	HS	LWB	HWB	LRB	HRB	LP	HP
Oven DM (gkg^{-1})	152	168	189	182	193	182	188	182	192
True DM (gkg^{-1})	166	180	204	192	220	200	214	191	204
OM (gkg^{-1} DM)	871	889	894	902	896	899	903	895	895
CP (gkg^{-1} DM)	209	188	178	191	193	195	202	164	150
WSC (gkg^{-1} DM)	15.2	14.7	13.6	19.0	17.0	17.8	13.2	16.9	17.8
<u>In Vitro</u> D-value (%)	61.4	61.0	57.4	68.0	67.7	69.9	69.6	58.4	47.1
ME ($MJkg^{-1}$ DM)	9.8	9.6	9.2	10.7	10.7	11.0	11.0	9.3	7.7
pH	4.3	4.1	4.2	4.2	4.3	4.3	4.1	4.3	4.3
Ammonia-N (gkg^{-1} total-N)	92	79	114	66	83	72	64	87	110
Lactic Acid (gkg^{-1} DM)	25.2	15.2	11.9	10.0	8.4	12.6	13.5	6.5	6.5

* Oven DM is used as the base for analytical parameters

produced was only 27.4 lt^{-1}. For newspaper treatment the amount of effluent produced was 76 and 20 lt^{-1} for LP and HP respectively.

Effluent Composition

Table 3.15 shows the composition of effluent produced from each treatment. Effluent DM content was increased in the case of the straw and newspaper treatments. The DM contents (gkg^{-1}) of effluent produced by LS, LP and HP silages were 61.3, 50.5 and 57.5 respectively. There was also a slight increase in the OM content of the effluent DM for these treatments. The figures for the OM concentration (gkg^{-1}) show that absorbents which reduced effluent volume, yielded considerably more concentrated effluent.

The CP content of effluent from the control silage was 212 gkg^{-1} DM. Treatments LS, LP and HP produced effluent with a CP content slightly higher than the control. However, barley treatments markedly increased CP content in the effluent. The effluent CP contents of LWB, HWB, LRB and HRB were 422, 493, 336.9 and 347 gkg^{-1} DM respectively.

The WSC of the control silage effluent was 48.9 gkg^{-1} DM. A similar WSC content was found in the effluent from barley treatments. Only LS and HP treatments gave effluent with WSC content higher than the control (see Table 3.15).

Lactic acid content of the control effluent was 38.7 gkg^{-1} DM. The lowest lactic acid content was 19.2 gkg^{-1} DM for LWB and the highest was 109 gkg^{-1} DM for the LS treatment.

The Ash content of the effluent ranged from (gkg^{-1} DM) 256 for HP treatment to 343 for LWB.

TABLE 3.14

Effluent produced from each silage treatment

Treatment	Effluent Volume	
	l	lt^{-1} of grass
Control	11.6	116
LS	2.6	27.4
HS	0	0
LWB	12.2	122
HWB	7.7	77
LRB	10.9	109
HRB	12.9	129
LP	7.6	76
HP	2.0	20

TABLE 3.15

Composition of effluent produced from each treatment

Composition	Treatment								
	C	LS	HS	LWB	HWB	LRB	HRB	LP	HP
DM (gkg^{-1})	39.2	61.3	-	37.9	40.2	38.6	46.5	50.5	57.5
pH	4.4	4.3	-	4.4	4.5	4.5	4.4	4.4	4.5
OM (gkg^{-1})	25.9	44.5	-	24.9	26.5	26.0	32.8	37.0	42.8
OM (gkg^{-1} DM)	660	726	-	657	659	674	705	733	744
CP (gkg^{-1} DM)	212	299	-	422	493	337	347	245	261
WSC (gkg^{-1} DM)	48.9	165	-	69.1	53.1	50.9	43.6	39	78.4
Lactic acid (gkg^{-1} DM)	38.7	109	-	19.2	47.9	49.1	68.2	54.3	66.8
Ash (gkg^{-1} DM)	340	274	-	343	341	326	295	267	256

DISCUSSION

COMPOSITION OF GRASS AND ABSORBENTS

The dry matter content of the grass used in this experiment was 140 gkg^{-1} DM. The WSC content of the grass was 14.3 gkg^{-1}. Haigh and Parker (1985) suggested that a minimum of 30 gkg^{-1} WSC is necessary to produce successful preservation for unwilted, non-additive treated silage and about 24 gkg^{-1} WSC for formic acid treated silage. Thus the grass used in the present experiment would be expected to give rise to preservation difficulties.

The *in vitro* D-values of the absorbents (see Table 3.12) shows that whole barley and rolled barley may be expected to have a beneficial effect on silage D-value, whereas chopped barley straw and shredded paper may be expected to reduce the D-value of the mixed silage.

Composition of Silages

The addition of chopped straw, barley and shredded newspaper increased the DM content of the silage. This would be expected when adding dry materials to grass at ensilage. The higher levels of absorbent tended to give the highest silage dry matter levels (see Table 3.13). The effect of adding absorbent on silage fermentation is of importance since silage fermentation is one of the most important factors which affect the nutritional value of the silage. None of these absorbents tested adversely affected silage preservation, as indicated by ammonia-N concentration or pH (see Table 3.13). Only the HS and HP treatments produced silages with ammonia-N concentration slightly higher than the control. All the silages were well preserved as indicated by these parameters but this would have been assisted by the use of the formic acid additive. Also the use of the small scale drum silos which allow rapid filling, rapid and effective exclusion of air and efficient sealing would tend to promote good silage preservation. A comparison using commercial scale silos could well give a different conclusion. However, this experiment suggests that adequate preservation can be achieved when large quantities of starchy grains (barley) or non-fermentable fibre (straw) are added to grass at ensilage.

Addition of barley, either whole or rolled, increased the in vitro D-value by 7.4 units and the calculated ME by 1.1 units, whereas addition of straw (HS) or paper (HP) reduced the in vitro D-value by 4 and 14.3 units respectively. The HS and HP treatments reduced the ME by 0.6 and 2.1 units respectively when compared to the control (see Table 3.13). However, the increase in D-value and ME when barley was ensiled with grass was expected, since barley has a high in vitro D-value (see Table 3.12), provided the assumption is made that most of the digestible nutrients of the barley are retained either intact or in equally digestible form in the silage. The reductions in the D-value and ME when straw or newspaper were mixed with grass at ensilage were also expected, mainly because these two absorbents show a low in vitro D-value (see Table 3.12) which is likely to dilute the D-value of the resultant mixed silage.

Effluent Production

Effluent production from this trial was assessed after four months of ensiling. The silages were taken out of the drums and the effluent which had accumulated below the false floors of the drums was collected and measured.

The amounts of effluent produced from grass ensiled at 150 gkg^{-1} DM were estimated to be 200-220 litres per tonne of grass FW (Bastiman, 1976; Patterson and Walker, 1980; Lowman et al, 1983). In this experiment however, the amount of effluent collected from the control silage was 11.6 cm^3 kg^{-1} grass FW or 116 lt^{-1} of grass FW. The DM content of the grass used in this trial was 140 gkg, so the volume of effluent collected was less than half of the volume per tonne that would be expected had the grass been ensiled in a commercial scale silo. However, this may be due to the small scale of the trial and the much lower pressure applied to the grass in the silo. In experiment 2, effluent volumes were measured following the application of a constant pressure to the silage so as to give effluent volumes that are similar to those given by farm scale silos. Nevertheless, this experiment gave a realistic comparison of the absorbents in terms of their ability to reduce effluent production. As is shown in Table 3.14, incorporation of 8% straw (HS) with grass at ensiling, prevented effluent production completely. Straw at 4% reduced effluent production by 76%. Shredded paper also reduced

effluent production but to a much smaller extent than chopped straw. LP and HP treatments reduced effluent production by 34 and 83% respectively. Addition of barley, either whole or rolled, had little or no effect on effluent production. Only the HWB treatment reduced effluent production (by 33%).

Effluent Composition

The composition of the dry matter in silage effluent will be influenced by the composition of the sap, by chemical changes resulting from fermentation and by changes in the effluent following its discharge.

The DM content of the effluent collected from the control silage was 39.2 gkg^{-1}. This agrees well with literature values (Watson and Nash, 1960; Woolford, 1978; Fisher et al, 1981; Patterson and Steen, 1981-82). Treatment LS produced only 2.6 l of effluent with a higher DM content of 61.3 gkg^{-1}. A similar pattern was shown by treatment HP (see Table 3.15). However, in both LS and HP treatments, the increase in DM content of the effluent is not likely to be due to nutrients being washed out from the absorbent with the effluent, as these absorbents contain very little soluble materials. The concentration of both DM and OM for treatments LS and HP may well reflect the low volumes of effluent produced. The absorbent reduces the volume of effluent passing through the mass of silage but substantial quantities of soluble materials are still carried with it. This result may be of practical importance since it suggests that, unless effluent loss from silos can be prevented completely, the benefit for pollution and nutrient loss from the use of absorbents may be much less than indicated by the reduction in effluent volume. Barley, either whole or rolled, showed very little effect on the DM content of the effluent. The concentration of both DM and OM for barley treatments is generally similar to that for the control effluent (see Table 3.15).

The CP content of the effluent collected from control silage was 212 gkg^{-1} DM which agrees with the findings of Lowman et al (1983). Treatments LWB and HWB (whole barley) gave the highest increase in CP content in their effluent, followed by rolled barley. The CP contents of LS, LP and HP treatments were slightly higher than the control.

CONCLUSIONS

1 All of the absorbents tested gave silages with satisfactory fermentation characteristics.

2 Addition of barley to grass at ensilage, increased the *in vitro* D-value of the resulting silage by 7.5 units, but had little or no effect on effluent production.

3 Shredded newspaper was effective in reducing effluent production. At 4 and 8% of grass FW, shredded paper reduced effluent production by 34 and 83% respectively, but resulted in a marked reduction in the *in vitro* D-value of the silage. At 8% of grass FW, shredded paper reduced silage D-value by 14.3 percentage units.

4 Chopped barley straw was the most effective controller of silage effluent. At 8% of grass FW, chopped straw prevented effluent production completely and at 4%, it reduced effluent production by 76%. At 8%, chopped straw reduced the *in vitro* D-value of the silage by 4 percentage units, whilst at an inclusion level of 4% the silage D-value was reduced by only 0.4 of a percentage unit.

EXPERIMENT TWO

Experiment 2 was carried out from grass cut during August 1986. A total of 43 drum silos were prepared with the following aims:

Experiment 2a

To compare nine potential absorbent materials in terms of their ability to reduce effluent production and to measure their effect on silage composition.

Experiment 2b

An experiment using mini pit silos carried out in August 1985 (see Section one of Chapter 4) showed that the addition of molassed beet shreds (SBP) to grass at ensiling resulted in a considerable reduction in silage effluent.

A conclusion of this trial was that absorbents such as molassed beet shreds (SBP) should be used in sufficient quantities to prevent effluent loss completely. Experiment 2b was designed to investigate the relationship between effluent volume, grass dry matter and molassed beet shreds (SBP) concentration so as to be able to predict for a particular grass dry matter, the level of SBP needed to prevent effluent loss.

EXPERIMENTAL

Grass

Silages for experiments 2a and 2b were made from the same grass. The grass was a second cut perennial ryegrass, harvested on the 4th August 1986 with a disc mower fitted with conditioner and picked up immediately with a precision-chop forage harvester without wilting.

Experiment 2a

In this trial nine absorbents were tested.

1 Dried distillery dark grains (Invergordon).

2 Molassed sugar beet nuts.

3 Dried distillery grain (Grants Vitaferm).

4 Dried distillery grain (North East Farmers).

5 Rolled Barley.

6 Molassed sugar beet shreds (SBP).

7 Viton straw cubes.

8 Chopped barley straw.

9 Grain distillery pressed draff (Grants).

Preparation of Experimental Silages

A total of 22 silages were made in one day (Day 1) to test the nine absorbents. For each absorbent, two drum silos were used; one with no silage additive and one with 4.5 $cm^3.kg^{-1}$ grass FW 85% formic acid. In addition, 4 control silos were made, two without additives and two with 4.5 $cm^3.kg^{-1}$ grass FW 85% formic acid. Grass for each drum was weighed, well mixed by hand, sampled, mixed with 6% (FW basis) of an absorbent (see Table 3.21) and tightly packed into each drum. In the case of the pressed wheat draff, an addition rate of 16.8% (FW basis) was used to allow for the lower DM content (317 gkg^{-1}) of this material. This level was calculated to give a similar inclusion rate on a DM basis as the other absorbents. The technique of silage preparation followed the description in Chapter 2, page 47).

Experiment 2b

In this experiment no additive was used. Silages were prepared using the same method described for experiment 2a.

A range of molassed beet shreds (SBP) levels from 0-10% of grass FW was used. Silages were made over a period of four days during which the grass dried from approximately 168 gkg^{-1} to 195 gkg^{-1} DM.

On day 1, five silages were made in the drums (D23 to D27) with different levels of SBP (see Table 3.22). After the drums were filled, the remaining grass was spread evenly over a concrete floor in a large shed. Ventilation was provided by operating large extraction fans set in the wall of the

TABLE 3.21

Weights of grass (kg FW) and proportion of each absorbent (% FW) ensiled in each drum.

Drum	Treatment	Add-F - or +	Grass FW (kg)	Absorbent (% FW)
D1	Control	-	71	0
D2	Control	+	72	0
D3	DDG* (Invergordon)	-	68	6
D4	DDG (Invergordon)	+	78	6
D5	Molassed beet nuts	+	68	6
D6	Molassed beet nuts	-	67	6
D7	DDG (Grants Vitaferm)	-	67	6
D8	DDG (Grants Vitaferm)	+	72	6
D9	DDG (N E Farmers)	-	65	6
D10	DDG (N E Farmers)	+	66	6
D11	Rolled Barley	-	61	6
D12	Rolled Barley	+	66	6
D13	Molassed beet shreds	-	63	6
D14	Molassed beet shreds	+	61	6
D15	Viton straw cubes	-	64	6
D16	Viton straw cubes	+	69	6
D17	Chopped barley straw	-	45	6
D18	Chopped barley straw	+	58	6
D19	Pressed wheat draff	-	60	16.8
D20	Pressed wheat draff	+	60	16.8
D21	Control	-	66	0
D22	Control	+	71	0

\- without additive
\+ with additive
* dried distillery grain

TABLE 3.22

Weights of grass (kg FW) and proportion of molassed beet shreds (% FW) ensiled in each drum

Drum	Grass FW (kg)	Beet Shreds Level (% FW)	Day
D23	61	0	1
D24	65	2	1
D25	58	4	1
D26	63	6	1
D27	60	8	1
D28	66	0	2
D29	63	2	2
D30	61	4	2
D31	65	6	2
D32	61	8	2
D33	64	0	3
D34	63	2	3
D35	66	4	3
D36	60	6	3
D37	60	8	3
D38	80	0	4 Wetted Grass
D39	80	2	4 Wetted Grass
D40	80	4	4 Wetted Grass
D41	80	6	4 Wetted Grass
D42	80	8	4 Wetted Grass
D43	80	10	4 Wetted Grass

building. The grass was turned manually three times a day. This method allowed slow drying of the grass in a controlled manner. On the second day another five silages were made (D28 to D32) with the same levels of SBP and the procedure was repeated on the third day after cutting (D33 to D37). On the fourth day, by which time grass DM figures were available for the previous days, the moisture content of the grass was increased by adding water. The grass was spread out evenly on a concrete floor and sufficient water was applied by a watering can fitted with a fine hose to bring the grass DM down to approximately 140 gkg^{-1}. The grass was then left for about four hours to allow it to absorb water. It was then well mixed and 6 silages were then made using SBP levels from 0-10% of grass FW (D38 to D43) as shown in Table 3.22.

RESULTS

Experiment 2a

Composition of grass and absorbents

The DM contents of the grass ensiled in individual drums (D1 to D22) was determined in the samples taken as each was filled and is shown in Table 3.23. Grass DM on day 1 ranged from 156 to 179 gkg^{-1}, with a mean value of 168 gkg^{-1}.

Table 3.24 shows the composition of the grass and the absorbents. The grass had a WSC content of 20.6 gkg^{-1} which should just be sufficient to allow adequate fermentation for preservation, although the use of a silage additive would generally be recommended for farm scale silos (Wilkins, 1974; Parker and Crawshaw, 1982; Haigh and Parker, 1985). The differences in composition between absorbents were considerable. For example, molassed beet nuts and molassed beet shred samples show a high content of WSC, whereas the DDG samples and the pressed wheat draff show a high CP content (see Table 3.24).

TABLE 3.23

Dry Matter Content of grass ensiled in individual drums

(Experiment 2a)

Drum Code	Grass DM (gkg^{-1})
D1	161
D2	169
D3	160
D4	172
D5	166
D6	164
D7	179
D8	156
D9	168
D10	164
D11	170
D12	171
D13	174
D14	170
D15	161
D16	174
D17	170
D18	163
D19	170
D20	164
D21	175
D22	166

TABLE 3.24

Composition of Grass and Absorbents

Material	DM (gkg^{-1})	OM (gkg^{-1} DM)	CP (gkg^{-1} DM)	WSC (gkg^{-1} DM)	In Vitro D-Value (%)	ME ($MJkg^{-1}$ DM)	Ash (gkg^{-1} DM)
Grass	168	894	164	123	62.0	10.5	106
DDG (Invergordon)	899	948	341	88	63.4	10.1	52
Molassed Beet Nuts	884	897	107	309	81.6	13.0	103
DDG (Vitaferm)	943	960	390	7	56.2	9.0	40
DDG (N E Farmers)	890	930	257	23	47.7	7.6	70
Rolled Barley	826	971	93	46	80.3	12.5	29
Molassed Beet Shreds	873	902	105	299	79.4	12.7	98
Viton Straw Cubes	871	864	36	28	49.4	7.9	136
Chopped Barley Straw	852	953	43	17	41	6.2	47
Pressed Wheat Draff	317	961	362	6	55.3	8.8	39

Composition of Silages

The drum silos were opened three months after ensiling. The silage for each treatment was mixed and sampled for chemical analysis. The compositions of all silages are shown in Table 3.25. Average DM content of the control silages was 164 gkg^{-1} compared to 199 gkg^{-1} for the rest of the treatments. Thus, addition of absorbents on average, increased silage DM by approximately 35 gkg^{-1}.

The mean CP content of the control silages was 164 gkg^{-1} DM. DDG treatments (D3, D4, D7, D8, D9, D10) produced silage with a CP content of 34 units higher than the control silages. The mean CP content of DDG treatments was 198 gkg^{-1} DM. Pressed wheat draff (D19, D20) also increased the CP content of the silage (by 57 units). However, chopped straw (D17, D18) reduced the CP content in the silages by 30 units giving a mean CP content of 134 gkg^{-1} DM.

The mean WSC content of the control silages (D1, D21) made without additives was 10.6 gkg^{-1} DM compared to 23.1 gkg^{-1} DM for control silages made with formic acid additive (D2, D22). It is clear that silages made without formic acid showed a lower WSC concentration when compared to those which received formic acid. The effect of formic acid on lactic acid content of the silages was opposite to the effect on WSC content. Silages made without formic acid showed a higher lactic acid content (mean value for D1 and D21 was 60 gkg^{-1} DM) when compared to formic acid treated silage (mean value for D2 and D22 was 12.3 gkg^{-1} DM).

Thus silages made with formic acid showed higher values for WSC and lower values for lactic acid when compared to silages made without formic acid. Acetic acid content of silages followed the same pattern as for lactic acid. Silages made without formic acid showed a higher acetic acid content (mean value for D1 and D21 was 14 gkg^{-1} DM) when compared to formic acid treated silages (mean value for D2 and D22 was 2 gkg^{-1} DM). The values for WSC, lactic and acetic acid indicated that fermentation was partially restricted by addition of formic acid.

Butyric acid content of the silages was low, the highest value obtained was 2.2 gkg^{-1} DM for D8 (DDG Vitaferm) and the lowest value was 0.24 for D22. Ethanol contents however, were low for silage made without formic acid (mean

TABLE 3.25

Composition of Silages

Composition	Treatment																					
	D1 -	D2 +	D3 -	D4 +	D5 +	D6 -	D7 -	D8 +	D9 -	D10 +	D11 -	D12 +	D13 -	D14 +	D15 -	D16 +	D17 -	D18 +	D19 -	D20 +	D21 -	D22 +
Oven DM (gkg^{-1})	157	163	183	208	189	195	206	204	212	197	195	210	210	196	197	192	206	210	196	178	171	166
OM (gkg^{-1} DM)	903	886	899	911	891	903	898	905	904	904	909	913	893	897	897	887	909	898	898	897	886	886
CP (gkg^{-1} DM)	161	165	181	193	168	158	216	215	192	189	159	148	148	152	153	147	132	136	219	223	170	160
WSC (gkg^{-1} DM)	10.0	19.3	16.9	46.3	23.7	15.0	13.8	41.7	14.7	23.0	12.8	41.6	18.4	43.6	10.7	21.2	7.7	23.9	9.5	15.6	10.4	26.
In Vitro D-Value (%)	67.9	64.8	66.8	67.1	68.1	71.2	65.7	69.9	66.7	65.9	69.9	70.6	70.7	68.4	65.6	64.7	60.9	59.9	63.3	63.6	66.1	64.
ME ($MJkg^{-1}$ DM)	10.7	10.3	10.6	10.6	10.7	11.2	10.4	10.4	10.6	10.4	11.0	11.1	11.1	10.8	10.4	10.2	9.7	9.6	10.1	10.1	10.5	10.
pH	3.9	4.2	4.0	4.1	4.3	4.0	3.9	4.2	4.0	4.2	4.0	4.3	4.0	4.3	4.1	4.3	4.0	4.4	3.9	4.3	4.0	4.
Ammonia-N (gkg^{-1} Total-N)	112	78	89	84	81	96	117	69	91	88	116	95	91	101	110	99	102	94	92	87	99	8
Lactic Acid (gkg^{-1} DM)	53.9	9.9	63.3	10.0	11.9	45.8	51.1	9.0	48.7	12.5	45.3	7.2	51.9	11.2	62.2	28.1	48.8	14.6	52.9	17.2	66.1	14.
Acetic Acid (gkg^{-1} DM)	15.1	2.0	13.9	1.9	1.6	13.6	12.5	3.3	13.6	3.5	12.5	3.1	19.8	3.7	16.0	7.8	13.2	3.9	11.4	3.4	12.9	2.
Propionic Acid (gkg^{-1} DM)	0	0	0	0.42	0	0	0.81	0.78	0.72	0.94	0.45	0.79	2.5	0.36	0.56	0.61	1.41	2.18	0.57	0.93	0.63	0.
Butyric Acid (gkg^{-1} DM)	1.3	0.34	0.68	0.93	0.39	0.29	0.54	2.24	1.08	0.67	0.54	0.87	0.8	0.99	0.93	0.52	1.15	1.31	0.57	0.31	0.52	0.
Isobutyric Acid (gkg^{-1} DM)	0.35	0	0	0	0	0	0.45	0.6	0	0	0.27	0.16	0	0	0.37	0	0	0	0.45	0	0	0
Ethanol (gkg^{-1} DM)	3.6	63.2	5.5	22.5	59.7	16.8	2.5	12.1	3.9	16.5	4.6	12.7	4.2	21.3	3.5	11.2	2.7	27.4	5.3	42.3	3.0	4

\- without Add F

\+ with Add F

value for D1 and D21 was 3.3 gkg^{-1} DM) but higher for formic acid treated silages (mean value for D2 and D22 was 53.6 gkg^{-1} DM). All silages in this experiment had satisfactory fermentation as assessed by pH, ammonia-N and the level of butyric acid. For the silages made without formic acid, the highest pH value obtained was 4.1 for D15 (viton straw cubes) and the pH values ranged from 3.9 to 4.1. For formic acid treated silages the pH values ranged from 4.1 to 4.4 (see Table 3.25). Ammonia-N contents for all silages were generally low but were slightly lower for formic-treated silages. Levels ranged from 89 to 117 gkg^{-1} total-N for silages made without formic acid and values for untreated controls were 112 and 99 gkg^{-1} total-N (D1 and D21 respectively). For formic acid-treated silages, ammonia-N contents ranged from 69 to 101 gkg^{-1} total-N and values for the control silages made with formic acid were 78 and 83 gkg^{-1} total-N for D2 and D22 respectively.

The affect of adding absorbents on the <u>in vitro</u> D-value of the silages is shown in Table 3.25. The mean <u>in vitro</u> D-value of the control silages (D1, D2, D21, D24) was 65.9%. Addition of chopped straw (D17 and D18) or pressed wheat draff (D19 and D20) decreased the D-value of the silage to 60.2 and 63.5% respectively, whereas addition of molassed beet nuts (D5 and D6), rolled barley (D11 and D12) and molassed beet shreds (D13 and D14) increased the D-value of the silages to 69.7, 70.3 and 69.6 respectively. However, DDG treatments (D3, D4, D7, D8, D9 and D10) produced silages with a mean D-value (67.0%) only slightly higher than the control.

<u>Effluent Production</u>

On opening the drums, no effluent was found to have collected beneath the false bottom of the drums. However, in order to simulate the pressure loadings experienced in a farm scale silo, the silages were subjected to controlled quantified pressure in a modified wine press. Four replicate samples, each of 900g from each silage were subjected to a standard pressure of 33 kg/dm^2 (see page 101 for details). Effluent (silage juice) was collected and the mean volume collected for each treatment is shown in Table 3.26. The mean effluent volume measured for the controls (D1, D2, D21, D22) was 81.9 cm^3kg^{-1} of grass FW. D19, D20 (pressed wheat draff), D11, D12 (rolled barley) and D3, D4 (DDG Invergordon) gave only slight reductions in effluent volume. The mean effluent produced for these treatments were 74.1, 67.1 and 65.9

TABLE 3.26

Mean effluent volume (cm^3 per kg grass FW) measured by wine press technique at a load of 33 kg/dm^2

Treatment	Effluent ($cm^3 kg^{-1}$ grass FW)
D1	73.9
D2	94.3
D3	68.8
D4	63.0
D5	54.2
D6	46.3
D7	18.4
D8	43.0
D9	43.0
D10	40.6
D11	62.0
D12	72.1
D13	29.0
D14	31.0
D15	42.9
D16	39.0
D17	0
D18	0
D19	70.4
D20	77.7
D21	70.6
D22	88.7

cm^3kg^{-1} grass FW for pressed wheat draff, rolled barley and DDG Invergordon respectively. However, chopped straw (D17, D18) prevented effluent production completely and molassed beet shreds (D13, D14 mean effluent volume 30 cm^3kg^{-1}) and DDG Vitaferm (D7, D8 mean volume 30.7 cm^3kg^{-1}) were the next most efficient absorbents.

Experiment 2b

Composition of Grass

During the two days of wilting, representative samples were taken daily for chemical analysis. A further sample was taken 4 hours after the addition of water to the grass on day 4 of the experiment. The composition of the grass ensiled each day and the composition of molassed beet shreds are shown in Table 3.27. The mean grass DM ensiled on day 1 (D23 to D27) was 173 gkg^{-1} (range 168-180) and on day 2 (D28 to D32) was 174 gkg^{-1} (range 168-178). On day 3 (D33-D37) the mean grass DM had increased to 189 gkg^{-1} (range 184-194). On day 4 (D38 to D43) however, after the grass was wetted, the mean DM was 154 gkg^{-1} (range 146-158). The concentration of WSC in the grass decreased during the wilting period. On day 1 (no wilting) WSC content was 123 gkg^{-1} DM (D23 to D27). This value decreased to 102 and 101 gkg^{-1} DM for day two (D28 to D32) and day three (D33 to D37) respectively. On day 4 (D38 to D43) the mean WSC was 88 gkg^{-1} DM. The *in vitro* D-value of grass had also decreased during wilting from 62% on day one to 59.5, 58.3 and 56.4% for days 2, 3 and 4 respectively.

Composition of Silages

Silage composition is shown in Table 3.29. Addition of molassed beet shreds (SBP) increased the DM content of the silages. The DM content of the control silage made on day 1 (D23) was 165 gkg^{-1} and for the SBP silages made on day 1 were 117, 195, 199 and 217 gkg^{-1} for D24, D25, D26 and D27 respectively. The same patterns were followed by silages made on day 2 and day 3 (D28 to D37). For the silages made on day 4 (wetted grass), the DM content of the control silage (D38) was 152 gkg^{-1} and for the SBP silages were 167, 169, 175, 200 and 201 for D39, D40, D41, D42 and D43 respectively.

TABLE 3.27

Composition of grass and molassed beet shreds ensiled over a three day wilting period

	DM* (gkg^{-1})	OM (gkg^{-1} DM)	CP (gkg^{-1} DM)	WSC (gkg^{-1} DM)	In vitro D-Value (%)	ME ($MJkg^{-1}$ DM)	Ash (gkg^{-1} DM)
Grass - drums D23-D27	173	894	164	123	62	10.5	106
Grass - drums D28-D32	174	893	153	102	59.5	10.0	107
Grass - drums D33-D37	189	899	149	101	58.3	9.8	101
Grass - drums D38-D43	154	888	143	88	56.4	9.4	112
Molassed Beet Shreds	873	902	105	298	79.4	12.7	98

* Grass DM values are means for the indicated drums.

TABLE 3.28

Dry matter content of grass ensiled in individual drums

Treatment	Grass DM (gkg^{-1})	Day
D23	177	
D24	168	
D25	170	1 No Wilting
D26	173	
D27	180	
D28	178	
D29	176	
D30	170	2 1 day Wilt
D31	168	
D32	178	
D33	189	
D34	194	
D35	184	3 2 day Wilt
D36	187	
D37	191	
D38	157	
D39	153	
D40	156	4 Wetted
D41	146	
D42	156	
D43	158	

TABLE 3.29

Composition of Silages ensiled with different levels of molassed beet shreds

SBP% / Composition	Day 1					Day 2					Day 3					Day 4					
	0	2	4	6	8	0	2	4	6	8	0	2	4	6	8	0	2	4	6	8	10
	D23	D24	D25	D26	D27	D28	D29	D30	D31	D32	D33	D34	D35	D36	D37	D38	D39	D40	D41	D42	D43
DM (gkg^{-1})	165	177	195	199	217	168	175	188	197	216	175	184	193	205	227	152	167	169	175	200	201
OM (gkg^{-1} DM)	898	891	907	903	903	883	898	883	886	901	888	884	887	879	891	883	879	877	892	882	894
CP (gkg^{-1} DM)	165	159	152	156	151	165	169	166	161	153	162	166	157	161	156	160	154	157	151	144	151
WSC (gkg^{-1} DM)	9.27	9.5	13.1	13.3	14.7	8.8	9.2	10.7	12.0	13.7	8.8	11.4	10.9	10.6	12.4	5.1	7.6	7.4	11.6	13.5	11.5
In Vitro D-Value (%)	64.9	65.3	69	69.6	69.6	63.3	64.9	65.9	66.7	67.4	62.2	63.4	64.3	65.1	66.6	59.4	61.8	61.4	64.9	65.5	67.7
ME ($MJkg^{-1}$ DM)	10.3	10.3	10.9	11.0	11.0	10.0	10.3	10.4	10.5	10.7	9.9	10.1	10.2	10.3	10.5	9.5	9.8	9.8	10.3	10.4	10.7
pH	3.9	3.9	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.1	4.0	4.0	4.0	4.0	4.1	4.0	4.0	3.9	4.1	4.0
Ammonia-N (gkg^{-1} Total-N)	88	87	86	90	107	108	101	99	116	64	99	120	101	137	92	150	106	119	98	133	101
Lactic Acid (gkg^{-1} DM)	57.9	64.8	59.2	62.5	48.7	65.5	69.2	66.6	63.4	66.9	64.5	65.2	65.3	69.6	66.7	83.0	72.3	84.1	72.3	75.5	62.6
Acetic Acid (gkg^{-1} DM)	13.1	17	12.4	13.8	13.9	14.1	12.0	15.1	15.0	13.3	17.9	14.6	14.5	14.3	14.2	18.1	18.0	18.4	17.8	19.5	15.5
Propionic Acid (gkg^{-1} DM)	0.87	0.89	0.1	0.8	0.63	0.92	0.88	2.2	1.1	1.1	1.3	1.1	1.2	0.98	0.5	2.0	1.1	1.4	0.8	0.8	0.6
Butyric Acid (gkg^{-1} DM)	0.65	0.8	0	1.4	0.6	1.5	1.6	1.6	0.75	1.4	2.5	1.7	1.6	1.4	1.2	1.3	1.5	1.7	0.6	1.4	1.2
Isobutyric Acid (gkg^{-1} DM)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0.7	0	0.5	0.5
Ethanol (gkg^{-1} DM)	3.5	4.3	3.2	2.3	2.4	3.5	3.7	3.8	2.1	2.2	3.4	1.7	2.2	1.5	2.5	3.0	1.9	3.1	2.4	3.0	3.1

The mean CP content of the control silages (D23, D28, D33, D38) was 162 gkg^{-1} DM. Addition of SBP slightly reduced the CP content of the silages (overall CP content gkg^{-1} DM for 2, 4, 6 and 8% SBP were 162, 158, 157 and 151 respectively).

Addition of SBP had little effect on the levels of WSC and lactic acid in the silages. Silage made with SBP showed a slight increase in residual WSC and in lactic acid content when compared to the controls (see Table 3.29).

The in vitro D-value of the silages showed an increase due to the addition of SBP. Silage D23 (control) had a D-value of 64.9%, whereas D24, D25, D26 and D27 (2, 4, 6 and 8% SBP) had D-values of 65.3, 69, 69.6 and 69.6% respectively. Silages made on days 2, 3 and 4 showed a similar pattern for D-value when compared to the control (see Table 3.29). Generally, addition of SBP at levels of 6 and 8% increased the in vitro D-value by 4.1 and 4.8 units respectively.

In general, the fermentation characteristics of all silages were good as assessed by pH value and levels of ammonia-N and butyric acid. The pH values ranged from 3.9 to 4.1 and the ammonia-N contents for D23 to D37 ranged from 64 to 120 gkg^{-1} total-N. The highest butyric acid content obtained was 2.5 gkg^{-1} DM. Generally, silages made on days 1, 2 and 3 were similar in their fermentation characteristics to their control. However, silage made on day 4 (D38 to D43 wetted grass) showed a beneficial effect due to the addition of SBP in reducing the ammonia-N content of the silages when compared to the control. The ammonia-N content of the control (D38) was 150 gkg^{-1} total-N and for D39, D40, D41 and D43 (2, 4, 6 and 10% SBP respectively) were 106, 119, 98 and 101 gkg^{-1} total-N respectively.

Effluent Production

Effluent production from each treatment was assessed three months after ensilage. Except for drums D38 and D39, no effluent was found to have collected beneath the false bottoms of the drums. D38 (wetted grass - zero SBP) produced 37.5 cm^3 effluent per kg grass FW whilst D39 (wetted grass with 2% SBP) produced only 8.4 $cm^3 kg^{-1}$ grass FW.

An estimation of the potential effluent production from the silage under farm silo conditions was made by using the wine press technique. Four replicate samples, each of 900g from each silage were subjected to a pressure of 33 kg/dm^2. Effluent (silage juice) was collected and measured and the volume collected from each drum is shown in Table 3.211. In the case of drums D38 and D39, the volume shown includes the effluent found to have collected beneath the silages. The data shows that for silages made during the first day of cutting (D23 to D27), addition of 6% SBP reduced effluent production by 78%, whereas addition of 8% SBP prevented effluent production completely. For the silages made after two days of wilting (D28 to D32), addition of 6% SBP prevented effluent production completely, but for silages made after 3 days of wilting only 4% SBP was needed to achieve this result. However, for the wetted grass silages (D38 to D43), it was found that 8% SBP was needed to prevent effluent production.

TABLE 3.211

Mean effluent volume (cm^3 per kg grass FW) measured by the wine press technique at a load of 33 kg/dm^2

Treatment	Effluent ($cm^3 kg^{-1}$ grass FW)
D23	77.1
D24	55.4
D25	34.1
D26	16.5
D27	0
D28	34.1
D29	19.0
D30	3.9
D31	0
D32	0
D33	18.7
D34	4.5
D35	0
D36	0
D37	0
D38	159
D39	94.1
D40	65.6
D41	40.2
D42	0
D43	0

DISCUSSION

Experiment 2a

In assessing the results of this experiment, it is essential to stress that the grass was cut in one day from one field. The DM concentration of the grass was planned to be approximately 140 gkg^{-1}, but this was not achieved, as the mean grass DM on day 1 was found to be 168 gkg^{-1} DM. When the DM content of the grass ensiled in each drum was determined, it showed that the DM ranged from 156 to 179 gkg^{-1} (see Table 3.23). This was in spite of attempts to equalise the grass put into each drum by multiple grab sampling from different parts of the bulk of grass spread out on a concrete floor. Nevertheless, great care was taken to mix the grass for each drum obtained in this way and to obtain a sample fairly representing the grass ensiled. The variation in grass DM between drums was sufficient to make it necessary to use a calculation technique for comparing absorbents which allowed for the differences.

The absorbents tested showed a considerable variation in their composition (see Table 3.24). DDG (Invergordon), DDG (Vitaferm), DDG (N E Farmers) and pressed wheat draff were high in CP content. Only molassed beet nuts and molassed beet shreds showed higher WSC contents which may improve silage fermentation. The *in vitro* D-value of the absorbents showed that molassed beet nuts, molassed beet shreds and rolled barley had a higher D-value, whereas DDG (Vitaferm), DDG (N E Farmers), chopped straw, viton straw cubes and pressed wheat draff showed a lower D-value when compared to the *in vitro* D-value of the grass. Thus, the former group of absorbents may be expected to maintain or increase silage D-value whilst a reduction may be expected for the latter group.

Composition of Silages

All silages in this experiment (2a) had satisfactory fermentation as assessed by pH value, the proportion of N in the form of ammonia and the level of butyric acid. McDonald and Whittenbury (1973) reported that, for unwilted silages achievement of a pH value of 4.2 or less will ensure that the material will normally remain stable. In this experiment, for the untreated silages

the highest pH value obtained was 4.1 for D15 (viton straw cubes) and the pH values ranged from 3.9 to 4.1, whereas for formic acid treated silages the pH values ranged from 4.1 to 4.4 (see Table 3.25). Ammonia-N concentrations for all treatments were generally low. Haigh and Hopkins (1977) reported that an ammonia-N value of less than 100 to 80 gkg^{-1} total-N is commonly used to indicate that silage is well fermented. In this experiment however, ammonia-N concentration for the untreated silages ranged from 89 to 117 gkg^{-1} total-N and for the untreated controls were 112 and 99 gkg^{-1} total-N for D1 and D21 respectively. This suggests that some of the absorbents such as Vitaferm (D7) and rolled barley (D11) show a slight effect in increasing ammonia-N concentration compared to the controls (see Table 3.25). The addition of formic acid to the grass at ensiling caused a small, but consistent reduction in ammonia-N concentration (means with and without formic acid were 87.2 gkg^{-1} total-N and 101 gkg^{-1} total-N respectively). Nevertheless, the effect of absorbents on silage preservation should be tested in farm scale silos in which efficient sealing and exclusion of air is more difficult to achieve than in the drum silo.

Comparing lactic and acetic acid contents of silages made either with or without formic acid treatment showed a higher acid concentration for the untreated silages. Mean values for lactic and acetic acids were 53.6 and 14.0 gkg^{-1} DM without the addition of formic acid and 13.3 and 3.3 gkg^{-1} DM with formic acid. The effect of formic acid addition on WSC levels in the silages was opposite to that for lactic and acetic acids. Addition of formic acid led to higher levels of residual WSC (means with and without formic acid 29.7 and 12.8 gkg^{-1} DM). These results indicated that an extensive fermentation of soluble sugar had taken place in the silages made without formic acid which resulted in higher lactic and acetic acid levels and a lower WSC content. Whereas, in the formic acid treated silages the fermentation was partially inhibited which resulted in a lower acid concentration but higher residual WSC concentrations in the silages (see Table 3.25). This conclusion is in agreement with McDonald (1981), Parker and Bastiman (1982) and Haigh and Parker (1985).

In this experiment the effect of adding absorbents to grass at ensiling on silage fermentation was minimal and no clear trends are apparent. The favourable conditions made possible by the small scale of the silos (ie rapid

filling and efficient sealing) produced well preserved silages which would tend to minimise any effects on fermentation due to absorbents. Nevertheless, it is interesting to note that inclusion of materials such as chopped barley straw or alkali treated straw cubes (viton) which contribute little or no fermentable substrates did not materially affect silage fermentation or preservation quality. Also the lack of any effect on ammonia-N content (gkg^{-1} total-N) due to the addition of the high protein distillery by-products was surprising. Silage CP values were increased by 24% by the incorporation of these materials, yet even in the absence of formic acid fermentation was sufficiently rapid and extensive to avoid the protein breakdown which would result from secondary clostridial fermentation.

The in vitro D-values of the silages were determined by the method of Alexander and McGowan (1966, 1969). Compared to values for the controls (mean D-value 65.9%), higher D-values were obtained for molassed beet nut silages (D5 and D6 mean D-value 69.7%), rolled barley silages (D11 and D12 mean D-value 70.3%) and molassed beet shred silages (D13 and D14 mean D-value 69.6%) and lower D-value for chopped straw silages (D17 and D18 mean D-value 60.4%) and pressed wheat draff silages (D19 and D20 mean D-value 63.5%). The calculated ME values show the same pattern as for D-value. The increases, compared to the control silages, in D-value and ME of the molassed beet nut silages, rolled barley silages and molassed beet shred silages reflect the higher D-value of the absorbents compared to the grass (see Table 3.24). Furthermore, the increase in D-value is as would be calculated from the mixing of the ingredients in the ratio used which suggests that the highly digestible components of the absorbents are retained in the silo. Similarly, the decrease of ME and D-value due to the addition of chopped straw and viton straw cubes is again consistent with the individual D-value of the grass and absorbents and the ratio in which they were mixed. Thus in general, a simple additive relationship appeared to exist between the D-value of silages measured in vitro and the D-values of the grass and absorbents measured separately.

Effect of Adding Absorbents on Effluent Production

It is well known that ensiling grass with a dry matter content less than 250 gkg^{-1} in a commercial silo will produce a considerable amount of effluent.

Stewart and McCullough (1974) reported that effluent production from herbage ensiled with a dry matter content of 150 to 200 gkg^{-1} produces 225 to 135 litres of effluent per tonne of grass. The amount of effluent estimated by Bastiman (1976), Patterson and Walker (1980) and Lowman et al (1983) for crops ensiled with a DM content less than 200 gkg^{-1} is in general agreement with those reported by Stewart and McCullough (1974). Ensiling grass with dry matter content of 140 gkg^{-1} in drum silos as reported in experiment 1 of this chapter produced a considerable amount of effluent which collected beneath the false bottoms of the drums. Nevertheless, the volumes collected in experiment 1 were much less than would be expected from grass of similar DM content ensiled in a farm scale silo.

In this experiment (2a), it was planned to use grass with DM content of approximately 140 gkg^{-1} or less, but this was not achieved. The grass DM on day 1 of the experiment ranged from 156 to 179 gkg^{-1} which suggested a considerable amount of effluent could be expected at least under farm conditions. However, no effluent was collected from the bottom of the drums which can be attributed to the low pressure applied to the silage in the drums.

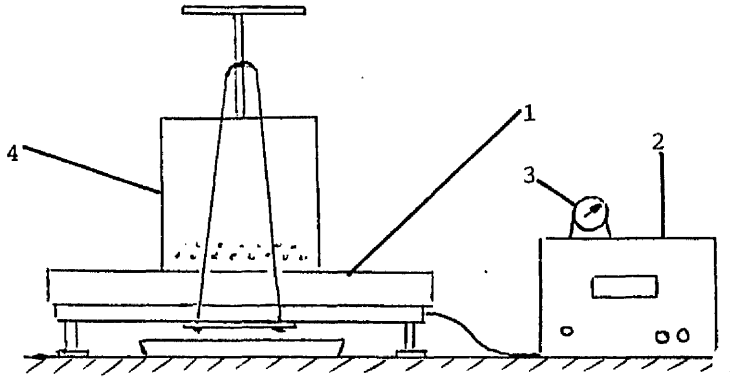
An estimation of the effluent production likely under commercial silo conditions was therefore made by measuring the volume of silage juice (effluent) expressed from known weights of silage under standardised conditions. This was achieved by the use of a wine press fitted with a load cell which allowed measurement of the actual pressure applied to the silage as shown in Figure 3.22.

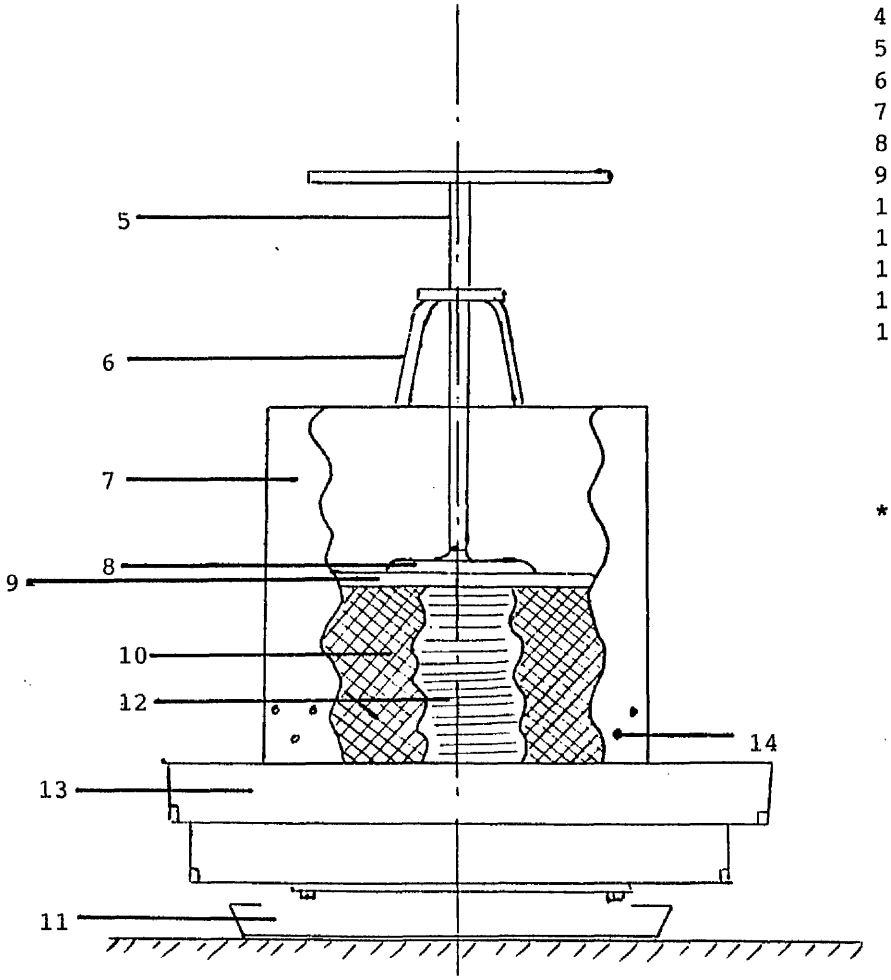
Bastiman (1976) reported the amount of effluent produced from grass ensiled at 170 gkg^{-1} under farm conditions is approximately 120 lt^{-1} grass FW. In this experiment, several samples each of 900g from the control silages were subjected to different pressures for three minute time periods and in each case the silage juice (effluent) was collected and measured. It was concluded that a pressure of 33 kg/dm^2 gave effluent volumes similar to that reported by Bastiman (1976).

A pressure of 33 kg/dm^2 may be considered slightly higher than that found in commercial silos, being approximately equivalent to the pressure at the bottom

FIGURE 3.22

DIGRAM SHOWING THE CONSTRUCTION OF THE WINE PRESS APPARATUS USED IN EXPERIMENTS 2 (a and b)





1 Weigh pads
2 Weigh scale (1 kg unit)
3 Timer

4 Small wine press*
5 Threaded T-bar
6 Pressure bar
7 160 mm plastic pipe
8 140 mm piston plate
9 150 mm piston plate
10 Fine mesh nylon bag
11 Collection tray
12 Silage sample (900 g)
13 Weigh pad
14 Drain holes

* Obtained from Boots, Nottingham, England

of a silo filled to a height of 4 m with silage. However, pressure is not the only factor which influences the rapid discharge of effluent from silage clamp. In the wine press test, the silage experiences the pressure loading for only a short time (3 minutes) compared to the situation in a farm silo. A lower pressure applied for a longer time would have yielded a similar "effluent" volume to that achieved using the standardised technique. It must also be pointed out that silage juice expressed by the wine press from materials that have been allowed to ferment for 3 months may not be the same in terms of volume as the effluent that would have drained "naturally" in the days immediately after ensilage under farm condition. Nevertheless, on the basis of measurements made in the mini-pit silos (chapter 4) the wine press technique appeared to give a valid indication of the effluent production that would be achieved in a large scale silo.

Preliminary examination of the results obtained, using the wine press (Table 3.26) suggested that chopped straw (D17, D18), DDG (Vitaferm D7, D8) and molassed beet shreds (D13, D14) were the most effective in reducing effluent production. However, to make a more accurate comparison of the absorbents a method of calculation was devised which allowed for the differences in the DM content of the grass added to each drum. Absorbent Efficiencies (AE) were calculated as follows:

1 For the 8 control silos (D1, D2, D21, D22, D23, D28, D33 and D38), a relationship between the DM content of the grass added to each drum and the volume of effluent measured using the wine press technique was obtained (Figure 3.23):

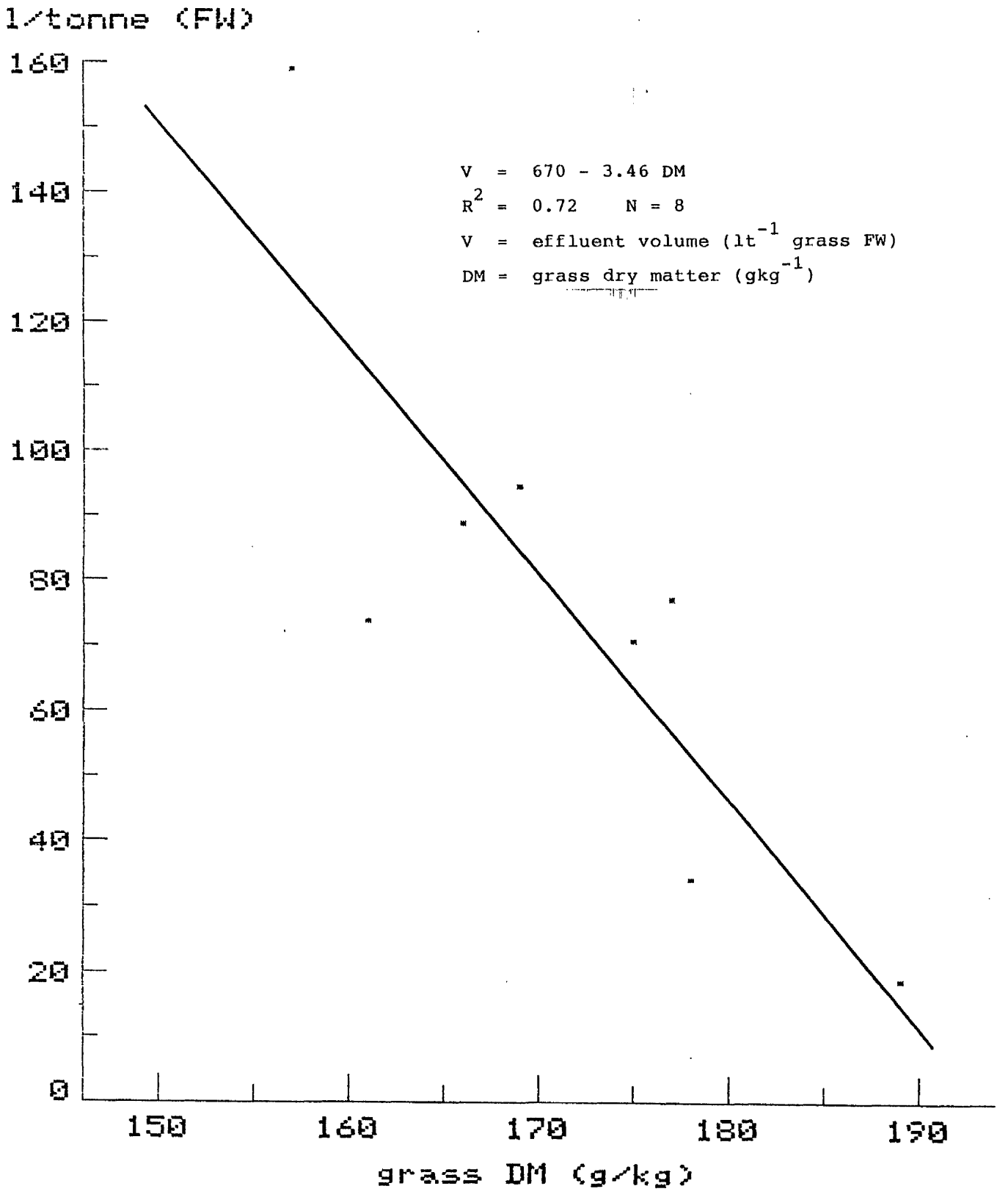
$$V = 670 - 3.46\ DM \qquad (1)$$

$$R^2 = 0.72 \qquad N = 8$$

V = effluent volume (lt^{-1} grass FW)
DM = grass dry matter (gkg^{-1})

FIGURE 3.23

THE RELATIONSHIP BETWEEN GRASS DM CONTENT AND EFFLUENT VOLUME FOR THE CONTROL DRUM SILOS



2 Equation 1 was used to predict for each drum silo, the effluent volume that would be measured if no absorbent had been added (PV lt^{-1} grass FW).

3 The Absorbent Efficiency (AE%) was calculated as follows:

$$AE = \frac{PV - MV}{PV} \times 100$$

MV = is the volume of effluent measured by the wine press for a particular treatment (lt^{-1} grass FW).

Table 3.212 shows the AE values obtained.

Chopped barley straw (D17, D18) completely prevents effluent production and gave an AE value of 100%. This agrees with the results of experiment 1 reported earlier in this chapter. The next most efficient absorbents were DDG (Vitaferm) which gave AE values of 65.2% and 67.1% (D7 and D8) and molassed beet shreds which gave values of 57.4% and 62.0% (D13 and D14).

In this experiment (2a), the effect of formic acid application on effluent production was not consistent. It is well known that application of formic acid to herbage increases effluent production in farm scale silos (Sutter, 1957; Henderson and McDonald, 1971; Pederson et al, 1973; Bastiman, 1976). Comparison of the AE values for each absorbent (Table 3.212) in the presence or absence of added formic acid, gives the best indication of the effect of the acid as this comparison allows for the variation in grass DM added to each drum. A lower AE value indicates greater effluent production. For D3 and D4 (DDG Invergordon), D5 and D6 (beet nuts), D11 and D12 (rolled barley), D15 and D16 (viton straw cubes), formic acid addition lowered AE values and therefore increased effluent output. However, for the remaining absorbents there was an increase in the AE value. Overall, for all absorbents formic acid addition reduced the AE values from 53 to 47%. Thus the increase in effluent

TABLE 3.212

Calculated Absorbent Efficiencies (AE%) for the Drum Silos used in Experiment 2a

Drum No	Formic Acid	Grass DM (gkg^{-1})	Effluent Measured (lt^{-1} grass FW)	Effluent Predicted (lt^{-1} grass FW)	AE %
D3	-	160	68.8	117	41.1
D4	+	172	63.0	76	17.1
D5	+	166	54.2	96.4	43.8
D6	-	164	46.3	104	55.6
D7	-	179	18.4	52.8	65.2
D8	+	156	43.0	131	67.1
D9	-	168	43.0	90.5	52.5
D10	+	164	40.6	104	61.1
D11	-	170	62	82.2	24.6
D12	+	171	72.1	78.1	7.6
D13	-	171	29.0	68.0	57.4
D14	+	170	31.0	81.5	62.0
D15	-	161	42.9	112	61.7
D16	+	174	39.0	69.4	43.8
D17	-	170	0	82.2	100
D18	+	163	0	105	100
D19	-	171	70.4	83.2	15.4
D20	+	164	77.7	103	24.3

production normally associated with the use of formic acid was scarcely evident in this trial. A likely explanation is that the effect of formic acid on effluent loss is restricted to the period immediately after ensiling and would therefore not be detected in this experiment as the measurements were made after 3 months of ensilage. An analysis of variance was carried out to test the significance of differences between absorbent efficiencies obtained with and without formic acid treatment (see Appendix 1). The mean values are shown in Table 3.213. Formic acid treatment did significantly ($P < 0.001$) reduce the AE values, although as discussed, the effect was smaller than observed in farm scale trials.

Figure 3.24 shows the mean (+ and - formic acid) AE values for those absorbents tested. The most effective controllers of silage effluent were chopped straw followed by DDG (Vitaferm), molassed beet shreds and DDG (N E Farmers). Broadly, the absorbents could be divided into three groups:

		Absorbent Efficiency
1	Chopped Straw	Highly Effective
2	Molassed Beet Nuts Viton Straw Cubes DDG (N E Farmers) Molassed Beet Shreds DDG (Vitaferm)	Moderately Effective
3	Rolled Barley Pressed Wheat Draff DDG (Invergordon)	Ineffective

However, it must be noted that this experiment measured only the effect of absorbents on effluent volume. As the work described in Chapter 4 shows, other factors such as the effect of absorbents on effluent composition and silage feeding value are also important.

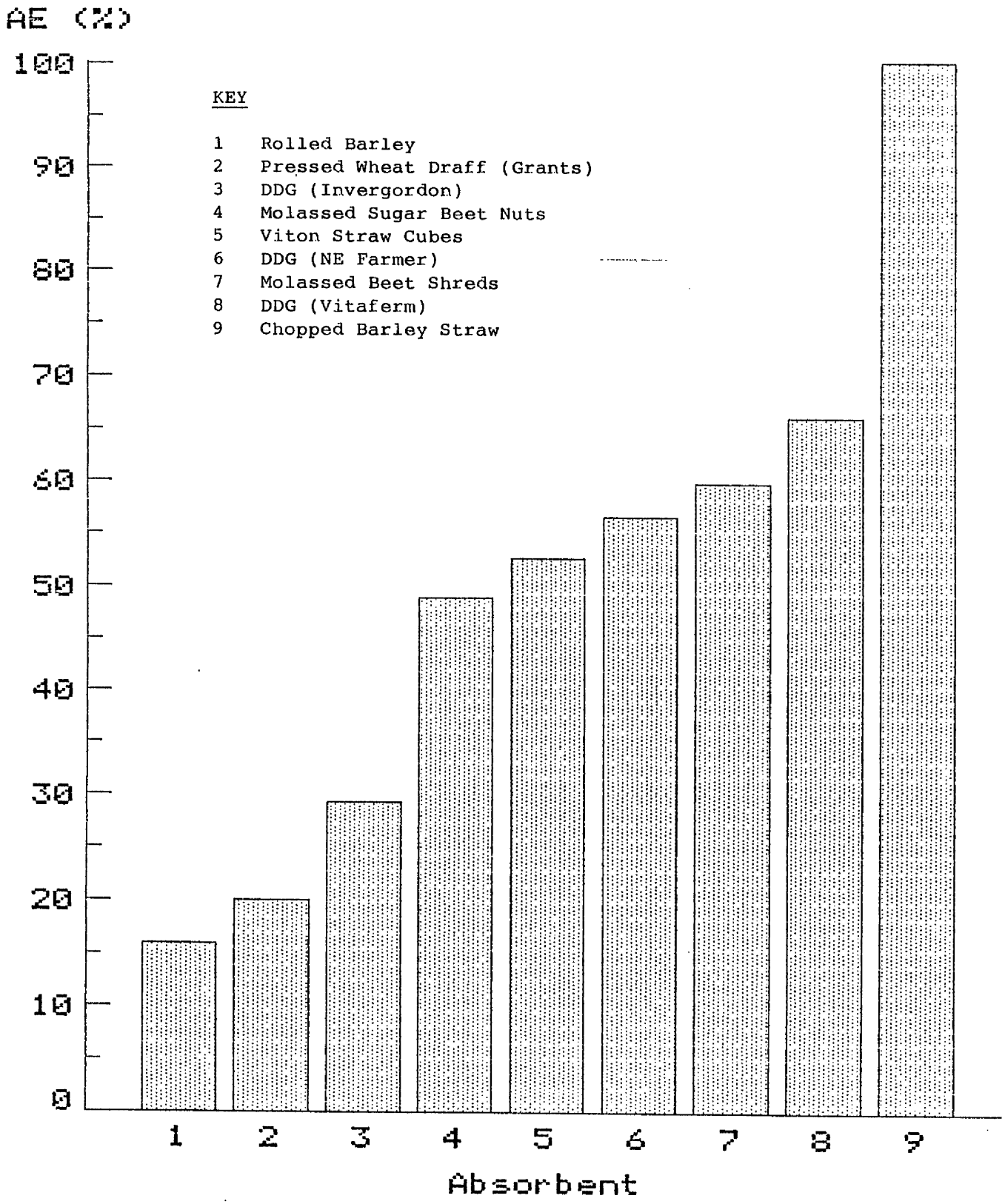
TABLE 3.213

Mean Effect of Formic Acid Treatment on Absorbent Efficiency (AE%)

Absorbent	AE%		Mean AE%
	Formic Acid		
	-	+	
DDG (Invergordon)	41.4	17.0	29.2
Molassed Beet Nuts	54.1	43.4	48.8
DDG (Vitaferm)	65.1	67.2	66.1
DDG (N E Farmers)	52.4	60.5	56.5
Rolled Barley	24.9	6.9	15.9
Molassed Beet Shreds	57.5	61.9	59.7
Viton Straw Cubes	61.6	43.7	52.6
Chopped Barley Straw	100	100	100
Pressed Wheat Draff	15.7	24.3	20.0
Mean	52.5	47.2	49.9
SEM	0.569		

FIGURE 3.24

THE ABSORBENT EFFICIENCIES (AE) OF ABSORBENTS
TESTED IN DRUM SILOS



Experiment 2b

Composition of Silages

In general, the fermentation characteristics of all silages as judged by pH, ammonia-N content and butyric acid concentration were satisfactory. The highest pH value recorded was 4.1. Treatments D23 to D37 (silages made on days 1, 2 and 3) generally achieved a concentration of ammonia-N (mean 99.7 range 64-137 gkg^{-1} total-N) and the levels were not affected by inclusion of molassed beet shreds (see Table 3.29). For treatments D38 to D43 (wetted grass silages made on day 4), addition of beet shreds did appear to improve fermentation. The ammonia-N concentration of D38 (control) was 150 gkg^{-1} total-N, whereas D39, D41 and D43 showed ammonia-N concentrations of 106, 98 and 101 gkg^{-1} total-N respectively (see Table 3.29).

Addition of molassed beet shreds (SBP) had little effect on the levels of WSC, lactic acid, acetic acid, propionic acid, butyric acid or ethanol in the silages. There was a tendency for a slight increase in residual WSC levels as SBP was added (overall WSC gkg^{-1} DM) for 0, 2, 4, 6 and 8% SBP were 9, 10, 11.6, 12 and 13.6 respectively.

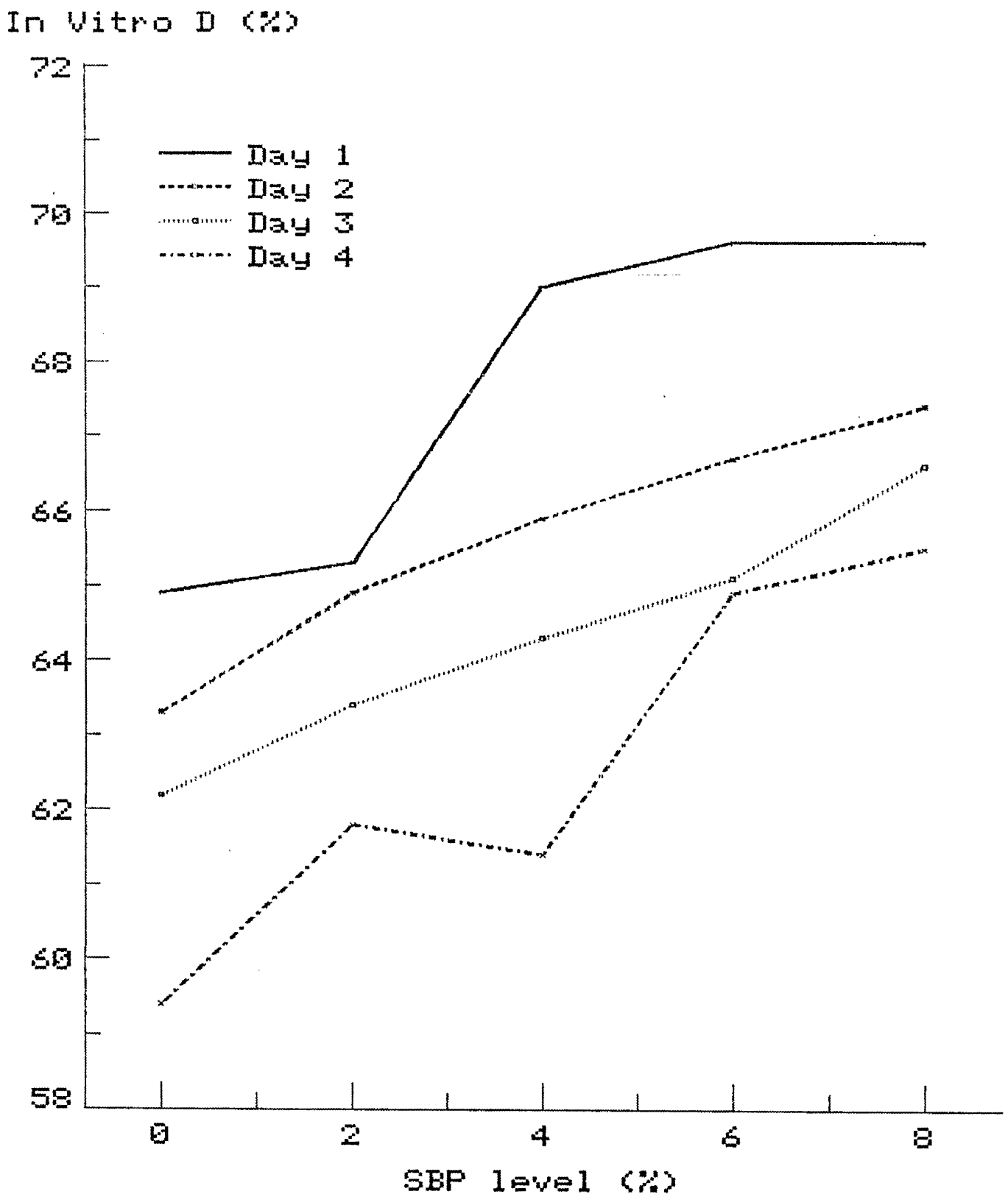
For in vitro D-values, two main effects were apparent. Firstly, the D-values of the silages tended to decrease in direct relation to the length of the wilting period. D-values for the control silages made on days 1, 2, 3 and 4 were 64.9, 63.3, 62.2 and 59.4% respectively. It should be noted that wilting was carried out slowly in a large shed which would tend to increase respiration losses. Secondly, the addition of SBP increased the in vitro D-value. Mean values (for all days) for 0, 2, 4, 6 and 8% SBP inclusion were 62.5, 63.9, 65.2, 66.6 and 67.3% respectively. These relationships are shown in Figure 3.25. SBP% alone accounted for only 46% of the variance in silage D-value. Addition of the day number on which the silage was made in a bivariate relationship increased the R^2 value to 0.93.

$$D = 66.5 + 0.66\ SBP - 1.59\ DN \qquad (2)$$

$N = 21 \qquad R^2 = 0.93$

FIGURE 3.25

THE EFFECT OF WILTING TIME AND LEVEL OF SBP INCLUSION
ON IN VITRO SILAGE D-VALUES



Where:

D = *in vitro* D-value (%)

SBP = level of molassed beet shreds (% FW)

DN = day on which silage was made

Thus each percent inclusion of SBP increased silage D-value by 0.66% unit whilst each extra day of wilting reduced D-value by 1.59% unit. The effect of SBP inclusion would be dependent on the initial D-value of the grass and would be less for very highly digestible crops.

Effluent Production

The results for the mini-pit silos (chapter 4) suggested that absorbents such as molassed beet shreds (SBP) should be used in sufficient quantities to completely prevent effluent production. The main objective of this experiment (2b) was therefore to investigate the relationship between effluent volume, grass DM and SBP concentration.

It has been planned to cut a grass with DM content of approximately 140 gkg^{-1} and to wilt the grass for four days, making silage on each day so as to cover a DM range of approximately 140-200 gkg^{-1}. However, this plan was not achieved as the grass from the first day of cut had a DM ranging from 156-179 gkg^{-1}. The original plan was followed for days 1, 2 and 3 but on the fourth day however, the grass DM was estimated to be 220 gkg^{-1}. It was concluded that for the purpose of obtaining the desired relationship, measurements of effluent production at grass DM level of approximately 140 gkg^{-1} were needed. This was achieved by adding water to the grass. The water was applied as a very fine spray onto the grass spread out on a concrete floor. The grass was then left for four hours during which time the added water had completely absorbed into the structure of the grass.

It is important to stress that effluent which was measured by the wine press technique would be better described as a silage juice, since it had not freely drained from a silo. However, the control drums gave effluent volume

approximately similar to measurements made by Bastiman (1976) for farm scale silos. Thus, although there must be some uncertainty about the validity of this approach, the relationship observed should be a fair reflection of what would apply on a farm scale. However, this conclusion must be tested in practice. The results obtained using 10 tonne mini-silos (chapter 4) are in good agreement with the relationship shown below, but further farm scale work is needed.

A relationship between grass DM (see Table 3.28), volume of effluent measured at 33 kg/dm^2 (see Table 3.211) and level of SBP was obtained by multiple regression thus:

$$V = (37.8 - 0.1725\ DM - 0.9022\ SBP)^2 \qquad (3)$$

$N = 20 \qquad R^2 = 0.85$

Where:

V = effluent volume (lt^{-1} grass FW) measured at 33 kg/dm^2

DM = grass dry matter gkg^{-1}

SBP = level of molassed beet shreds (% grass FW)

Figure 3.26 shows the predicted effluent volumes for 0, 4, 6 and 8% SBP (% grass FW) and for grass DM ranging from 120-220 gkg^{-1}. Figure 3.27 shows actual effluent volumes recorded, plotted against volumes predicted using equation 3.

Figure 3.26 shows that ensiling grass with DM content of 160 gkg^{-1} mixed with 4, 6 and 8 levels of SBP (% grass FW) could reduce effluent production to approximately 50, 25 and 12 lt^{-1} grass FW respectively. Whereas for a grass DM content of 180 gkg^{-1} comparable figures would be 15, 3 and 0 lt^{-1} grass FW respectively.

It is possible to calculate from equation 3 the amount of SBP required to be added to a particular grass DM to produce no effluent. This can be achieved

FIGURE 3.26

THE RELATIONSHIP BETWEEN GRASS DM, SBP LEVEL AND EFFLUENT VOLUME DERIVED FROM EXPERIMENT 2b

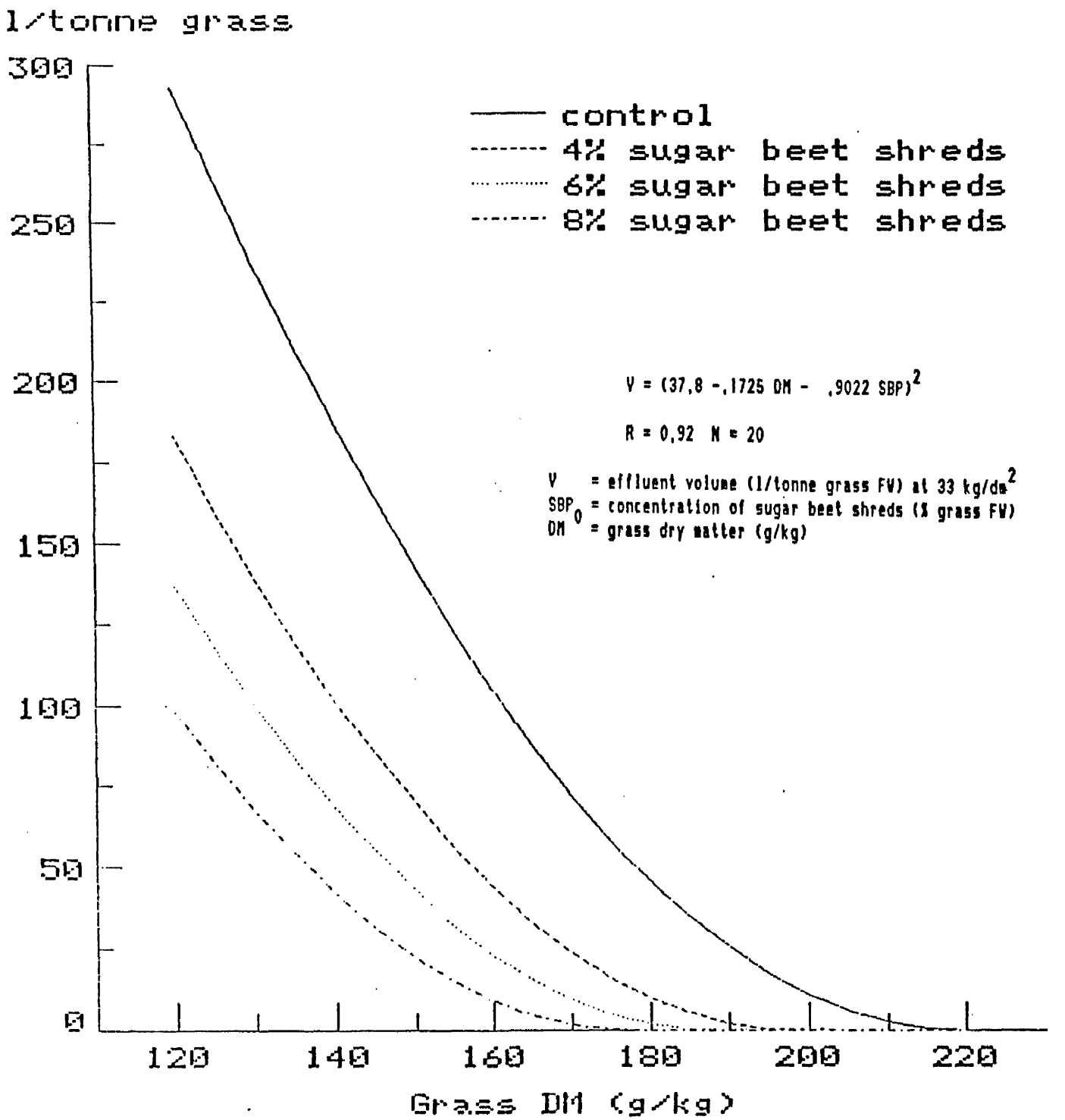
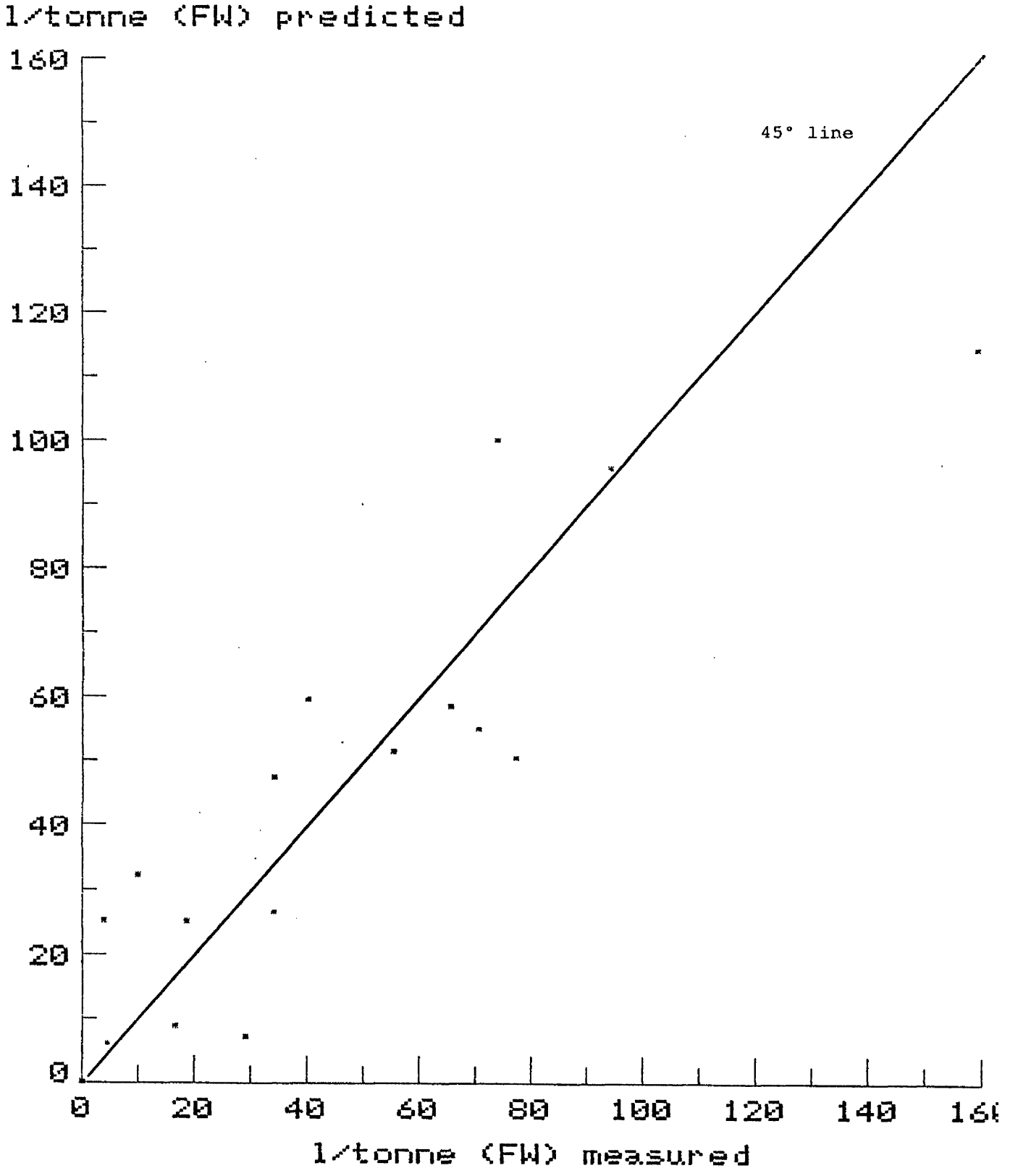


FIGURE 3.27

COMPARISON BETWEEN EFFLUENT VOLUMES MEASURED FOR DRUM SILAGES WITH VOLUMES PREDICTED USING EQUATION (3)



by solution of equation (3) for V = 0 and gives:

$$SBP_{(0)} = 41.9 - 0.191\ DM \qquad (4)$$

Where:

$SBP_{(0)}$ = level of beet shreds (% grass FW) required to produce no effluent

DM = grass dry matter gkg^{-1}

The relationship is shown graphically in Figures 3.28a on a fresh weight basis and 3.28b on dry weight basis. It shows that high levels of SBP are required to prevent effluent production completely. For grass of DM content of 160 gkg^{-1}, 110 kg of SBP is needed per tonne of grass FW to prevent effluent production completely. This level of SBP addition means that SBP makes up 38% of the total silage + SBP mixture on a dry matter basis. However, ensiling grass with dry matter content of 180 gkg^{-1} required only 80 kg of SBP per tonne of grass FW (25% of mixture DM) to prevent effluent production. This relationship suggest that, if SBP levels are to be kept below 25% of the mixture on a dry matter basis, it will often be necessary to use a short wilting period.

CONCLUSIONS

1 All of the absorbents tested allowed the production of well fermented silages.

2 Application of formic acid did not improve preservation quality as measured by pH, ammonia-N or butyric acid levels, mainly because all silages, including controls, were well preserved.

3 Of the absorbents tested, the most effective controllers of silage effluent were chopped straw, DDG (Vitaferm) and molassed beet shreds.

FIGURE 3.28a

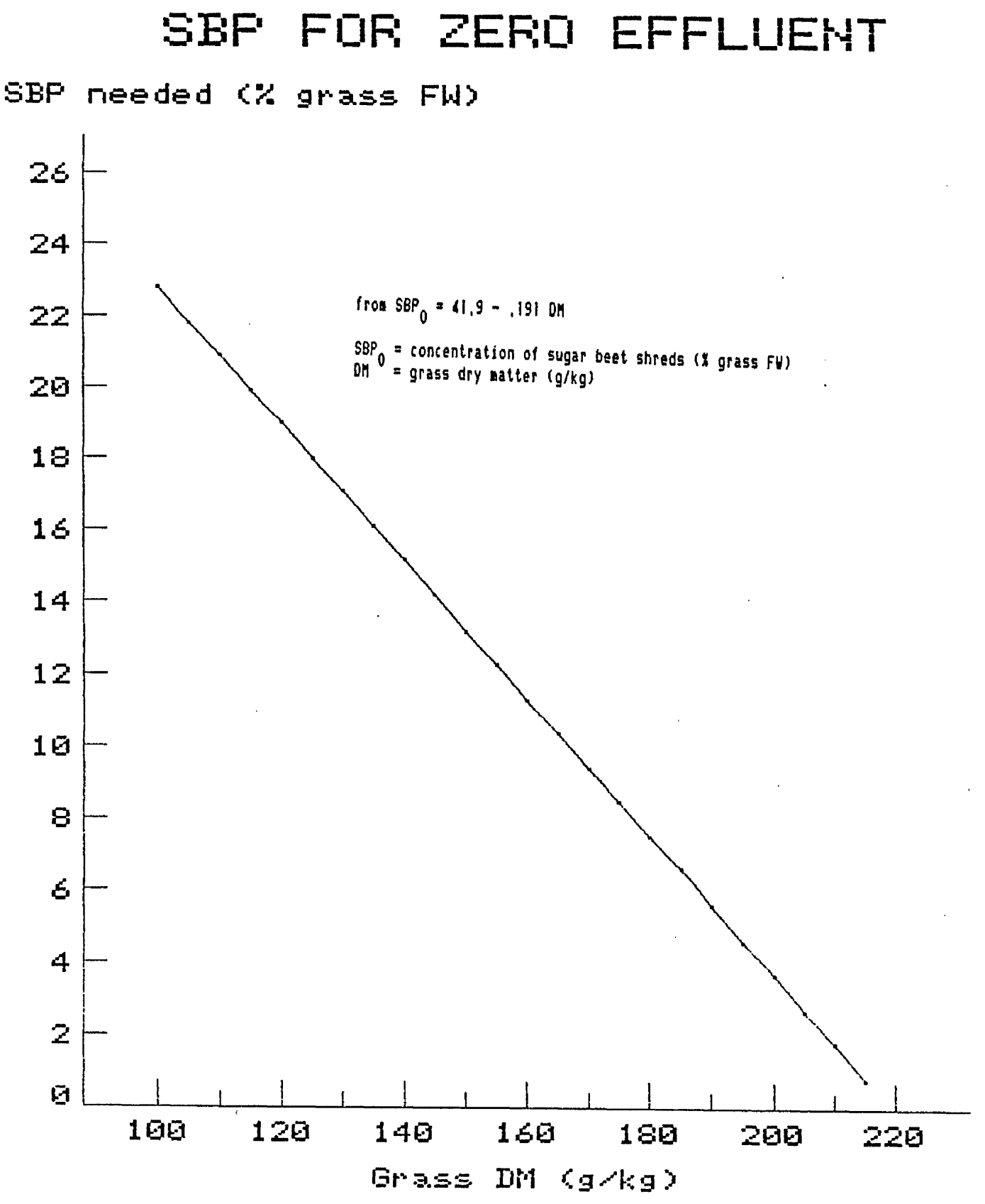
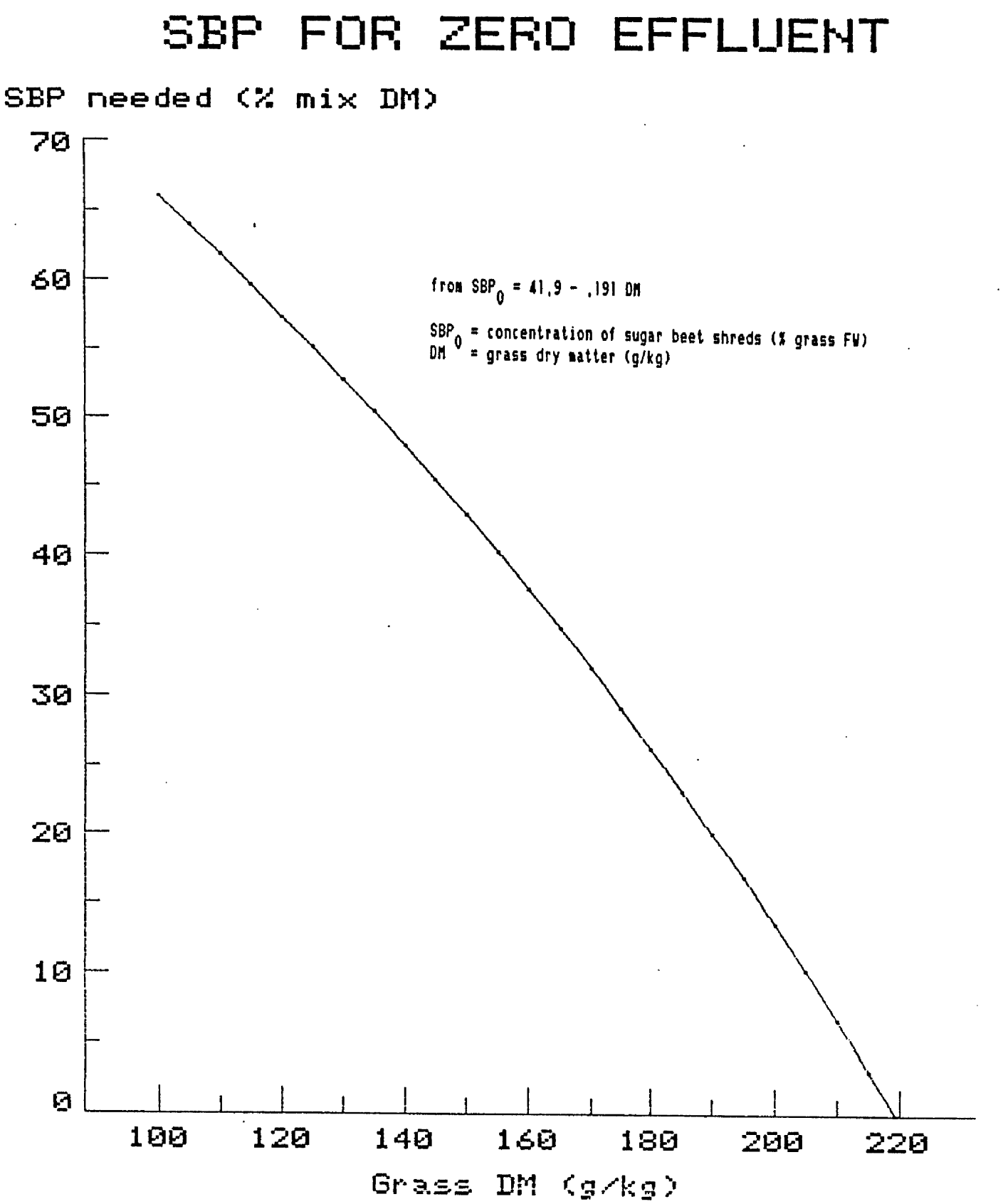

SBP FOR ZERO EFFLUENT
SBP needed (% grass FW)
26
24
22
20
18
16
14
12
10
8
6
4
2
0
from SBP0 = 41.9 - .191 DM
SBP0 = concentration of sugar beet shreds (% grass FW)
DM = grass dry matter (g/kg)
100
120
140
160
180
200
220
Grass DM (g/kg)

FIGURE 3.28b


SBP FOR ZERO EFFLUENT
SBP needed (% mix DM)
70
60
50
40
30
20
10
0
from SBP0 = 41.9 - .191 DM
SBP0 = concentration of sugar beet shreds (% grass FW)
DM = grass dry matter (g/kg)
100
120
140
160
180
200
220
Grass DM (g/kg)

4 Barley gave only 20% of the effluent reduction measured for chopped straw.

5 Chopped straw inclusion reduced silage D-value by 5 to 6 units, whilst molassed beet shreds increased D-value by 2 to 4 units.

6 The levels of molassed beet shreds required to prevent effluent production completely can be predicted from the equation:

$$SBP_{(0)} = 41.9 - 0.191\ DM$$

7 At a grass DM of 180 gkg^{-1}, 80 kg per tonne of grass FW of molassed beet shreds are needed to prevent effluent loss. At this level, SBP makes up 25% of the resulting mixture on a dry matter basis.

EXPERIMENT 3

THE EFFECT OF PROLONGED SOAKING IN SILAGE EFFLUENT ON THE DIGESTIBILITY OF BARLEY STRAW MEASURED **IN SACCO**

Introduction

Chemical treatment (notably with alkalis) is a commonly used method of enhancing the digestibility of lignified crop residues. These treatments maximise damage to plant structure to promote microbial attack and to prevent or slow down the rate of accumulation of lignin at the cell wall surface by the specific degradation of lignin or by the promotion of its solubilisation. Alkali treatments appear to improve digestibility by promoting lignin solubilisation. Up to half of the lignin initially present in cereal straws can be made water-soluble by treatment with sodium hydroxide (Chesson, 1981). A crucial factor in this solubilisation is the cleavage of specific alkali-labile linkages formed between the structural polysaccharides (hemicellulose) of the cell wall and lignin itself (Smith and Hartley, 1983; Chesson et al, 1983b). Strong alkalis, such as sodium hydroxide, may also bring about the limited cleavage of some lignin internal linkages (Johansson and Micksche, 1972).

The various methods of treating stacked straw with either anhydrous or aqueous ammonia appear equally effective in increasing digestibility and nitrogen content (Kumah and Owen, 1983; Ørskov et al, 1983). Greater increases in digestibility have been reported with urea-ammonia treatment of rice straw in Bangladesh (Saadullah et al, 1981, with cattle) and in Sri Lanka (Jayasuriya and Perera, 1982, with sheep) and with barley straw in Cyprus (Hadjipanayiotou, 1982, with sheep).

A large number of chemicals have been investigated as potential upgrading agents for straw. Ben Ghedalia and Miron (1981) found sulphur dioxide treatment of ground straw (50 gkg^{-1} straw DM; 40% moisture; 72 hours exposure) to improve OMD (48 hours incubation with rumen liquor) to 80% compared to values of 44% and 70% for untreated straw and NaOH treated respectively. Fahmy and Ørskov (1984) have shown improvements in nylon bag digestibilities of untreated and ammonia-treated straw ensiled with sulphuric acid.

This trial was carried out to investigate the effect of prolonged soaking in silage effluent on straw OM degradability measured in the rumen of sheep using the nylon bag technique.

The sheep were fed diets adequate in rumen degradable protein (ARC, 1980) as the intention was to examine effluent as a potential upgrading agent, not as a protein source.

EXPERIMENTAL

Straw

Approximately 2 kg of barley straw was chopped through a grinder to an average length of approximately 10 mm. The coarsely ground straw was thoroughly mixed.

Animals

Four mature Suffolk cross weather sheep, approximate liveweight 75 kg, fitted with permanent rumen cannulae were used to estimate the *in sacco* degradability of the straw. The sheep were kept indoors in loose pens.

Diet

During the trial period the sheep were given a maintenance ration of 800 gd^{-1} hay and 200 gd^{-1} Ewbol sheep pencils* in two meals offered at 0845 and 1645 hrs. The compositions of the hay and concentrate portions of the diet are shown in Table 3.31.

* BOCM, UK.

TABLE 3.31

Composition of the Diet Fed to the Sheep during Experiment 3

A Composition of Hay

DM (gkg^{-1})	852
OM (gkg^{-1} DM)	931
CP (gkg^{-1} DM)	106
In vitro D-value (%)	52.4
ME ($MJkg^{-1}$ DM)	7.9

B Composition of Concentrate (302 Ewbol pencils)

				Vitamin IU kg^{-1}			Minerals	
Protein (%)	Fibre (%)	Oil (%)	Ash (%)	A	D_3	E	Selenium ($mgkg^{-1}$)	Magnesium (gkg^{-1})
14	13.5	3.0	9.8	5000	2000	7.5	0.2	12.0

Bags

The bags were made of synthetic polyester fibre (Sericol Group Ltd, London) with pore size of 40-50 μ m. The bags were 10 x 21 cm with a round bottom to prevent the samples collecting in the corners. The bags were clearly labelled in numerical sequence.

Silage Effluent

The effluent was taken from the control silage made in a mini pit silo (1985). The analysis of the effluent is shown in Table 4.112 treatment A, page 154. The effluent was preserved by the addition of 300 cm^3 of 40% formaldehyde solution to each 100 l of effluent (0.3% formalin).

EXPERIMENTAL DESIGN

a) Preliminary Experiment

A total of 32 bags were weighed to three decimal places and used as shown in Table 3.32. All bags were tightly tied with nylon fishing line after the addition of straw and placed in beakers containing the appropriate liquids and maintained at 37°C in a water bath for 12 hours. The bags were then washed in cold running tap water and were further cold-washed in an automatic washing machine. After washing, all bags were oven-dried at 60°C for 48 hours, allowed to cool in a dessicator and weighed to three decimal places. OM determination was then carried out on the material removed from the bags. Losses of DM and OM were calculated.

b) Main Experiment

In this trial, 4 g of straw FW (3.6 g dry weight) plus either 80 cm^3 0.3% formalin solution (C-control) or 80 cm^3 silage effluent (T-treated) were incubated in large test tubes. Each tube was sealed with plastic film and all tubes were stored in a refrigerator at 5°C for 0, 2, 4, 6 and 8 weeks. For each period, a total of 32 test tube contents (16C and 16T) were transferred into 32 preweighed nylon bags and tightly tied. The bags were divided into 8 groups of 4 bags (2C and 2T), see

TABLE 3.32

Experimental Design for Preliminary Experiment

Treatment	Bags	Straw FW (g)	Liquid
1	1-8	4	0
2	9-16	4	80 cm^3 effluent
3	17-24	4	80 cm^3 0.3% formalin
4	25-32	0	80 cm^3 effluent

Table 3.33. Each set of 4 bags (2C and 2T) were attached to a rubber bung by four strings which passed through flexible plastic tubes. The bungs were of specific size to fit the cannulae of the four sheep. At the same time as straw was being weighed into test tubes, a representative sample was taken for DM and OM determination.

Calculation of OM Digestibility Response to Soaking in Effluent

Each set of 4 bags incubated in the rumen of a sheep were comprised of 2 control bags (straw + 0.3% formalin solution) and 2 treated bags (straw + effluent). This design made it possible to allow for any changes with time in the digestive capabilities of each sheep, since an equal number of control bags were always incubated at the same time as those containing effluent-treated straw. The response to soaking in effluent (RE) was calculated for each incubated set by subtracting the mean OM disappearance for the 2 control bags (C) from the OM disappearance for each of the two bags containing the effluent-soaked straw (T) as follows:

$$RE = D_t - D_c$$

Where,

D_t = OM disappearance for each bag containing effluent-soaked straw (T)

D_c = Mean OM disappearance for two control bags (C) incubated at the same time.

TABLE 3.33

Experimental Design for Main Experiment

Length of Soaking period (weeks)	Sheep				Duration of Rumen Incubation (hrs)
	A	B	C	D	
0	2T 2C	2T 2C	2T 2C	2T 2C	24
	2T 2C	2T 2C	2T 2C	2T 2C	48
2	2T 2C	2T 2C	2T 2C	2T 2C	24
	2T 2C	2T 2C	2T 2C	2T 2C	48
4	2T 2C	2T 2C	2T 2C	2T 2C	24
	2T 2C	2T 2C	2T 2C	2T 2C	48
6	2T 2C	2T 2C	2T 2C	2T 2C	24
	2T 2C	2T 2C	2T 2C	2T 2C	48
8	2T 2C	2T 2C	2T 2C	2T 2C	24
	2T 2C	2T 2C	2T 2C	2T 2C	48

RESULTS

a) Preliminary Experiment

The mean in sacco OM degradabilities (%) of straw, straw + 0.3% formalin or straw + effluent were 4.4, 4.7 and 4.5 respectively, with a standard deviation of 0.54. There were no significant ($P < 0.05$) differences in OM degradabilities between the above treatments. However, when effluent alone was incubated in the bags, 100% disappearance was observed.

b) Main Experiment

The individual OM degradabilities for the control straw (straw + 0.3% formalin solution) and for the treated straw (straw + effluent) are shown in Appendix 2 and corresponding RE values are shown in Appendix 3. The analysis of variance for RE values are shown in Appendix 4.

Increasing rumen incubation time from 24 hours to 48 hours increased the mean OM degradability (%) from 44.8 to 57.2 for the control and from 45.4 to 58.6 for the treated straw.

Table 3.34 shows the OM degradability of the control and treated straw for different periods of soaking. The mean OM degradabilities of the control and treated straw were 51.0% and 52.0% respectively and the difference was significant ($P < 0.05$). However, the differences in OM degradability between the control and treated straw was not related to duration of soaking. The OM degradability of the control for 0 week of soaking was 52.3% and for 2, 4, 6 and 8 weeks of soaking (in 0.3% formalin) were 50.4, 52.9, 49.5 and 50.1% respectively. For the treated straw, the OM degradability did not increase significantly ($P < 0.05$) with increasing time of soaking in silage effluent. However, the OM degradability was higher for treated straw than the corresponding control during weeks 2, 6 and 8, although the difference was significant ($P < 0.05$) only at 2 weeks of soaking.

Table 3.35 shows the mean response of OM degradability (RE) to soaking straw in effluent. The grand mean for RE was 0.85, indicating that overall, straw OM degradability was increased by soaking in effluent by

TABLE 3.34

Mean* Degradability of OM (%) of Straw Soaked in Effluent (treated) or 0.3% Formalin Solution (control)

Soaking Period (weeks)	OM Degradability		LSD P = 0.05
	Control	Treated	
0	52.3^{bc}	51.6^{cbe}	1.95
2	50.4^{ab}	53.3^{c}	
4	52.9^{c}	52.1^{cb}	
6	49.5^{a}	51.4^{cba}	
8	50.1^{ae}	51.5^{cba}	
Mean	51.0	52.0	
LSD P = 0.05	0.87		

* Means in the main part of the table not sharing a common subscript differ significantly ($P < 0.05$)

TABLE 3.35

Mean Response of Organic Matter Degradability (RE) to Soaking in Effluent

Soaking Period (weeks)	RE (%)		LSD P = 0.05
	24 hours Incubation Time	48 hours Incubation Time	
0	-1.0	-0.4	
2	3.0*	2.1*	
4	-1.2	-0.5	1.89
6	-0.4	4.1*	
8	2.0*	0.8	
Mean	0.49	1.21*	
LSD P = 0.05	0.94		

* Indicates that the value differs significantly (P < 0.05) from zero.

0.85 of a percentage unit. This value is significantly ($P < 0.05$) greater than zero. The mean RE values for 24 hours and 48 hours rumen incubation time were 0.49 and 1.21 respectively. Only the mean RE value for 48 hours incubation (1.21) was significantly greater ($P < 0.05$) than zero. Thus for 24 hours incubation, no significant overall effect of soaking in effluent was detected. However, the RE values for both rumen incubation times were not related to the period of soaking in effluent. For 48 hours rumen incubation time, the degradability response to soaking in effluent (RE) was significant ($P < 0.05$) only for weeks 2 and 6. A similar pattern was observed for 24 hours incubation, except that a significant ($P < 0.05$) response to soaking occurred at weeks 2 and 8.

DISCUSSION

Treatment with alkalis or acids can increase straw digestibility (Chesson, 1981; Smith and Hartley, 1983; Fahmy and Ørskov, 1984). The aim of this trial was to investigate the effect of prolonged soaking of straw in silage effluent on OM digestibility.

Silage effluent contains approximately 250 gkg^{-1} DM crude protein, much of which is in the form of highly degradable protein. Thus silage effluent may act as a source of rumen degradable protein (RDP). Barley straw is very deficient in RDP and requires supplementation with an RDP source if its full potential digestibility is to be achieved. The objective of this trial was to investigate the effect of effluent on the degradability of straw OM in a situation where RDP was not limiting digestion. The trial did not aim to evaluate silage effluent as an RDP source, but to assess its use as a chemical for the upgrading of straw fibre.

The preliminary experiment was carried out to examine the validity of the experimental method used for measuring the effect of soaking on straw degradability. It showed that when only silage effluent was added to nylon bags, all of the added DM disappeared during the washing procedure. This demonstrates that the DM constituent of silage effluent are either in a soluble form or in the form of very fine particles which are washed from the bags. No significant ($P < 0.05$) differences in OM losses from bags containing straw, straw + 0.3% formalin solution or straw + effluent were obtained when the bags were washed in cold running tap-water and in an automatic washing machine following a 12 hour incubation period in a water bath at 37°C.

The results of the preliminary experiment show that, following the washing procedure used in this trial, the OM recovered from bags does not contain residual effluent OM. Therefore, after rumen incubation, the bag residues consisted mainly of undigested straw. However, microbial contamination of straw residues is a possibility (Varvikko and Lindberg, 1985), although this should be limited by the severity of washing used in this trial and would be expected to be similar for both the control and treated bags.

The main experiment showed that soaking straw in effluent for 0, 2, 4, 6 and 8 weeks resulted in an overall increase in straw OM degradability by 0.85 percentage units. There were significant ($P < 0.05$) changes in mean straw OM degradability for control bags over the course of the experiment (see Table 3.34). These changes were caused by apparently random variation in the digestive capability of individual sheep. However, although the changes in OM degradability were small, it was necessary to allow for them when assessing the effect of soaking in effluent. Thus the RE value was calculated for each (T) bag by comparing the observed OM disappearance with that for the two (C) bags incubated in the same sheep at the same time.

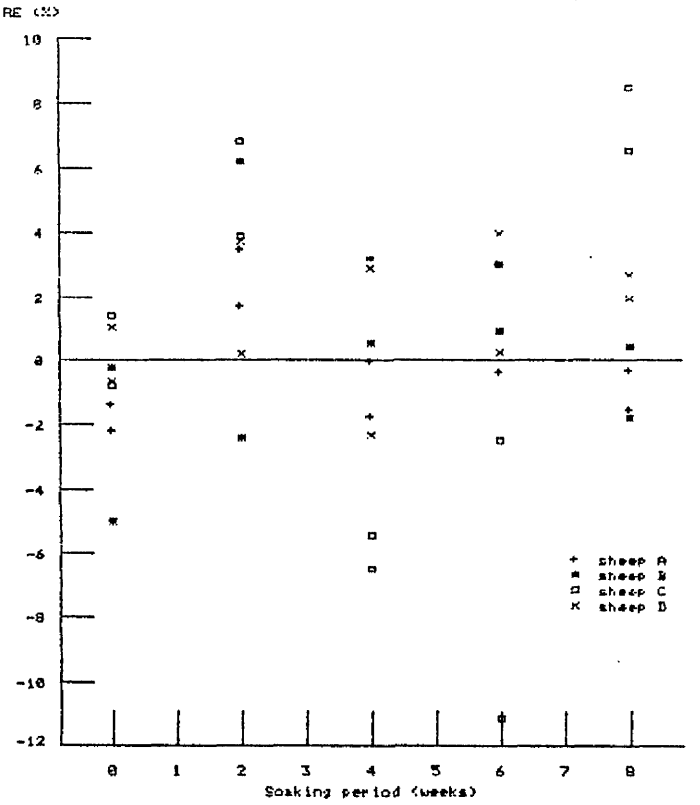
There was considerable variation in the RE values calculated for individual bags incubated in the four sheep over the 8 weeks of the trial (see Figures 3.31a and b). It showed that soaking straw in silage effluent did not produce a consistent response and was not simply related to the length of soaking period. The results showed that prolonged soaking in silage effluent had very little effect on degradability of straw OM measured in sacco. Overall, there was a small but significant ($P < 0.05$) increase in OM disappearance (0.85 percentage unit). The improvement was greater for bags incubated for 48 hours but showed no clear relationship to the duration of soaking in effluent.

Fahmy and Ørskov (1984) treated straw with 0, 20, 40 and 60g H_2SO_4 per kg of straw and found in sacco DM degradability (%) values of 42, 54, 59 and 67 respectively. However the acid concentration of the treatment solution to which the straw was exposed in the present trial was much lower than that used by Fahmy and Ørskov (1984). In the case of the 20 gkg^{-1} treatment used by these workers, 100 cm^3 of a 20% solution of H_2SO_4 was added to each kg of straw. In the present trial, a much higher volume of effluent was used (20 lkg^{-1} straw) but the acid concentration in effluent was much lower. Lactic acid is the strongest acid found in silage effluent but its concentration in the effluent was only 1.3 gl^{-1}. Thus the total lactic acid applied per kg of straw was 26 gkg^{-1} which is comparable to the weight of H_2SO_4 used by Fahmy and Ørskov (1984) but was applied in a much larger volume. The reasons why the response to soaking in effluent was so small in the present trial compared to the response obtained for H_2SO_4 by Fahmy and Ørskov (1984) may be partly due to the weaker acid strength of lactic acid, but is likely to be mainly due to the much lower acid concentration in the treatment solution. The acid

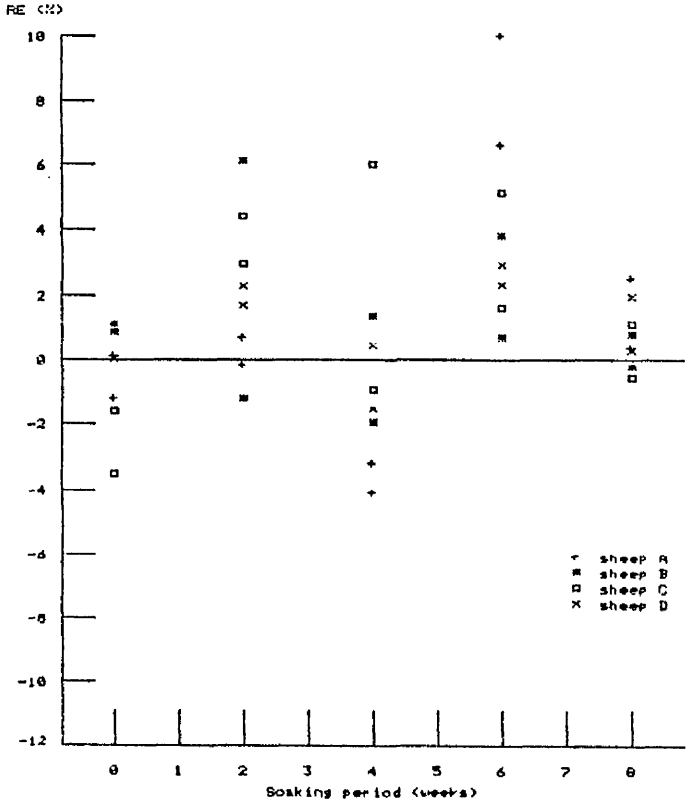
FIGURE 3.31

THE EFFECT OF SOAKING IN EFFLUENT ON IN SACCO OM DEGRADABILITY RESPONSE (RE%) COMPARED TO CONTROL INCUBATIONS

a) 24 hrs incubation



b) 48 hrs incubation



strength of the treatment solution used by Fahmy and Ørskov (1984) was approximately 20 times stronger than that found in effluent. The results suggested it is not possible to compensate for very low acid concentration in the treatment solution by adding a large volume to each kg of straw.

It is concluded that soaking straw in silage effluent resulted only in a very slight improvement in OM degradability (0.85% unit) which is of no practical significance as a method of nutritionally upgrading straw. Thus, when straw is used as an absorbent in silage clamps, the main potential benefit depends on the reduction in effluent production. This agrees with the results described in Chapter 4 for the "mini pit" silos which show that silage OMD is depressed by straw additives to a degree which can be calculated from the OMD of silage made without straw and the OMD of the straw, allowing only for the level of addition of the straw. There appears to be no synergistic effect due to ensiling straw with grass in terms of OMD. The only situation in which straw utilisation may be improved by soaking in effluent would be when the straw is fed as part of a diet deficient in RDP. Under these circumstances, effluent would help to overcome the inherent RDP deficiency of straw and would improve straw digestibility and intake. Under RDP - adequate conditions, effluent soaking would not be expected to improve straw utilisation.

CHAPTER FOUR

THE EFFECTS OF ENSILING ABSORBENTS WITH GRASS IN "MINI PIT" SILOS ON EFFLUENT PRODUCTION AND SILAGE QUALITY

SECTION 1

1985 TRIAL

OBJECTIVE

The six "mini pit" silos described on page 47 , each of capacity 10 m^3, were used to investigate the effect of adding absorbents to grass at ensiling on:-

a) Effluent production and composition

b) Silage Quality

c) Amount of grass that can be stored in a particular silo

EXPERIMENTAL

Absorbents

The following absorbents were tested in this trial:

1 Chopped barley straw

2 Viton straw cubes

3 Barley straw bales

4 Molassed sugar beet pulp shreds (SBP)

Grass

A second cut perennial ryegrass was cut on 25th of July 1985 with a disc mower fitted with conditioner and lifted with a precision-chop forage harvester without wilting. Formic acid was applied at a rate of 4.5 l/tonne grass.

Preparation of Experimental Silages

a) **Experimental Design**

Six silages as shown in Table 4.11 were made from the same grass. Absorbents were either added as a single layer on the floor of the pit or distributed throughout the silage as a series of horizontal layers at approximately 12 cm intervals. The straw bales were tightly packed on edge (cut ends of straws uppermost) into the pit bottom.

b) **Amount of Grass and Absorbents**

Grass was picked up from the field so as to minimise differences between loads by ensuring that each contained grass from different parts of the field. Six separate loads were weighed and dropped on the concrete apron close to the silos. The six silos were filled in turn and the work was completed within 8 hours. Absorbents were added at a rate of 6% of grass fresh weight. The amounts of grass and absorbent for each treatment are shown in Table 4.12.

c) For general details of the method of adding the absorbents, consolidation, covering the silos and effluent collection and sampling (see Chapter 2, pages 49-52). Samples of grass for analysis were obtained by grab sampling each tractor load (approximately 0.3 tonne lifted by fore-end loader) as the pits were filled. Overall composition of the silages was measured in samples obtained by taking six vertical core samples from each pit prior to opening the silos for commencement of the calf trial. For silos which contained absorbents added entirely in the pit bottom, only the grass above the absorbent was sampled. The bottom layers were sampled separately when the pits were opened.

Animals

Twelve Friesian castrated male calves were used. Their mean initial liveweight at the start of the experiment on 10th of January 1986 was 116 kg.

TABLE 4.11

Experimental Design for 1985 Absorbent Trial carried out in "Mini Pit" Silos

Code	Absorbent	Method of Adding the Absorbent
A	No Absorbent	-
B	Viton Straw Cubes	Bottom Layer
C	Chopped Barley Straw	Multi-layered throughout the pit
D	Viton Straw Cubes	Multi-layered throughout the pit
E	Barley Straw Bales	Bottom Layer
F	Molassed Beet Shreds	Multi-layered throughout the pit

TABLE 4.12

Amounts of Grass and Absorbent Ensiled for each Treatment
(kg fresh weight)

Code	Treatment	Grass (kg FW)	Absorbent (kg FW)
A	Control	4,188	-
B	Viton Straw Cubes on Bottom	4,350	261
C	Chopped Barley Straw multi-layer	3,850	231
D	Viton Straw Cubes multi-layer	4,200	252
E	Barley Straw Bales in Bottom	4,375	263
F	Molassed Beet Shreds multi-layer	3,988	239

Housing and Management

The calves were divided into two similar blocks of six animals on the basis of their liveweights. All calves were penned individually on concrete floors with sawdust bedding.

Six wooden metabolism crates were used. Each crate was fitted with a slatted floor and provided with a detachable feed box at the front, together with a removable plastic bucket. Fresh drinking water was provided ad libitum throughout the duration of the trial. Liveweights of the calves were recorded prior to crating.

Experimental Design

The six experimental diets were given to the calves according to an incomplete block design as shown in Table 4.13. Each experimental period was of 18 days duration. For the first 8 days calves were housed in pens to allow a recovery period following restriction in metabolism crates. During this period they received the experimental diet. Thereafter they were transferred to the metabolism crates for the remaining 10 days of the experimental period. Faecal collection was carried out for the last 6 days of each period.

Feeding Routine

An acclimatisation period of one week was given at the start of the experiment to introduce silages to the calves, during which all animals were fed 2.5 kg dry weight of silage per calf per day supplemented with 200g soya bean meal mixed with 25g mineral/vitamin* mix. At the end of this period, each calf was transferred to its appropriate experimental diet. The diets were given twice daily, at 0845 and 1645. The quantities of feed were estimated to provide the maintenance energy requirement of calf plus 10%. A mixture of soya bean meal (200g/calf/day) and mineral/vitamin mix (25g/calf/ day) was sprinkled on the silage before feeding.

From each treatment, a quantity of silage was removed from the silo once a week, weighed and mixed well. Two representative samples were taken, one kept

* Cattle Standard, Scotmin, Maybole, Ayrshire.

TABLE 4.13

Experimental Design of Digestibility Trial

Allocation of Silages*

	Block 1						Block 2					
Period \ Calf No	23	26	9	21	32	37	29	3	17	7	4	22
1	A	B	C	D	E	F	A	B	C	D	E	F
2	D	E	F	A	B	C	F	A	B	C	D	E
3	E	F	A	B	C	D	B	C	D	E	F	A

*See Table 4.11 for explanation of Silage Treatment Codes.

in a deep freeze for chemical analysis and the other was used for dry matter determination. For each treatment, silage was weighed equally into twelve bags which were sealed and stored in a deep freeze. Two bags from each treatment were taken out of the freezer in the evening and fed in the next day, one in the morning and the other in the evening.

COLLECTION, SAMPLING AND PREPARATION OF MATERIAL FOR ANALYSIS

Feed

After weighing and mixing the silage, a representative sample was taken for DM determination, then, after drying, milled and stored in sealed containers.

Feed Refusals

Any residues remaining from the previous day's feed were removed prior to the next feed, weighed and stored. Residues for each two days were mixed, sampled and processed as described for feed samples.

Faeces

During the collection period, faeces were removed every day, weighed and stored in a sealed plastic bucket at 5°C. The six day faecal collection period was divided up into three sub-periods, each of two days. Faeces for each two day period were mixed using a food mixer and two representative samples were taken for DM determination and subsequent analysis.

ANALYTICAL METHODS

In general, the techniques described in chapter 2 were used but the following modifications should be pointed out.

Dry Matter

All feed, feed residues and faeces samples were dried in metal trays for 24 hours at 100°C in a forced draught oven. Duplicate samples, each of approximately 300g were used in all cases. The dried samples were then ground

to pass a 6.6 mm sieve in a Christie and Norris* mill prior to subsequent analysis.

RESULTS

Composition of Grass

The grass composition for each silo is shown in Table 4.14. Grass DM contents ranged from 138 to 167 gkg^{-1} (mean 148 gkg^{-1}). The mean WSC concentration of the grass was 73.6 gkg^{-1} DM and the mean *in vitro* D-value was 58.3%.

Composition of Absorbents

Table 4.15 shows the composition of absorbents. DM contents of the absorbents were 869, 845 and 844 gkg^{-1} for Viton Straw Cubes, Chopped Barley Straw and Molassed Beet Shreds respectively. The CP content of the molassed beet shreds (SBP) was 109 gkg^{-1} DM, whereas Viton straw cubes and chopped barley straw have a CP content of 34 and 44 gkg^{-1} DM respectively. Only molassed beet shreds contained a high content of WSC (290 gkg^{-1} DM).

The mean values obtained for the digestibility of organic matter (*in vivo* OMD) and energy (*in vivo* ED) are also shown in Table 4.15. The values have been calculated from intake and faecal excretion measured in a separate trial using six sheep over the last six days of a sixteen day period on each absorbent (see Appendix 5). The ME values were calculated from the following equation:

$$ME\ (MJkg^{-1}\ DM) = 0.81 \times DE\ (MJkg^{-1}\ DM) \qquad \text{(ARC 1980)}$$

The *in vivo* OMD for Viton straw cubes, chopped barley straw and molassed beet shreds were 0.580, 0.499 and 0.902 respectively. The corresponding ME values were 7.8, 7.4 and 12.3 $MJkg^{-1}$ DM respectively. Thus the two straw materials

* Christie and Norris Ltd, Kings Road, Chelmsford, CM1 1SB.

TABLE 4.14

Composition of Grass used in Each Treatment

Composition	Treatment						
	A	B	C	D	E	F	Mean*
DM (gkg^{-1})	149	140	167	138	145	149	148
OM (gkg^{-1} DM)	894	880	854	889	885	894	883
CP (gkg^{-1} DM)	183	185	142	202	183	187	183
WSC (gkg^{-1} DM)	73.0	79.7	82.1	72.6	65.8	68.5	73.6
<u>In vitro</u> D-value (%)	58.5	60.4	54.7	61.0	56.9	58.5	58.3
ME ($MJkg^{-1}$ DM)	9.8	10.2	9.2	10.3	9.5	9.8	9.8
Ash (gkg^{-1} DM)	106	120	146	111	115	106	117

* Mean Composition of Grass

TABLE 4.15

Composition of the Absorbents

Composition	Absorbent		
	Viton Straw Cubes	Chopped Barley Straw	Molassed Beet Shreds
DM (gkg^{-1})	869	845	844
OM (gkg^{-1} DM)	860	951	906
CP (gkg^{-1} DM)	34	44	109
WSC (gkg^{-1} DM)	29.2	12	290
In vivo OMD	0.580	0.499	0.902
In vivo ED	0.548	0.476	0.890
ME ($MJkg^{-1}$ DM)	7.8	7.4	12.3
GE ($MJkg^{-1}$ DM)	18.3	19.9	17.7
Ash (gkg^{-1} DM)	140	49	94

were similar both in composition and *in vivo* digestibility. The SBP showed much higher digestibility and higher levels of CP and WSC compared to the straw materials.

Composition of Silages

Silage analyses are shown in Table 4.16. It should be noted that in the case of treatments B and E, which contained absorbents added entirely in the pit bottom, the analysis refers only to the grass silage above the absorbent. The oven DM content of silage A (control silage) was 156 gkg^{-1}. Only treatment D (Viton straw cubes layered) showed a marked increase (compared to silage A) in the DM content of the silage (201 gkg^{-1}). For the remaining multi-layered silages (C and F) the silage DM was only slightly higher than for the control silage.

The CP content of the control silage was 181 gkg^{-1} DM. Treatment C (chopped straw) showed the largest reduction in CP content (105 gkg^{-1} DM) followed by treatment D (CP content 136 gkg^{-1} DM) and treatment F (CP content 157 gkg^{-1} DM).

The WSC content of the control silage was 14.7 gkg^{-1} DM. Treatment E (straw bales) showed the highest WSC concentration (20.2 gkg^{-1} DM), whereas treatments C (chopped straw) and D (Viton layered) showed the lowest WSC concentration (11.1 and 11.0 gkg^{-1} DM respectively).

All treatments generally showed a similar ammonia-N concentration to the control. It ranged from 61 gkg^{-1} total-N for treatment C (chopped straw) to 81 gkg^{-1} total-N for treatment D (Viton layered). pH values for all treatments were also low, ranging from 3.6 for treatment E (straw bale) to 4.0 for treatments C and D. Butyric acid values for all treatments were low, with the highest value of 1.6 gkg^{-1} DM for the control silage. Thus, according to pH values, ammonia-N and butyric acid concentration, all silages were well preserved.

The lactic acid content of the control silage was 52.9 gkg^{-1} DM. Treatment C (chopped straw) showed the lowest lactic acid content (31.2 gkg^{-1} DM), whereas treatment E (straw bales) which also showed the lowest pH recorded the highest

TABLE 4.16

Composition of Silages

Composition°	Treatment					
	A	B+	C	D	E+	F
Oven DM (gkg^{-1})	156	155	164	201	168	169
Toluene DM (gkg^{-1})	171	174	177	210	180	179
OM (gkg^{-1} DM)	894	871	880	860	899	885
CP (gkg^{-1} DM)	181	177	105	136	175	157
WSC (gkg^{-1} DM)	14.7	15.6	11.1	11.0	20.2	13.0
Ash (gkg^{-1} DM)	106	129	120	140	101	115
Ca (gkg^{-1} DM)	6.4	6.0	4.1	5.3	6.2	6.8
P (gkg^{-1} DM)	3.5	3.4	2.0	2.5	3.4	2.4
Mg (gkg^{-1} DM)	1.8	1.5	1.0	1.2	1.7	1.5
GE* ($MJkg^{-1}$ DM)	19.9	19.3	19.3	19.5	19.3	19.4
pH	3.8	3.8	4.0	4.0	3.6	3.7
Ammonia-N (gkg^{-1} total-N	70	80	61	81	79	69
Lactic Acid (gkg^{-1} DM)	52.9	40.5	31.2	75.0	102	53.4
Acetic Acid (gkg^{-1} DM)	12.3	7.9	4.9	14.0	12.2	7.7
Propionic Acid (gkg^{-1} DM)	1.2	0.94	1.2	0.89	0.86	1.1
Butyric Acid (gkg^{-1} DM)	1.6	0.82	0.88	0.71	1.1	0.64
Ethanol (gkg^{-1} DM)	21.9	14.1	2.0	3.5	1.4	4.0

* GE was measured on fresh minced silage

+ Analysis is only for the grass above the bottom layer of absorbent

° Oven DM is used as the base for analytical parameters

concentration (102 gkg^{-1} DM). Acetic acid for all treatments ranged from 7.7 gkg^{-1} DM for treatment F (molassed beet shreds) to 13.9 gkg^{-1} DM for treatment D (Viton layered).

Digestibility of the Silages

Table 4.17 shows the apparent in vivo digestibilities of the six silages which were measured using calves. Addition of chopped straw (treatment C) or Viton cubes (treatment D) to grass at ensiling, resulted in a significant ($P < 0.01$) reduction in digestibility of organic matter and gross energy when compared to the values for the control (treatment A). However, addition of SBP (treatment F) to grass at ensilage, resulted in a significant ($P < 0.05$) increase in both OMD and ED when compared to the control. Chopped straw and Viton straw cubes (treatments C and D respectively), significantly ($P < 0.001$) reduced the ME of the silage by 1.0 and 0.9 $MJkg^{-1}$ DM compared to the value for the control silage. Incorporation of SBP (treatment F) showed a small beneficial effect on the ME of the silage (0.27 $MJkg^{-1}$ DM) but the effect was not significant ($P < 0.05$).

No significant ($P < 0.05$) differences in OMD, ED and ME were obtained between silages made with multi-layers of chopped straw (treatment C) and Viton straw cubes silage (treatment D).

Analysis of variance for data obtained for OMD, ED and ME for the six treatments are reported in Appendices 6, 7 and 8. Complete tabulated results are shown in Appendix 9.

Composition of Bottom-Layered Absorbents after Ensiling

Analysis was carried out on representative samples of absorbents which had been used in the bottoms of the silos (treatments B and E). Table 4.18 shows the composition of these two absorbents. Treatments B (Viton straw cubes) and E (straw bale) had a DM content of 303 and 296 gkg^{-1} respectively. The ash content of Viton straw cubes was dramatically reduced from 140 to 56 gkg^{-1} DM before and after ensiling respectively. The digestibility of these two absorbents was measured in vivo using six sheep (see Appendix 5). The OMD values were 0.567 and 0.466 for Viton and straw bale (chopped) compared to

TABLE 4.17

Mean* Apparent Digestibilities of the Experimental Silages Measured Using 12 Friesian Calves

Treatment	Mean Apparent Digestibility		ME+
	OMD	ED	
A	0.683^{b}	0.672^{b}	10.82^{be}
B[1]	0.693^{bc}	0.679^{b}	10.61^{bc}
C	0.625^{a}	0.629^{a}	9.81^{a}
D	0.631^{a}	0.629^{a}	9.93^{a}
E[1]	0.677^{b}	0.667^{b}	10.44^{c}
F	0.717^{c}	0.705^{c}	11.09^{e}

* Means in the same column not sharing common subscripts differ significantly ($P < 0.05$).

1 Values refer only to ensiled grass above the bottom absorbent layer

\+ Calculated from ME = 0.81 X DE ($MJkg^{-1}$ DM) expressed on an Oven DM basis

TABLE 4.18

Composition of Absorbents (bottom layers) after Ensiling

Composition	Absorbent	
	Viton Straw Cubes	Straw Bales
DM (gkg^{-1})	303	296
OM (gkg^{-1} DM)	944	947
CP (gkg^{-1} DM)	39	56
WSC (gkg^{-1} DM)	12.6	8.9
<u>In vivo</u> OMD	0.567	0.466
<u>In vivo</u> ED	0.532	0.422
ME ($MJkg^{-1}$ DM)	8.51	6.65
GE ($MJkg^{-1}$ DM)	19.8	19.5
Ash (gkg^{-1} DM)	56	53

values of 0.580 and 0.499 obtained for samples of these materials which had not been used as absorbents.

Volume Occupied by Silage

Silage densities were measured after the silage had been compacted and sheeted, but before the silo roof was erected. The volume occupied by the silage was calculated from measurements taken of the distances between the top surface of the silage and the top of the silo walls made at 0.5 m intervals along each wall. Table 4.19 shows silage densities (tonnes/m^3 for grass and absorbent) and the volume (m^3) required to ensile one tonne of grass (not including absorbent). It also shows the change of volume (%) for each treatment when compared to the control. Treatments E (straw bales) and C (chopped straw) had the greatest effect on silage density.

Effluent Production

Table 4.111 shows the total effluent volume produced from each treatment, together with volume of effluent produced per tonne of grass.

Due to slight differences in the DM of grass added to each silo, an average grass DM was calculated (148 gkg^{-1}) and effluent volume per tonne of grass was corrected by assuming a direct linear relationship between effluent production and grass DM over the narrow range of grass DM values observed as follows:-

$$\text{Corrected Effluent Volume } (lt^{-1} \text{ grass}) = \frac{\text{total observed effluent (l)}}{\text{grass fresh weight (t)}} \times \frac{\text{grass DM } (gkg^{-1}) \text{ for particular treatment}}{\text{Average Grass DM } (gkg^{-1})}$$

The results suggested that only treatments C (chopped straw) and F (SBP) reduced effluent volume appreciably (by 61 and 48% respectively). Treatment E (straw bales) however, showed a slight increase in effluent volume (of 7%).

TABLE 4.19

Effect of Adding Absorbent on Silage Density and the Volume Required to Store one Tonne of Grass*

Treatment	Silage Density tonne/m^3	Silo Volume needed m^3/tonne grass	Change in silo volume needed compared to Control (%)
A	0.89	1.12	-
B	0.81	1.31	+17
C	0.54	1.97	+76
D	0.84	1.26	+13
E	0.53	2.01	+79
F	0.69	1.53	+37

* Measured immediately after sheeting the silos.

TABLE 4.111

Effluent Produced from Grass Silage Treatments

Treatment	Total Effluent Produced (l)	Effluent Produced (lt^{-1} of grass)	Corrected Volume* (lt^{-1} grass)
A	751	136	137
B	595	137	130
C	181	47	53
D	511	122	114
E	652	149	146
F	282	71	71

* Corrected for DM content of grass see page150 for details of correction.

Composition of Silage Effluent

Table 4.112 shows the composition of the effluent collected from the six silos. The DM content of the effluent collected from the control silage was 42 gkg^{-1}. Addition of Viton straw cubes, either on the bottom of the silo (treatment B) or mixed with the grass (treatment D), resulted in a marked increase in the effluent DM content (67 and 53 gkg^{-1} respectively). Effluent collected from treatment F (molassed beet shreds) also had a higher DM content (57 gkg^{-1}) compared to the control silage.

The CP content of the effluent collected from the control silage (treatment A) was 262 gkg^{-1} DM. Treatments B and C showed a lower CP content of their effluent, whereas effluent from treatments D, E and F showed CP contents similar to that for the control silage.

WSC content of the control silage effluent was 366 gkg^{-1} DM and similar values were observed for treatments C and E (348 and 387 gkg^{-1} DM respectively). Treatments B, D and F gave WSC levels in effluent considerably lower than for the control silage (163, 235 and 246 gkg^{-1} DM respectively). The ash contents of all effluents were high, ranging from 261 gkg^{-1} DM for treatment F to 350 gkg^{-1} DM for treatment E.

The biochemical oxygen demand (BOD_5) of effluent for each silage treatment are shown in Table 4.112. The BOD_5 of the control silage effluent was 20.0 gO_2l^{-1}, whereas higher values of 51.6, 43.0 and 52.5 gO_2l^{-1} effluent were recorded for treatments B, C and F respectively. Only treatment C (chopped straw) produced effluent with a BOD_5 value less than the control effluent.

In-silo Nutrient Losses

Nutrient recoveries were calculated as follows:

$$\text{Silage Nutrient Recovery (\%)} = \frac{\text{total nutrient recovered in silage + absorbent}}{\text{total nutrient added in grass + absorbent}} \times 100$$

TABLE 4.112

Composition of Silage Effluents

Composition	Treatment					
	A	B	C	D	E	F
DM (gkg^{-1})	41	67	37	53	38	57
pH	3.9	4.2	4.1	4.2	3.8	3.9
OM (gkg^{-1} DM)	692	695	655	766	655	739
CP (gkg^{-1} DM)	262	153	169	215	281	259
WSC (gkg^{-1} DM)	366	163	348	235	387	246
Lactic Acid (gkg^{-1} DM)	31.4	78.6	74.3	107	55.6	125
Ammonia-N (gkg^{-1} total-N)	18.6	17.1	33.6	15.8	39.0	12.3
Ash (gkg^{-1} DM)	308	305	345	234	350	261
BOD_5 (gO_2l^{-1} effluent)	20.0	51.6	16.5	43.0	20.1	52.5
Acetic Acid (gl^{-1})	1.2	8.3	2.1	1.5	0.5	1.6
Propionic Acid (gl^{-1})	0.3	0.1	0.8	0.2	0.5	0.3
Butyric Acid (gl^{-1})	0.2	0	0.5	0.1	0.3	0.3
Ethanol (gl^{-1})	0.5	0.6	0.2	0.4	0.3	1.2

Table 4.113 shows the proportion of nutrients recovered in silages. DM recovery for the control was 77.3% and the values for the remaining silages were within 3% units of this figure. CP recovery in the control silage was 77.7%. Only treatment C (chopped straw) with a recovery of 54.3% showed a marked deviation from this figure. DOM recovery for the control silage was 76.9% and treatments B, E and F gave similar values. However, slightly lower recoveries were recorded for treatments C and D (72.8 and 73.1% respectively).

Table 4.114 shows the proportion of nutrients added to the silo in grass and absorbent which recovered in silage effluents. DM recovery in the control silage effluent was 5.0%. Treatment C (chopped straw) gave the biggest reduction in DM recovery in silage effluent. Only 0.8% of the total DM ensiled in treatment C was recovered in effluent. The next lowest DM recoveries were for treatments F and E (2.0 and 2.9% respectively). Treatment B however, showed a similar DM recovery to the control (4.7%). OM recoveries for all treatments followed the same pattern as for DM. CP recovered in control silage effluent was 7.4%. The lowest loss of CP in effluent was observed for treatment C followed by treatment F (0.9 and 3.2% respectively). The percentage of WSC recovered in effluent from the control silage was 25.0%. The values were much lower for the other silages effluent with the lowest recoveries measured for treatments F and C (3.8 and 4.7% respectively).

Table 4.115 shows the nutrients recovered in the bottom layered absorbents from silo B and E as a percentage of nutrients added in the absorbent before ensiling. Straw bales (treatment E) showed a higher recovery of DM, OM, DOM and ME than treatment B (Viton straw cubes). The DM recovery for straw bales and Viton cubes were 109 and 83% respectively. OM recoveries followed the same pattern as for DM. Thus for the straw bales there was a net increase in total DM and OM due to the soaking of the bales in silage effluent. However, for DOM and ME there was no net gain or loss due to the bales being used as an absorbent. For the Viton straw cubes used as a bottom layer, there was a 10% loss in OM, DOM and ME.

TABLE 4.113

Proportion of Nutrients Recovered in Silages[+] (%)

Nutrient	Treatment					
	A	B	C	D	E	F
DM	77.3	75.1	76.9	78.5	80.9	79.0
OM	78.3	76.6	75.3	77	82.2	78.7
DOM*	76.9	75.2	72.8	73.1	76.9	75.3
ME	85.4	81	81.7	84	80	84
CP	77.7	72.5	54.3	76.7	74.2	76.7
WSC	15.4	17.9	14.4	14.3	22.6	8.0

[+] See page 153 for details of calculation

* Digestible organic matter measured *in vivo*.

TABLE 4.114

Proportion of Nutrients Added in Grass and Absorbent Recovered In Effluent

Nutrient	Treatment					
	A	B	C	D	E	F
DM	5.0	4.7	0.8	3.4	2.9	2.0
OM	4.0	3.8	0.6	3.0	2.1	1.7
CP	7.4	5.2	0.9	5.2	5.6	3.2
WSC	25.0	12.5	4.7	13.0	19.1	3.8

TABLE 4.115

Proportion of Nutrients Recovered in Absorbents* (%)

Nutrient	Treatment	
	B (Viton straw cubes)	E (straw bales)
DM	83	109
OM	91	108
DOM+	89	101
ME	91	97

* For absorbents which have been stored in the bottom of the silo

\+ Digestible organic matter measured *in vivo*.

DISCUSSION

Composition of Grass

The grass dry matter of samples taken as the six silos were filled, ranged from 138 to 167 gkg^{-1} (mean 148 gkg^{-1}). This range was wider than had been anticipated as precautions had been taken to ensure the similarity of each load of grass. It reflects the difficulty of achieving accurate experimental control in field scale trials and it meant that it was necessary to apply small corrections to the effluent data to allow for differences in grass DM for each silo. The mean WSC content of the grass was 10.8 gkg^{-1}. A WSC concentration of 25-30 gkg^{-1} in herbage for ensiling is desirable for unwilted silage to be made without additives (Dijkstra, 1957; Zimmer, 1971; Hastings, 1972; Wilkins, 1974; ADAS, 1979). In a recent study, Haigh and Parker (1985) from 22 samples of unwilted silage treated with formic acid, suggested that a minimum WSC necessary to produce successful preservation is 24 gkg^{-1}. These results indicate that the WSC of the grass used in this trial is low and problems with regard to preservation would be anticipated on the basis of farm scale trials.

Composition of Silages

The DM content of the control silage was 156 gkg^{-1}. Treatment C (chopped straw silage) and F (molassed beet shred silage) showed a DM content of 164 and 169 gkg^{-1} respectively (see Table 4.16). Although these two treatments have been mixed with dry materials (DM 845 and 844 gkg^{-1} for chopped straw and SBP respectively), their silage DM contents were only slightly higher than the control. This was probably due to the efficiency of these absorbents in retaining effluent within the silo. Treatment D (Viton layers) however, showed a silage with DM content of 201 gkg^{-1}, considerably higher than the control. This increase in DM content probably reflects the poor absorbent characteristics of Viton which caused only a slight reduction in effluent volume.

CP content of the control silage was 181 gkg^{-1} DM. Treatment C (chopped straw silage) showed the greatest reduction in CP content (105 gkg^{-1} DM) as would be expected from the low CP content of the absorbent (44 gkg^{-1} DM) which would

dilute that of the grass. Treatments D (Viton cubes layers) and F (SBP) also showed reductions in CP content compared to the control, but to a lesser extent than for the chopped straw treatment.

McDonald (1981) classified silages into categories depending upon their main fermentation characteristics as follows:

1 Lactate silages characterised by having low pH values (3.7 to 4.2) and containing high levels of lactic acid (80-120 gkg^{-1} DM) and low contents of acetic acid (less than 35 gkg^{-1} DM) and butyric acid (less than 2 gkg^{-1} DM).

2 Acetate silages characterised by having pH value 4.3 to 4.8 and containing higher values of acetic acid (approximately 90 gkg^{-1} DM) and lower values of lactic acid (approximately 30 gkg^{-1} DM).

3 Clostridial silages characterised by having pH values within the range of 5.0 to 7.0 and containing high levels of butyric acid (approximately 30 gkg^{-1} DM) and a very small content acetic and lactic acids.

4 Wilted silages characterised by having pH values within the range of 4.1 to 4.5 and containing low levels of lactic acid (30-55 gkg^{-1} DM) and acetic acid (10-15 gkg^{-1} DM) but a higher content of WSC depending on the content of ensiled crop.

5 Additive inhibited silages characterised by having pH value less than 4.3 and lactic acid content of approximately 30-50 gkg^{-1} DM (depending on the application rate of formic acid) and acetic acid content of about 10 gkg^{-1} DM and butyric acid content of less than 1 gkg^{-1} DM, but a higher content of WSC depending on the content of the ensiled crop.

In this trial the pH of the silages ranged from 3.6 to 4.0 and the mean (gkg^{-1} DM) lactic, acetic and butyric acid contents of the silages were 59.2, 9.8 and 0.96 respectively. However, according to the McDonald (1981) classification, as reported above, this silage is considered an additive inhibited silage, but the content of WSC of the silage (mean 14.3 gkg^{-1} DM) is

lower than typical for this category of silage.

All silages were well preserved with low pH, ammonia-N and butyric acid contents. The pH value of the control silage was 3.8 and ranged for other silage from 3.6 for treatment E to 4.0 for treatments C and D. McDonald and Whittenbury (1973) reported that achievement of a pH value of 4.2 or less for unwilted silage will ensure that the material will normally remain stable. The ammonia-N content of the silages ranged from 61 gkg^{-1} for treatment C to 80 gkg^{-1} total-N for treatment D (see Table 4.16). The control silage has an ammonia-N content of 70 gkg^{-1} total-N. Haigh and Hopkins (1977) reported that an ammonia-N of less than 80-100 gkg^{-1} total-N is commonly used to indicate that silage is well fermented. Butyric acid content of the silages ranged from 0.64 for treatment F (molassed beet shred silage) to 1.62 gkg^{-1} DM for the control. Butyric acid content of less than 5 gkg^{-1} DM is indicative of good quality grass silage (Brierem and Ulvesli, 1960; Wieringa, 1966). It is concluded that, according to the pH values, ammonia-N and butyric acid concentrations, absorbent addition had no clear effect on silage preservation when compared to the control. The fact that the control silage was well preserved, meant that it would be difficult to prove any advantages due to incorporation of absorbents. However, the experiment showed no reduction in silage preservation quality when absorbents were incorporated. In the case of Viton straw cubes and chopped straw, reduced preservation quality may have been anticipated as both materials contributed very little fermentable substrates and the former material was strongly alkaline (pH 10).

Digestibility of the Silage

Measurement of the effect of adding absorbent to grass at ensiling on the digestibility of the silage was one of the main objectives of this trial. The effect can only be assessed for absorbents added as layers in the silo (treatments C, D and F) which were fed as a mixture of grass and absorbent to the calves. The digestibilities of other treatments were also measured but applied only to the grass above the bottom absorbent layer (see Table 4.17). The OMD of the control diet (treatment A) was 0.683, which agrees well with OMD reported by McIlmoyle (1976) and Steen and McIlmoyle (1985) for silages made from similar herbage. The energy digestibility (ED) of the control silage was also similar to that reported by McIlmoyle (1976) and Steen and

McIlmoyle (1985). Addition of chopped straw (treatment C) or Viton straw cubes (treatment D) to grass at ensiling resulted in a significant ($P < 0.01$) reduction in OMD and a highly significant ($P < 0.001$) reduction in ED when compared to the control. No significant ($P < 0.05$) difference between treatments C and D in OMD or ED were found (see Table 4.17). However, addition of SBP (treatment F) resulted in a significant ($P < 0.05$) increase in OMD and ED when compared to the control.

The metabolisable energy (ME) values of the silages were calculated from DE using ME = 0.81 X DE ($MJkg^{-1}$ DM) and therefore showed a similar pattern of treatment differences. However, the slightly lower GE of silage F (SBP) compared to the control (19.4 and 19.9 $MJkg^{-1}$ DM respectively) resulted in the ME value of the former silage being only 0.27 $MJkg^{-1}$ higher than the control which was not a significant difference ($P < 0.05$).

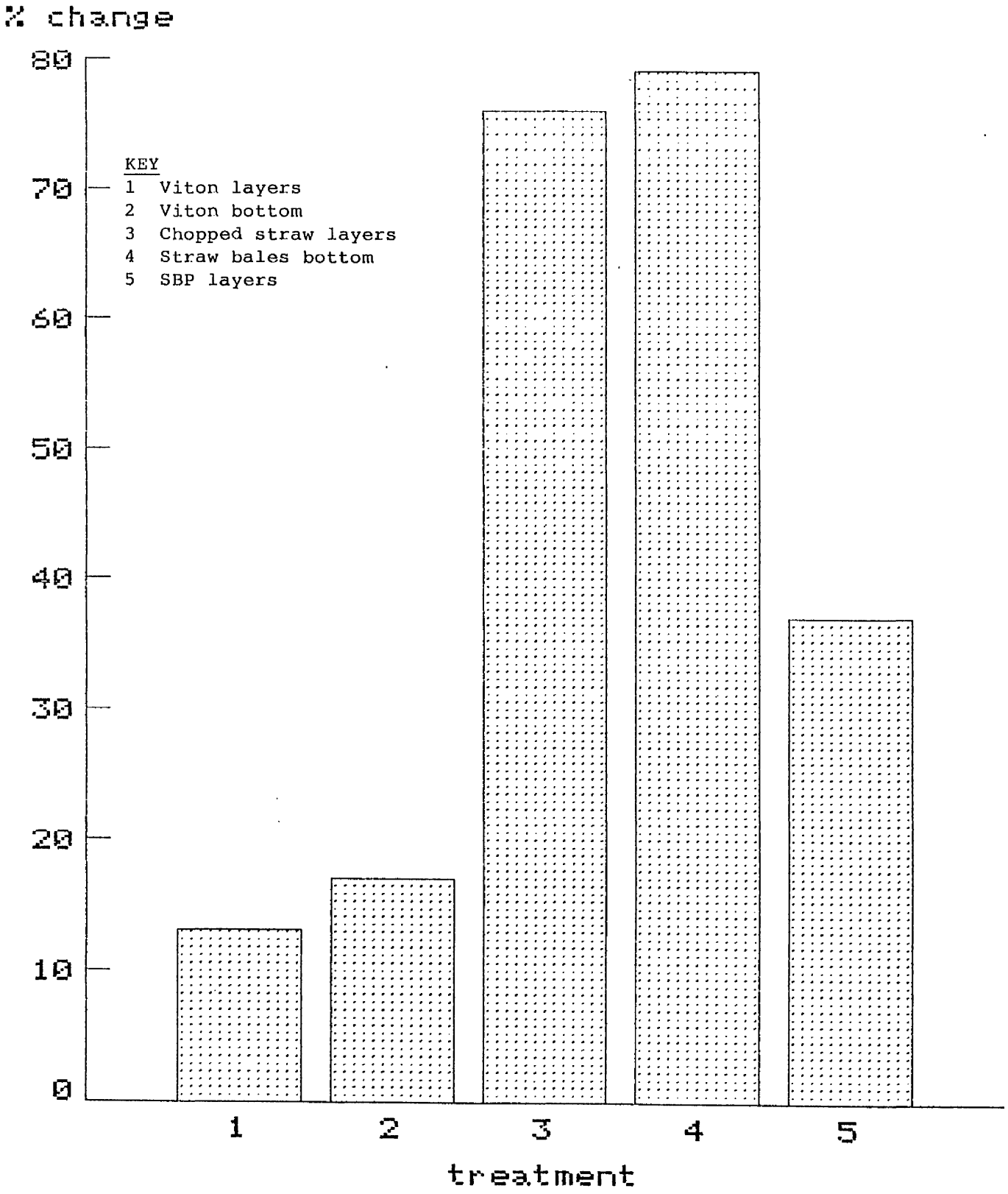
The reduction in the apparent digestibilities of OM and GE for treatments C and D compared to the control was expected, since both straw and Viton straw cubes showed a low digestibility when measured in a separate trial (see Table 4.15) which would be expected to dilute the digestibility of the grass in the mixed silage. However, the expected OMD for the chopped straw silage (0.636) at the inclusion rate is similar to that observed (0.629). The increase in the apparent digestibilities for treatment F (SBP) over the control may have been expected to be slightly higher than actually obtained since the SBP showed an in vivo OMD of 0.90 which at the inclusion rate used would be expected to increase the OMD of silage F to 0.74. However, the observed OMD for this silage was 0.717 which is slightly lower than the expected value. This discrepancy indicates that some of the highly digestible nutrients in the SBP were lost either in fermentation losses in the silo or due to being washed out in silage effluent.

Volume Occupied by Silage

Adding an absorbent to grass in a silo must decrease the amount of grass which can be stored in the silo. However, ideally the absorbents should have a high moisture holding capacity which reduces the quantity needed to control effluent and should have a high density so as to occupy as small a volume as possible in the silo. Measurements made in this trial (Figure 4.11) showed

FIGURE 4.11

THE EFFECT OF ABSORBENT ADDITION ON THE STORAGE VOLUME REQUIRED PER TONNE OF GRASS FW (1985 TRIAL)



that straw bales (treatment E) used at 6% of grass FW, increased the silo volume needed to store one tonne of grass by 79%. Treatment C (chopped straw) also greatly increased the storage volume needed (76%). Treatment F (SBP) increased the storage volume by 37%, whereas treatments D and B had smaller effects (13 and 17% respectively).

The low density of straw (either chopped or baled) is thus a serious limitation to its use as an absorbent, but must be considered in conjunction with the effect on effluent losses, silage quality and the total nutrients stored in a given silo.

Effluent Production

The volume of effluent lost from a silage clamp is dependent on the moisture content of the herbage at ensiling (Jones and Murdoch, 1954; Castle and Watson, 1973). Stewart and McCullough (1974) suggested that the volume of effluent produced from grass ensiled at less than 150 gkg^{-1} is between 378 and 189 l/tonne grass. Bastimen (1976), Patterson and Walker (1980) estimated effluent production to be 200-225 l/tonne grass for grass ensiled at 150 gkg^{-1}. In this trial however, the volume of effluent produced from the control silage was 137 l/tonne which is considerably lower than most literature values for silage made at this DM. These differences may be due to the small scale in which this trial was conducted, which might be expected to result in a lower degree of compaction and pressure than would be achieved in a farm scale silo. However, density for the control silage (0.89 tonne/m^3), as measured before any settlement of the silage had occurred, is similar to a value of 0.83 tonne/m^3 reported by Johnston et al (1985) for grass of similar DM in large scale silos. Thus the degree of compaction achieved in the "mini pit" silos was comparable to that commonly found in farm scale silos. Nevertheless, the pressures experienced in a farm scale silo by grass at depths of greater than 1.5 m from the silage upper surface would be greater than that for the "mini pit" silos where the silage depth did not exceed this figure. For silage of density 0.89 tonne/m^3, the pressure experienced by grass at a depth of 1.5 m (the bottom of the mini pit silos) would be approximately 13 kg/dm^2. However, at a depth of 3.5 m (as in a large farm scale silo) the pressure would be approximately 31 kg/dm^2 which is similar to the pressure used in the wine press technique described in Chapter 3. Other

work has shown that consolidation and the amount of pressure applied to grass can affect effluent production in a particular silo (Kirsh et al, 1955; McDonald et al, 1960).

Both absorbents added to grass silage as a bottom layer (Viton cubes and straw bales) proved ineffective in reducing effluent volume (see Table 4.111). Treatment B (Viton on bottom) reduced effluent volume by only 7 l/tonne grass compared to the control, whilst treatment E (straw bales) gave an increase of 9 l/tonne grass FW. The increase in effluent volume observed for treatment E compared to the control was particularly surprising since this is the method most frequently recommended to farmers. The straw bales appeared to promote effluent flow perhaps, by providing convenient drainage channels. this hypothesis is supported by the recent findings of Clark (1987). In his study, 150 mm wide prepunched metal drainage channels were placed on the silo floor at 6 m intervals. These drainage channels continued up the side wall of the silo to a height of 1.2 m. In two experiments he found that providing drainage channels increased effluent production by 44 and 51%. In the present trial the initial rate of effluent flow was faster for the bale silo which is also consistent with the work of Clark (1987). The straw bales did soak up effluent (final straw DM was 296 gkg^{-1}) but nevertheless, the volume of effluent collected was slightly greater than the control.

Adding chopped straw or SBP to grass silage as a series of layers in the silo proved effective in reducing effluent production. However, Viton straw cubes (treatment D) reduced effluent production by only 17% compared to the control (see Table 4.111). This reduction was nevertheless greater than when the same weight/tonne grass of Viton cubes were added as a single layer in the bottom of the pit (17% and 5% respectively). Chopped straw addition (treatment C) reduced effluent production by 61% compared to the control, giving 53 l/tonne of grass. This is in agreement with results reported by Pederson (1979). Addition of SBP resulted in a 48% reduction in effluent volume compared to the control. It is concluded that, of those absorbents tested, only chopped straw and SBP gave a practically useful reduction of effluent production.

Composition of Effluent

The composition of the dry matter in silage effluent will be influenced by the

composition of the sap, by chemical changes resulting from the fermentation and by changes in the effluent following its discharge.

The DM content of the effluent collected from the control silage was 42 gkg^{-1}. This value in in agreement with literature values (Watson and Nash, 1960; Woolford, 1978, Fisher et al, 1981; Patterson and Steen, [1981-82]). Addition of straw either chopped as in treatment C or as bales as in treatment E, resulted in a slight reduction in effluent DM (see Table 4.112). This however, was expected since neither absorbent contains soluble materials that would be lost in the effluent. Addition of Viton straw cubes either on the silo bottom as in treatment B or mixed with grass as in treatment D, resulted in a marked increase in DM content (61% and 28% respectively) of the effluent compared to the control. Addition of SBP (treatment F) also resulted in a large increase in effluent DM (37% compared to control).

The CP content of the effluent is shown in Table 4.112. Control silage effluent had a CP content of 262 gkg^{-1} DM. This value is similar to that found by Lowman et al (1983). They reported that the crude protein content of grass silage effluent ranged from 160 to 300 gkg^{-1} DM, and is typically approximately 260 gkg^{-1} DM. Effluent collected from treatments B and C had crude protein content lower than the control, whereas treatments E and F showed a similar CP content to the control.

The WSC content of the effluent collected from the control silage was 366 gkg^{-1} DM which was higher than the values reported by Patterson and Steen (1981-82), who found levels in the range of 142 to 286 gkg^{-1} DM. Lactic acid content of the effluent collected from the control silo was 31.4 gkg^{-1} DM. This value was lower than that reported by Patterson and Steen (1981-82) and by Steen (1986). However, the higher value of WSC and the lower value of lactic acid may indicate a restriction in silage fermentation due to the high rate of formic acid applied in the present study (4.5 lt^{-1}). The WSC concentration of the effluent collected from the silage which contained SBP (246 gkg^{-1} DM) was considerably lower than for the control. However, the lactic acid level for the effluent from this silage (125 gkg^{-1} DM) was considerably higher than for the control. These results suggest that the soluble sugars (mainly molasses) which leaked from the SBP silage undergo considerable fermentation, either in the silo, or in the effluent collection

tank.

Losses of OM and BOD_5 in Effluent

Table 4.116 shows the effect of adding absorbents on OM concentration in effluent (gl^{-1}) and on the total OM loss in effluent per tonne of grass. A similar pattern was observed as has been described for DM. Viton straw cubes increased the OM concentration in effluent by 62% (treatment B) and 41% (treatment D) compared to the control effluent. SBP also increased the OM concentration in effluent (by 46% compared to the control).

The increases in DM and OM content of the effluent collected from the Viton straw cube treatments or the SBP treatments are presumably due to small particles and soluble constituents from the added absorbents being washed out with the effluent. An effect of alkali treatment on straw (as in the manufacture of Viton cubes) is to make soluble up to 30% of the straw OM (Beckmann, 1921). Molassed beet shreds contain approximately 30% of their DM in the form of WSC (see Table 4.15). Nevertheless, the increase in effluent OM concentration compared to the control for the latter absorbent represents only approximately 6% of the WSC added to the clamp as absorbent. Thus most of the soluble (and highly digestible) components of the Viton cubes and the SBP were retained in the clamp. However, the consequences of the increase in effluent OM concentration when Viton cubes or SBP are used as absorbents are serious from the viewpoint of pollution control.

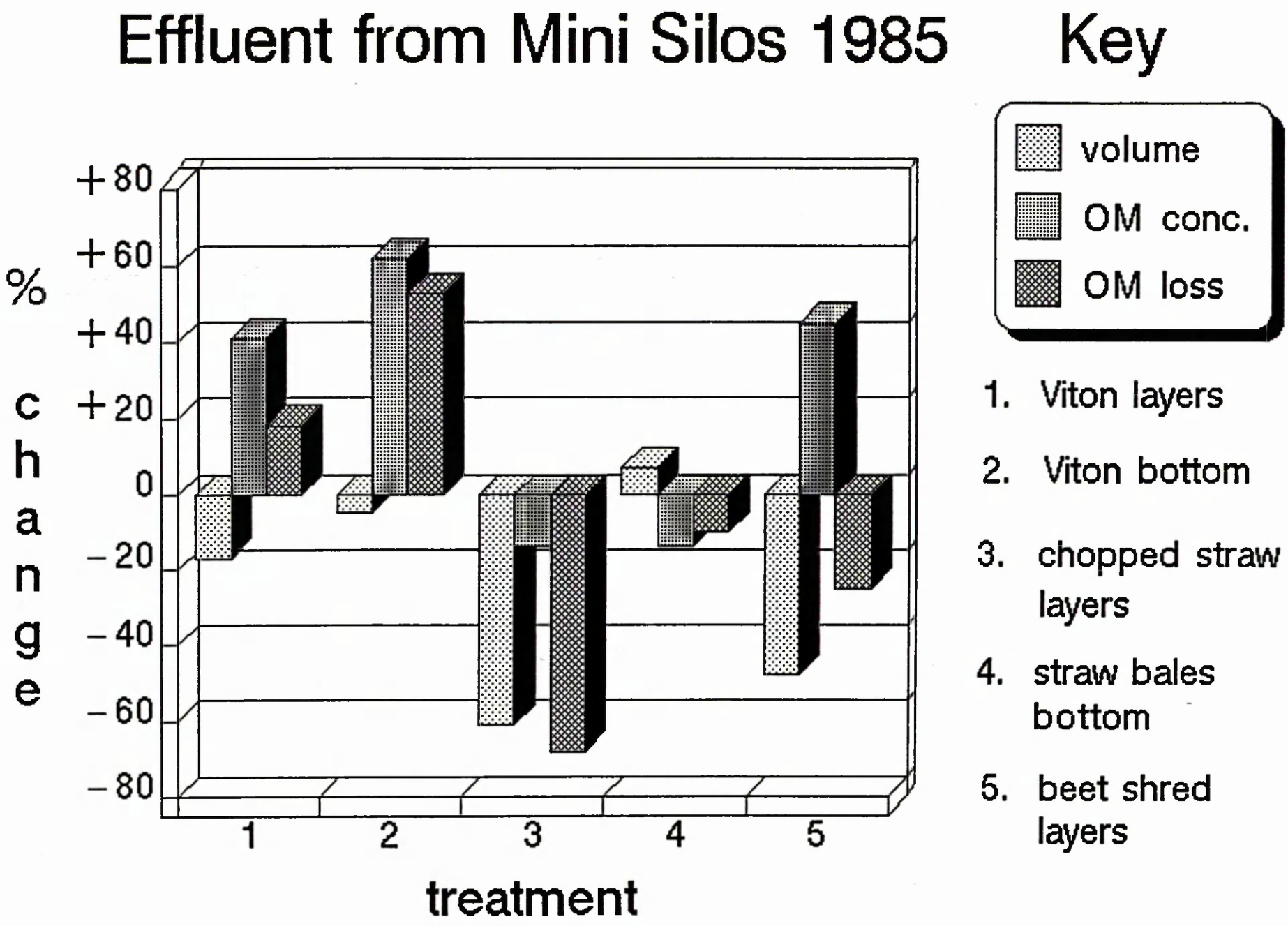
The % changes in OM concentration, total OM loss and volume of effluent compared to the control silage can be seen clearly in Figure 4.12. Addition of Viton in layers (treatment D) reduced effluent volume by 17%, but increased OM concentration and total OM losses by 41 and 15% respectively. When used in the silo bottom (treatment b), Viton cubes reduced effluent volume by 5% but increased OM concentration and total OM losses by 62 and 52% respectively. Thus Viton had only a small effect on effluent volume. Moreover, since its use considerably increased the total OM lost in effluent, Viton cubes would increase the risk of pollution from silage clamps. SBP (treatment F) reduced effluent volume by 48%, increased OM concentration in effluent by 46%, but reduced the total OM loss in effluent by 25%. Here, the SBP increased OM concentration, but since it reduced effluent volume, there was an appreciable reduction in total OM loss in effluent. Thus in this study, both Viton cubes

TABLE 4.116

Effect of Adding Absorbents on OM Concentration (g/l) and Total OM Loss (kg/t grass) in Silage Effluent

Treatment	OM Concentration (gl^{-1} effluent)	OM Loss kgt^{-1} grass
A	28.9	4.0
B	46.8	6.1
C	24.4	1.3
D	40.8	4.6
E	24.6	3.6
F	42.2	3.0

FIGURE 4.12


Effluent from Mini Silos 1985
Key
volume
OM conc.
OM loss
1. Viton layers
2. Viton bottom
3. chopped straw layers
4. straw bales bottom
5. beet shred layers
% change
+80
+60
+40
+20
0
-20
-40
-60
-80
1
2
3
4
5
treatment

and SBP performed poorly in terms of their ability to reduce effluent pollution and nutrient loss. However, unlike Viton cubes, SBP shows considerably more potential as an effluent absorbent as the latter material does give a substantial reduction in effluent volume. Thus, for SBP, the opportunity exists of overcoming the problem of increased OM concentration in effluent by ensuring that sufficient SBP are added completely to prevent effluent loss. Furthermore, unlike the Viton cubes, SBP improved silage quality as measured by in vivo digestibility.

Straw bales (treatment E) increased effluent production by 7%. This alone would eliminate its use by farmers as a means of preventing pollution by silage effluent. It had only a small effect on effluent OM concentration and losses. However, chopped straw (treatment c) proved to be the most effective absorbent tested. It decreased effluent volume, OM concentration and loss by 61, 16 and 67% respectively. However, this performance must be balanced to an extent by the fact that inclusion of chopped straw reduced silage digestibility and greatly increased the volume of silo required.

The effect of adding absorbents on silage effluent biochemical oxygen demand (BOD_5) were investigated (see Table 4.117). Values ranging from 40 to 90 gO_2l^{-1} effluent have been reported in the literature (Jones and Murdoch, 1954; Moor et al, 1961; Spillane and O'Shea, 1973; Stewart and McCullough, 1974; Woolford, 1978). In this trial however, the BOD_5 of the control silage effluent was 20.0 gO_2l^{-1} effluent. This value is therefore lower than recorded elsewhere, but is consistent with the lower effluent DM content in the present study.

The % change in BOD_5 in gO_2l^{-1} of effluent (concentration) and in kgO_2t^{-1} grass (total loss) compared to values for the control silage can be seen clearly in Figure 4.13. It is clear that only chopped straw (treatment C) reduced BOD_5 losses per tonne of grass (by 68%), whereas Viton in bottom and in layers increased the BOD_5 losses by 145 and 79% respectively. SBP also increased the BOD_5 losses per tonne of grass (by 37%).

Nutrient Recoveries in Silages and Effluent

Nutrient recovery in silage for each silo was calculated from total nutrient

TABLE 4.117

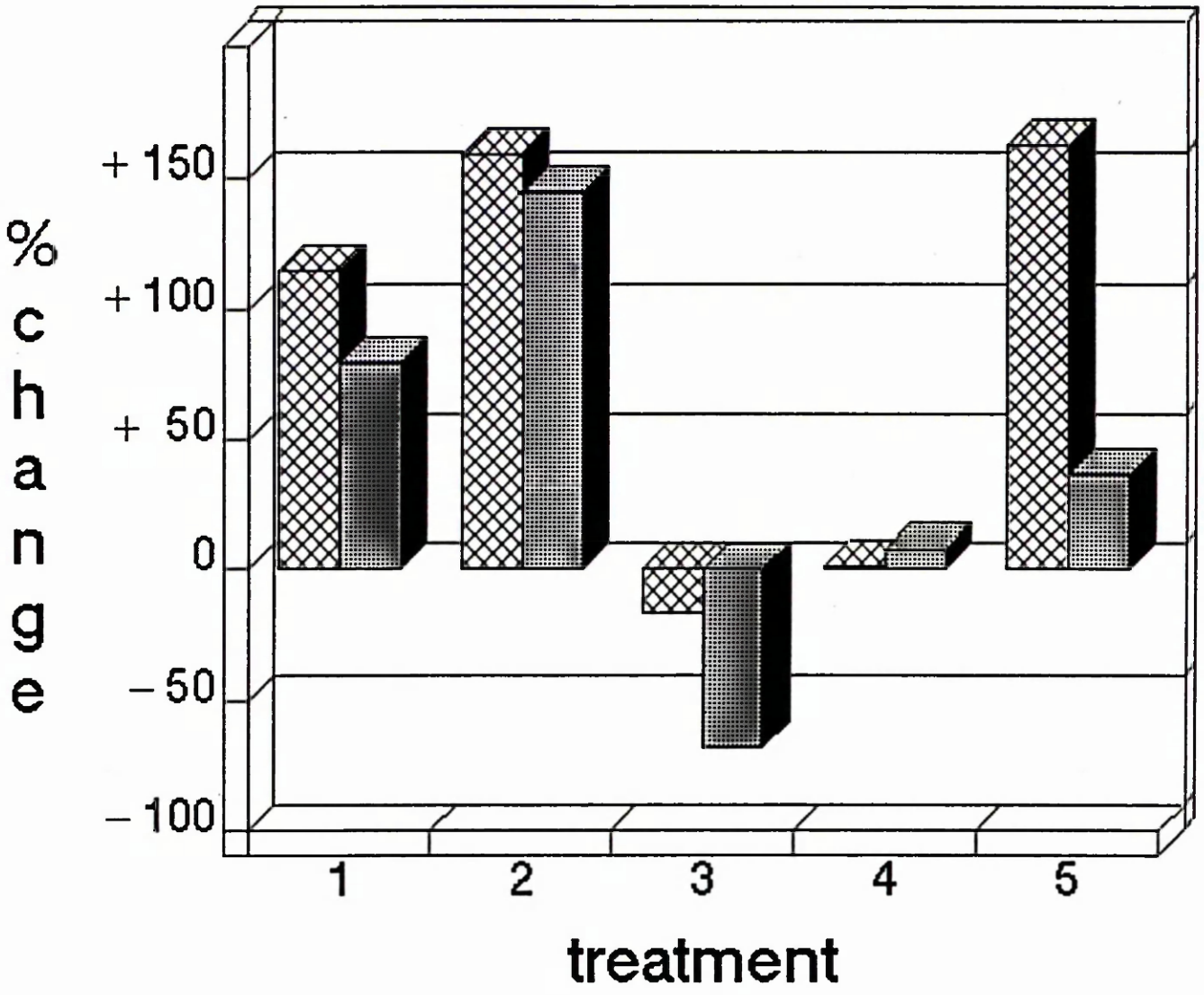
Effect of Adding Absorbents on BOD_5 of Silage Effluent

Treatment	BOD_5	
	gO_2l^{-1} effluent	kgO_2t^{-1} grass
A	20.0	2.73
B	51.6	6.70
C	16.5	0.88
D	43.0	4.88
E	20.1	2.95
F	52.5	3.73

FIGURE 4.13

Mini silos 1985

BOD losses in effluent



Key

conc.

total loss

1. Viton layers
2. Viton bottom
3. chopped straw layers
4. straw bales bottom
5. beet shred layers

added to the clamp in grass and absorbent (see Appendix 10) and the total nutrients removed from the clamp (see Appendix 11). The dry matter recovery from the control silage was 77.3%. This value is in line with dry matter recoveries reported in other experiments involving silages with similar dry matter contents (Appleton, 1981; Zimmer and Wilkins, 1984; Steen, 1985). The dry matter recoveries for all six silage treatments were approximately similar (see Table 4.113).

ME recovery from the control silage was 85.4%, which is similar to the value reported by Steen (1985) for a grass silage of DM 163 gkg^{-1} and treated with 2.5 l/t formic acid. In general, the ME recoveries for all six treatments were also similar to the control.

Nutrient recovered in silage effluent for each treatment as a proportion of total nutrient ensiled are shown in Table 4.114. It was calculated from total nutrients added to the clamp (see Appendix 10) and nutrient output measured in effluent (see Appendix 12). The dry matter recovered in the effluent collected from the control silage (treatment A) was 5.0%. This value is in line with results reported by other workers (Watson and Nash, 1960; Woolford, 1978; Fisher et al, 1981; Patterson and Steen, 1981-82).

Treatments C and F (chopped straw and molassed beet shreds) decreased the dry matter losses in effluent to 0.8 and 2.0% respectively. The OM recovered in the control silage effluent was 4.0% of the total OM ensiled. Treatment C (chopped straw) proved the most effective in reducing OM loss in effluent. Only 0.6% of the total OM ensiled was recovered in silage effluent. Treatment F (SBP) was also effective in reducing OM loss (to 1.7%) despite the fact that its inclusion increased effluent OM concentration.

Consideration of the nutrient recoveries in silage and effluent gives no indication of increased OM, DOM or ME recovery in silage as a result of reducing effluent losses due to the addition of absorbent. The reduction (of 3.5% units) of OM lost in effluent (compared to the control) due to inclusion of chopped straw was not reflected in a corresponding increase in nutrient recovered in silage. In fact, silage nutrient recoveries were approximately 1 percentage unit lower for the chopped straw treatment than for the control. The failure to measure any benefit in nutrients recovered in silage due to the

use of absorbents could have several explanations. Firstly, measurement of silage nutrient recovery is very difficult as it involves many weighings over a number of weeks. Secondly, it is very difficult to obtain samples that are truly representative of each quantity of silage removed from a silo. This is especially the case for silages containing layers of absorbents and could well introduce bias into the estimate of recovery. Thus the practicalities of silage nutrient recovery make it very difficult to detect any small differences between treatments caused by the retention of effluent within the silo. A third possibility for the similarity of silage nutrient recoveries is that inclusion of the absorbent increased in-silo respiration and fermentation losses sufficiently to compensate for the reduction in losses in effluent. Thus is appears that incorporation of absorbent may not necessarily improve the efficiency of nutrient conservation in the silo. Nevertheless the large reduction in effluent production and hence pollution potential may justify the inclusion of absorbents.

Nutrients Recovered in Bottom Layered Absorbents

This applied to the absorbents which were stored under the silage to absorb effluent. The two absorbents were Viton straw cubes (treatment B) and straw bales (treatment E).

After removing the silages from silos B and E, the absorbents were collected, weighed and their DM contents were determined. A digestibility trial using sheep was carried out to measure the digestibilities of OM and GE from which DOM and ME were calculated (see Table 4.18). This in vivo evaluation procedure was applied to samples of the Viton cubes and baled straw representative of the materials as added to the silos and as recovered when the silos were emptied.

Nutrients recovered in the two absorbents when the silos were emptied were calculated as a percentage of nutrients added to the clamp in the absorbent (Appendices 13 and 14).

The DM recovery of Viton straw cubes (treatment B) was 83% (see Table 4.115), which means that 17% of the DM added in the Viton was lost. Approximately half of this loss can be accounted for as increased DM loss in effluent due to

the use of Viton cubes. For OM, DOM and ME the recoveries were approximately 90% indicating a loss of about 10% during ensiling. Again the increase in nutrient loss in effluent accounts for approximately half of the nutrients lost from the Viton cubes during ensiling. The remaining loss was probably due to fermentation losses within the ensiled Viton cubes.

The DM and OM recoveries for the straw bales (treatment E) were 109 and 108% respectively (see Table 4.115). This increase in total DM and OM must have been cause by absorption of materials from the effluent as it saturated the bales. Also the bales may have acted as a filter, removing particular matter from effluent which would account for the lower DM and OM contents of the effluent measured for this treatment (see Table 4.112). However, straw bales increased effluent volume by 7% and therefore proved useless as a means of preventing pollution. Moreover, effluent soaked straw bales proved often unpalatable to sheep and rapidly deteriorated with obvious mould growth and the development of an unpleasant smell.

CONCLUSIONS

1 All of the absorbents tested allowed the production of well fermented silages.

2 Using Viton straw cubes either in the bottom of the clamp or in a series of layers, had little effect on effluent volume produced from grass silage. Moreover, it increased OM loss in effluent by 53% and would thus increase the risk of pollution.

3 Baled straw was the least effective absorbent tested in terms of control of effluent volume. It increased effluent volume by 7%, increased volume required to store one tonne of grass by 79% and because the effluent-soaked bales were unpalatable to sheep, it created a problem of solid waste disposal.

4 Absorbents control effluent more effectively when used in a series of layers rather than a single deep layer in the clamp bottom.

5 Molassed beet shreds reduced effluent volume by 48%, increased silage ME by 0.27 $MJkg^{-1}$ DM and increased volume required to store one tonne of grass only by 37%, but it increased the OM concentration in effluent by 46% and therefore decreased total OM lost in effluent by only 25%. If SBP are to be effective for prevention of pollution the material must be added in sufficient quantities to prevent effluent production completely.

6 Chopped straw proved the most effective absorbent in terms of its effect on effluent volume and OM loss. It reduced effluent volume by 61% and total OM loss by 68%. However, the disadvantages of using chopped straw are that it increased the volume required to store one tonne of grass by 76% and reduced silage ME by 1.01 $MJkg^{-1}$ DM.

SECTION 2

1986 TRIAL

OBJECTIVE

The work described in section one of this chapter showed that incorporation of chopped barley straw or molassed beet shreds with grass at ensiling resulted in a marked reduction in silage effluent. Molassed beet shreds gave an additional beneficial effect in that it increased the ME of the silage, whereas addition of chopped straw resulted in a significant reduction in silage ME.

The main objectives of this trial were to further investigate the effects of ensiling chopped straw or molassed beet shreds with grass silage on effluent production and silage quality. In addition, the trial was designed so as to provide sufficient silage to carry out an intake and performance trial using growing calves.

EXPERIMENTAL

Absorbents

The following absorbents were tested:

1 Molassed sugar beet shreds

2 Chopped barley straw

3 Straw bales

The work in section one of this chapter showed that putting straw bales in the bottom of grass silage promoted effluent flow. This was particularly surprising since it is a method frequently used by farmers. The purpose of retesting straw bales as an effluent absorbent was to confirm this important

finding using first cut grass.

Grass

A first cut perennial ryegrass was cut on 3rd June 1986 with a disc mower fitted with conditioner and was lifted with a precision-chop forage harvester without wilting. Formic acid was applied at a rate of 3l per tonne of grass fresh weight.

Preparation of Experimental Silages

a) **Experimental Design**

Six silages were made from the same grass. The design is shown in Table 4.21.

b) **Amounts of Grass and Absorbent**

Six loads of grass were weighed prior to ensiling. The amounts of grass and absorbent for each treatment are shown in Table 4.22.

c) For details of the method of absorbent addition, consolidation, covering the clamps and effluent collection and sampling see Chapter 2, page 49-52.

Silage Digestibility

The digestibilities of the experimental silages were measured *in vivo* using calves.

Animals

Eighteen Friesian calves born in September 1986 were used in the trial. Their mean liveweight at the start of the trial was approximately 175 kg.

TABLE 4.21

Experimental Design

Silo Code	Absorbent	Method of Absorbent Addition
1	Control	-
2	Molassed Beet Shreds	Multi-layered
3	Straw Bales	Bottom Layer
4	Chopped Barley Straw	Multi-layered
5	Molassed Beet Shreds	Multi-layered
6	Chopped Barley Straw	Multi-layered

TABLE 4.22

Weights of Grass and Absorbent Ensiled in Each Silo
(kg Fresh Weight)

Silo	Grass (kg)	Absorbent		Silo Code
		(kg)	% (FW)	
Control	8,870	0	0	1
Molassed Beet Shreds	7,370	560	7.6	2
Straw Bales	4,796	320	6.7	3
Chopped Barley Straw	5,374	402	7.5	4
Molassed Beet Shreds	7,675	560	7.3	5
Chopped Barley Straw	4,837	401	8.3	6

Housing and Management

Digestibility measurements followed the silage intake and performance trial described in Section 3 of this chapter. Silages from silos one and three (not including straw bales); two and five; four and six were mixed together in equal amounts (fresh weight basis) for the in vivo evaluation. Six calves were assigned to each of the three silage mixtures as described in section 3. Calves had consumed their respective silages for a minimum period of six weeks before the start of the digestibility trial. Calves were housed in metabolism cages as described in section 1 (page 139) of this chapter. Faecal collections were carried out for a period of 6 days following a 10 day equilibration period.

Experimental Diets

The calves were offered the following ration:

Silage (see below) + soya bean meal* (200 gd^{-1}) + mineral mixture+ (70 gd^{-1})

Silages

Control	silo 1 and 3
Molassed Beet Shreds	silo 2 and 5
Chopped Straw	silo 4 and 6

Silage Feeding Level: 0.017 kg DM/kg liveweight/day

Collection, Sampling and Preparation of Materials for Analysis

For details of collection, sampling and preparation of materials for analysis, see section one of this chapter, page 141.

Analytical Methods

For details of analytical methods see section one of this chapter, page 141.

* See Table 4.31, page 210 for composition of soya bean meal

\+ "Cattle Standard" Scotmin, Maybole, Ayrshire

RESULTS

Composition of Grass

Table 4.23 shows the composition of grass ensiled in the six experimental silos. Grass DM ranged from 116 to 129 gkg^{-1}, with an average DM content of 123 gkg^{-1}. Mean CP, WSC and *in vitro* D-values were 170 gkg^{-1} DM, 72.8 gkg^{-1} DM and 66.4% respectively.

Composition of Absorbents

Table 4.24 shows the composition of the absorbents tested. Molassed beet shreds and chopped straw had DM contents of 845 and 846 gkg^{-1} respectively. There were large differences in composition between these two absorbents, particularly in the case of their WSC and ME values. Molassed beet shreds had a WSC concentration of 286 gkg^{-1} DM and an ME value of 12.7 $MJkg^{-1}$ DM, whereas chopped straw had corresponding values of 11.3 gkg^{-1} DM and 6.1 $MJkg^{-1}$ DM.

Composition of Silages

Silage analyses are shown in Table 4.25. The oven DM contents of the control silage was 152 gkg^{-1}. Silages 2 and 5 (molassed beet shreds) gave DM contents of 206 and 186 gkg^{-1} respectively, whilst silages 4 and 6 (chopped straw) gave values of 194 and 206 gkg^{-1} respectively. It is clear that both beet shreds and chopped straw resulted in a marked increase in silage DM concentration when compared to the control. Silage from silo 3 which had a layer of straw bales on the clamp bottom, had a DM content of 147 gkg^{-1} - slightly lower than the control silo.

The CP content of the control silage was 175 gkg^{-1} DM. Addition of chopped straw (silos 4 and 6) resulted in a marked reduction in CP content to 122 and 104 gkg^{-1} DM respectively. Addition of molassed beet shreds (silos 2 and 5) led to a smaller reduction in CP content of the silage to values of 145 and 153 gkg^{-1} DM respectively.

TABLE 4.23

Composition of Grass Used in Each Silo

Composition	Silo						
	1	2	3	4	5	6	$\bar{x}$*
DM (gkg^{-1})	120	127	116	129	126	120	123
OM (gkg^{-1} DM)	886	883	879	888	881	881	883
CP (gkg^{-1} DM)	176	166	173	172	166	169	170
WSC (gkg^{-1} DM)	65.4	77.2	64.1	77.4	80.8	71.9	72.8
In vitro D-value (%)	66.7	66.4	65.2	69.3	64.9	65.9	66.4
ME ($MJkg^{-1}$ DM)	11.4	11.4	11.1	11.9	11.1	11.3	11.4

* Mean composition of grass

TABLE 4.24

Composition of Absorbents

Composition	Absorbent	
	Molassed Beet Shreds	Chopped Straw
DM (gkg^{-1})	845	846
OM (gkg^{-1} DM)	907	952
CP (gkg^{-1} DM)	108	45
WSC (gkg^{-1} DM)	286	11.3
In vitro D-value (%)	79.7	41.5
ME ($MJkg^{-1}$ DM)	12.7	6.1

TABLE 4.25

Composition of Silages

Composition°	Silo					
	1	2	3+	4	5	6
Oven DM (gkg^{-1})	152	206	147	194	186	206
Toluene DM (gkg^{-1})	167	220	159	213	204	212
OM (gkg^{-1} DM)	902	886	903	915	895	916
CP (gkg^{-1} DM)	175	145	170	122	153	104
WSC (gkg^{-1} DM)	3.5	11.1	3.2	1.9	11.7	3.7
In vitro D-value (%)	69.3	72.8	68.3	55.5	69.2	51.7
Ca (gkg^{-1} DM)	6.0	8.9	5.8	5.5	8.2	5.1
P (gkg^{-1} DM)	3.9	2.7	3.7	3.1	3.1	2.6
Mg (gkg^{-1} DM)	1.5	1.4	1.6	1.2	1.6	1.1
GE* ($MJkg^{-1}$ DM)	20.76	19.39	21.47	19.42	20.02	19.58
pH	4.0	4.0	4.1	4.0	4.0	4.5
Ammonia-N (gkg^{-1} total-N)	137	107	152	121	111	153
Lactic Acid (gkg^{-1} DM)	65.5	52.6	77.4	48.8	56.6	32.9
Acetic Acid (gkg^{-1} DM)	22.0	18.9	27.1	19.5	21.7	15.4
Propionic Acid (gkg^{-1} DM)	9.0	7.2	0	8.1	10.1	4.0
Butyric Acid (gkg^{-1} DM)	0	0	0	0	0	0
Isobutyric Acid (gkg^{-1} DM)	0.79	0.34	0	1.2	1.1	0.79
Ethanol (gkg^{-1} DM)	7.7	8.6	5.0	6.0	9.3	5.0

* Measured in fresh minced silage

\+ Compositions refer to the grass silage above the straw bales.

° Oven DM is used as the base for analytical parameters

The pH value of the control silage was 4.0. Only silo 6 gave a higher pH (4.5) as all other silages showed a similar pH value to that recorded for the control silage (see Table 4.25).

Ammonia-N concentration of the control silage was 137 gkg^{-1} total-N. The chopped straw silos (4 and 6) showed similar ammonia-N concentration to the control silage (121 and 153 gkg^{-1} CP respectively). However, silos 2 and 5 (beet shreds) recorded ammonia-N contents as being 30 and 26 units lower than the control respectively (107 and 111 gkg^{-1} total-N respectively). Treatment 3 (straw bale) had ammonia-N content of 152 gkg^{-1} total-N. Generally all silages obtained satisfactory fermentations and levels of butyric acid were below detection limits.

The lactic acid content of the control silage was 65.5 gkg^{-1} DM. Silos 2 and 5 (beet shreds) had lactic acid contents of 52.6 and 56.6 gkg^{-1} DM respectively, whilst silos 4 and 6 (chopped straw) gave slightly lower values of 58.8 and 32.9 gkg^{-1} DM respectively. Only treatment 3 (straw bale) showed a higher lactic acid content (77.4 gkg^{-1} DM) than the control.

Silage Digestibility **in vivo**

Table 4.26 shows the mean values obtained for the digestibility of organic matter (OMD) energy (ED). The values have been calculated from intake and faecal excretion measured over the last six days of a sixteen day feeding period. The mean ME values for each treatment is also shown in Table 4.26 as calculated from the following equation:

$$ME\ (MJkg^{-1}\ DM) = 0.81 \times DE\ (MJkg^{-1}\ DM) \qquad \text{(ARC 1980)}$$

Full analysis of variance was carried out on all the data obtained for the three silages (see Appendices 15, 16 and 17). Complete tabulated results are presented in Appendix 18.

The result of this trial showed that incorporation of chopped straw with grass at ensiling leads to a highly significant ($P < 0.001$) reduction in the OMD and ED values of the silage when compared to the control or molassed beet shred silages. Addition of molassed beet shreds to grass at ensiling showed no

TABLE 4.26

Mean* apparent Digestibility of the Silages measured in vivo
Using 18 Friesian Calves

Treatment	Mean Apparent Digestibility		ME+ ($MJkg^{-1}$ DM)
	OM	Energy	
Control	0.775^{b}	0.762^{b}	12.81^{c}
Chopped Straw Silage	0.634^{a}	0.620^{a}	9.79^{a}
Molassed Beet Shred Silage	0.780^{b}	0.766^{b}	12.23^{b}

* Means in the same column not sharing common subscripts differ significantly ($P < 0.05$).

\+ Estimated from ME = 0.81 X DE expressed as ove DM basis.

significant ($P < 0.05$) effect on OMD or ED when compared to the control (see Table 4.26).

The calculated ME value for chopped straw silage treatment was however, significantly ($P < 0.001$) lower than the control or molassed beet shred silages. Also, the ME value of molassed beet shred silage was significantly lower than the control silage (see Table 4.26).

Effluent Production and Composition

Table 4.27 shows the total silage effluent volume produced from each treatment together with the volume of effluent produced as litres per tonne of grass. The data shows that inclusion of a bottom layer of straw bales increased effluent production by 17%. However, incorporation of chopped straw in layers reduced effluent production by 45 and 50% for silos 4 and 6 respectively. Molassed beet shreds used in the same way also reduced effluent production considerably by 62 and 51% for silos 2 and 5 respectively.

Table 4.28 shows the composition of the effluent produced from each silo. The DM content of the effluent collected from the control silage was 39 gkg^{-1}. Effluent collected from silos 4 and 6 (chopped straw silage treatments) were generally similar in DM content to the control, whereas effluent from molassed beet shred silages (silos 2 and 5) showed higher DM contents (69 and 58 gkg^{-1} respectively).

The CP content of the control silage effluent was 297 gkg^{-1} DM. Effluent produced from molassed beet shred silages (silos 2 and 5) showed similar CP contents to the control effluent, whereas effluent collected from the chopped straw silages (silos 4 and 6) had a lower CP content than the control (191 and 211 gkg^{-1} DM). Effluent from silo 3 (straw bales) also showed a lower CP content than the control (see Table 4.28).

The WSC of the control silage effluent was 339 gkg^{-1} DM and similar values were recorded for the other silos (mean 303 gkg^{-1} DM).

TABLE 4.27

Volume of Silage Effluent produced from each Silo

Code	Silo	Total Effluent Produced (litre)	Effluent Produced (litre per tonne grass)
1	Control	1770	200
2	Molassed Beet Shreds	556	75
3	Straw Bales	1121	234
4	Chopped Straw	586	109
5	Molassed Beet Shreds	744	97
6	Chopped Straw	485	100

TABLE 4.28

Composition of Silage Effluent

Composition	Silo					
	1	2	3	4	5	6
DM (gkg^{-1})	39	69	40	40	58	48
OM (gkg^{-1} DM)	750	801	742	740	788	739
pH	4.2	4.3	4.3	4.2	4.3	4.6
CP (gkg^{-1} DM)	297	284	214	192	261	211
Ammonia-N (gkg^{-1} total-N)	41.7	29.6	36.8	54.5	25.9	43.4
WSC (gkg^{-1} DM)	339	297	294	306	314	269
Lactic Acid (gkg^{-1} DM)	151	95.3	191	145	125	81.3
Ash (gkg^{-1} DM)	250	199	258	260	212	261
Acetic Acid (gl^{-1})	0.82	1.03	1.12	0.56	1.03	0.66
Propionic Acid (gl^{-1})	0.1	0.03	0.1	0.18	0.1	0.07
Butyric Acid (gl^{-1})	0.06	0.1	0	0.06	0.1	0.04
Isobutyric Acid (gl^{-1})	0	0	0.1	0	0.1	0.02
Ethanol (gl^{-1})	0.42	0.61	0.60	0.4	0.68	0.37

Ash content of the control silage effluent was 250 gkg^{-1} DM. For the other treatments, ash content ranged from 199 gkg^{-1} DM for silo 2 (beet shreds) to 261 gkg^{-1} DM for silo 6 (chopped straw), although the level was not consistently related to the type of absorbent.

Space Occupied by Silage

Table 4.29 shows the silage densities (tonne/m^3 for grass and absorbent) and volumes (m^3) required to store one tonne of grass (not including absorbent). These values were calculated from measurements taken immediately after sheeting the clamps as described in Section 1 (page 150) of this chapter. The percentage change in the volume per tonne of grass for each treatment when compared to the control is also shown in Table 4.29.

Chopped straw addition increased the volume required to store one tonne of grass by 73 and 85% for silos 4 and 6 respectively. However, molassed beet shreds increased the silo volume required by only 23 and 21% for silos 2 and 5 respectively. Straw bales (silo 3) increased the storage volume required by 74%.

TABLE 4.29

Effect of Adding Absorbent on Silage Density and the Silo Volume Required to Store one tonne of Grass

Silo	Silage Density (tonne/m^3)	Silo Volume Needed (m^3/tonne grass)	Change in Silo volume needed (%)
1	1.09	0.92	-
2	0.95	1.13	+23
3	0.67	1.60	+74
4	0.67	1.59	+73
5	0.97	1.11	+21
6	0.64	1.70	+85

DISCUSSION

Grass

A first cut perennial ryegrass was cut and ensiled in one day. The average grass DM was very low (123 gkg^{-1}) and the WSC content (9.0 gkg^{-1}) was also low for a first cut grass (McDonald, 1981). Wilkins (1974) and ADAS (1979) suggested a WSC concentration of 25-30 gkg^{-1} in herbage as the minimum necessary for unwilted silage to be made without additives. Recently, a WSC content of 24 gkg^{-1} for unwilted silage treated with formic acid has been suggested as the minimum needed to produce successful preservation (Haigh and Parker, 1985). However, the combination of very low DM content and low WSC concentrations obtained in the present trial suggests that the trial provided a severe test of ensiling technique. Formic acid (as Add-F) was added as it was considered that it would be normal agricultural practice to use such an additive for grass of this composition.

Composition of Silages

Addition of chopped straw or molassed beet shreds (SBP) to grass at ensiling resulted in increases in silage DM when compared to the control, whilst the DM content was little affected by the use of straw bales as a bottom layer (see Table 4.25). The increases in silage DM due to the multi-layered absorbents are consistent with the relative DM contents of grass and absorbent, the absorbent inclusion levels and the volumes of effluent lost.

Addition of chopped straw (silos 4 and 6) resulted in a marked reduction in silage CP content to values that were 53 and 71 gkg^{-1} DM respectively less than the CP content of the control silage. The CP contents of SBP silages (silos 2 and 5) were also reduced by absorbent addition. The reductions in CP content for this treatment were less than that for chopped straw being only 30 and 22 gkg^{-1} DM respectively less than the control. The reduced CP contents of silages 2, 5 and 4, 6 are broadly as can be calculated from the dilution of the grass CP by the absorbents based on their relative CP values and inclusion rates. Thus the reduction in CP compared to the control for the chopped straw

silages were approximately twice those for SBP as would be expected from the relative CP concentrations of these absorbents (45 and 108 gkg^{-1} DM respectively).

However, the effect of adding these absorbents on silage fermentation is more important since fermentation quality is one of the most important factors affecting the nutritive value of the silage. Analysis of lactic, acetic and butyric acids suggest that the silage made in this trial can be classified as "additive inhibited" according to the classification of McDonald (1981). This conclusion is the same as for the silages made in 1985 in the "mini pit" silos as described in Section 1, page 160 of this Chapter. As it is shown in Table 4.25, addition of chopped straw did not markedly alter the fermentation quality of the silage when compared to the control. Silo 4 (chopped straw) produced silage with an ammonia-N concentration of 16 units less than the control, whereas silo 6 (also chopped straw) produced silage with an ammonia-N content 16 units higher than the control. Silage from silo 6 showed the least satisfactory fermentation having the highest ammonia-N (153 gkg^{-1} total-N), the lowest lactic acid (32.9 gkg^{-1} DM) and the highest pH (4.5). However, SBP treatment produced silages with better fermentation quality than the control as assessed by ammonia-N content. The ammonia-N content for silos 2 and 5 (SBP) were 30 and 26 gkg^{-1} total-N respectively less than the control. This slight improvement in preservation quality may have been due to the extra fermentable sugar added as the molasses of the beet shreds. Calculations show this to be approximately 18 kg of WSC per tonne of grass which is similar to the recommended rate for molasses used as a silage additive. However, the extra WSC added to the beet shred silages did not result in higher lactic or VFA concentration in the silage, presumably because of the restriction in silage fermentation due to the addition of Add-F.

For unwilted silages, achievement of a pH value of 4.2 or less ensures that the material normally remains stable (McDonald and Whittenbury, 1973). In this trial only silo 6 (chopped straw) gave silage (pH 4.5) with pH value higher than 4.2 as the rest of the silages recorded pH values of 4.0 or 4.1.

It is generally concluded that, for this trial, silage preservation as assessed by pH and concentration of ammonia-N and butyric acid were satisfactory. The low DM and WSC levels in the grass provided moderately

"testing conditions" for the achievement of well preserved silages. The fact that moderate preservation quality was obtained suggests that the use of absorbents is unlikely in practice to give problems with this aspect of silage quality. This is perhaps a surprising conclusion in the case of inclusion of chopped straw which adds little or nothing to the supply of fermentable carbohydrate yet greatly reduces silage density, thus increasing the opportunities for the trapping and penetration of air into the silo.

Silage Digestibility **In Vivo**

The OMD of the control silage was 0.775. This value is in line with that reported by Anderson (1982) and by Steen (1985) for a similar silage. The digestibility of energy (ED) of the control silage reported in this experiment (see Table 4.26) is similar to that reported by Beever et al (1984) for silages made from similar herbage.

Addition of chopped straw to grass at ensiling resulted in a significant (P 0.001) reduction in the OMD when compared to the control or beet shred silage. The OMD values for the chopped straw silage and the control were 0.634 and 0.775 respectively which are similar to that reported by Terry et al (1975), who fed sheep diets containing silage only or silage mixed with chopped straw at feeding, in the proportion of 2.5:1. This gave a mixture containing 54% silage and 46% straw on a DM basis. They reported OMD values of 0.784 and 0.642 for silage alone and the silage + straw mixture respectively. A reduction in silage OMD due to straw incorporation is to be expected since straw has a much lower OMD than the grass (0.436 and 0.753 respectively). Nevertheless, in the current trial the observed reduction in silage OMD due to straw incorporation (0.14 or 14 percentage units) was approximately 0.04 or 4 percentage units greater than would be predicted from the OMD values of grass and straw and the inclusion rate. A similar pattern was found for ED.

Addition of SBP to grass at ensiling showed no significant ($P < 0.05$) effect on digestibility of OM or energy when compared to the control. The OMD of the SBP silage at the inclusion rate used would be 0.817 assuming a simple additive relationship between the OMD of the mixture of grass + SBP and its components. The measured OMD (0.78) was slightly lower than this value.

Incorporation of SBP did not give the small increase in silage OMD that might be expected. A similar conclusion can be drawn from the silage made in 1985 described in Section 1 of this Chapter.

The ME of the chopped straw silage was significantly ($P < 0.001$) lower than that for the control or molassed beet shred silage. The ME for molassed beet shred silage was significantly lower ($P < 0.001$) than the control silage (see Table 4.26). However, the reduction in ME of SBP silage compared to the control was slight and entirely due to the differences in GE of the two silages. The GE of the control silage was 20.76 $MJkg^{-1}$ DM compared to 19.71 $MJkg^{-1}$ DM for SBP silage. It is difficult to account for these differences in GE in terms of the observed differences in chemical composition of the control and beet shred silages. Ethanol content for the control silage (7.7 gkg^{-1} DM) and SBP silages (8.9 gkg^{-1} DM) were generally similar and cannot explain the differences in GE of the two silages. The ME value for the SBP silage is also lower than the control if expressed on a toluene DM base, as both silages contained similar contents of volatiles per unit of oven DM.

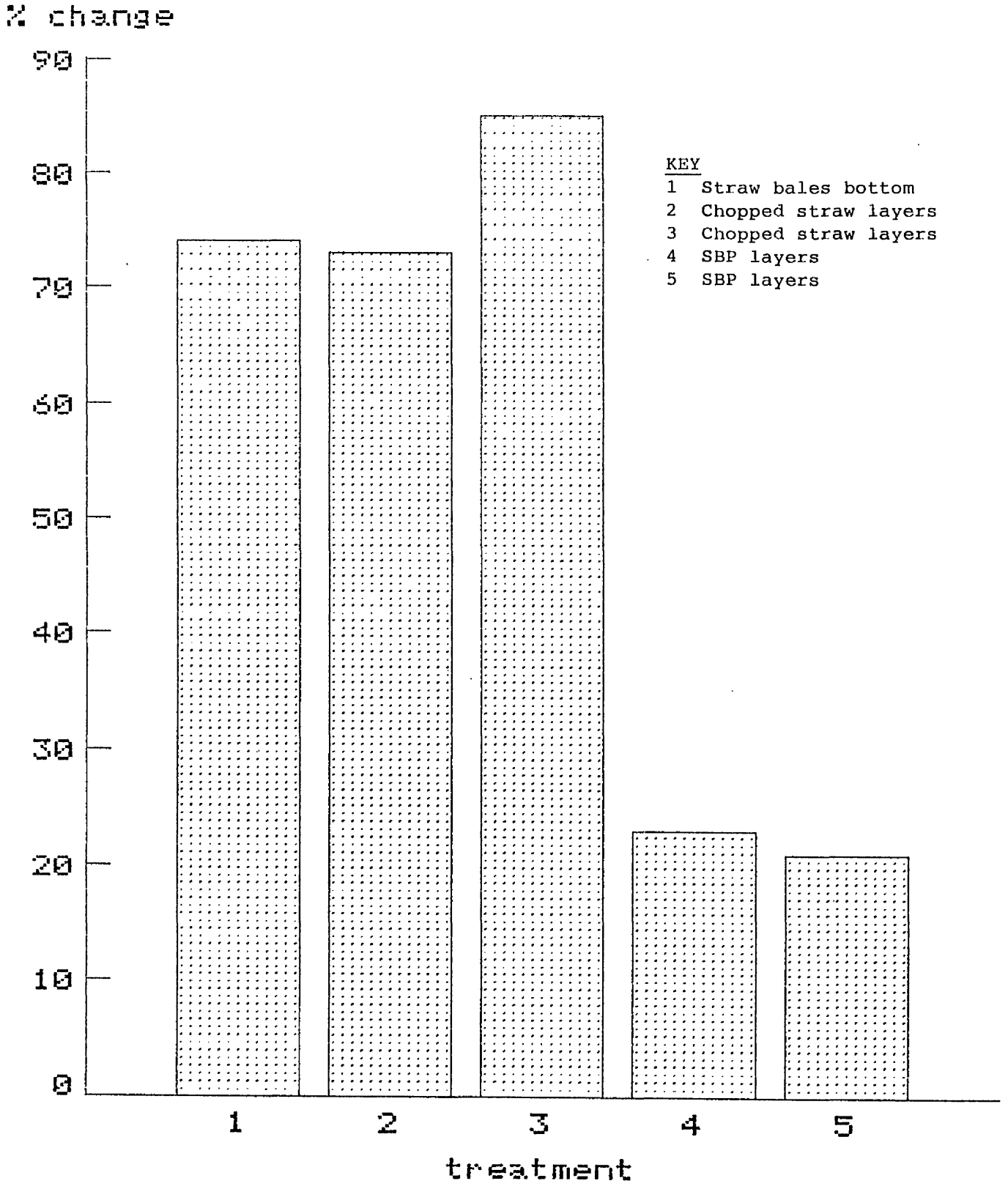
Space Occupied by Silage

It is important to investigate the effect of adding absorbent on the quantity of grass that can be stored in a given silo. The data from this trial showed that addition of chopped straw at a rate of 7.5% of grass fresh weight (silo 4) or 8.3% of grass fresh weight (silo 6) increased the volume required to store one tonne of grass by 74 and 85% respectively. This can be seen clearly in Figure 4.21. Addition of SBP at a rate of 7.6% (silo 2) or 7.3% of grass fresh weight (silo 5) increased the volume required to store one tonne of grass by 23 and 21% respectively.

The changes in volume occupied by silage in this trial for chopped straw and SBP agree well with those reported in section one of this chapter for the same absorbents. The large reduction in silage density when chopped straw is mixed with grass is a serious limitation to the use of this technique. However, the reduction in density which would increase both the amount of air initially trapped in the silo and the permeability of the silo to air did not greatly affect silage fermentation, although there was a slight indication of reduced silage quality in the case of silo 6.

FIGURE 4.21

THE EFFECT OF ABSORBENT ADDITION ON THE STORAGE VOLUME REQUIRED PER TONNE OF GRASS FW (1986 TRIAL)



Effluent Production

The volume of effluent collected from the control silage was 200 litres per tonne of grass. Bastiman (1976), Patterson and Walker (1980) estimated the amount of effluent produced from grass ensiled at a DM content of 150 gkg^{-1} to be 200 to 225 litres per tonne of grass. The dry matter content of the grass used in this trial was 123 gkg^{-1} which would be expected to have produced more than 200 l/tonne grass. However, the lower than expected volume may be due to the small scale of the clamps used in this trial which as discussed in Section 1 of this Chapter (page 164) would result in less pressure being applied to the grass.

Putting straw bale under grass as a method of reducing effluent is a frequently recommended control method. The results of this trial and the 1985 "mini pit" silo trial suggested that straw bales should not be used under silage to reduce effluent as in both years effluent production was actually increased by this procedure. The volume of effluent collected from this treatment (silo 3) was 17% higher than the control (see Table 4.27). Although the bales did soak up effluent (final straw DM was 250 gkg^{-1}) but appeared to promote effluent flow from the clamp. Effluent flow from the clamp containing the straw bales commenced rapidly after filling before any of the other silos, suggesting that the straw bales enhanced flow of effluent by providing convenient drainage channels. This observation agrees well with that reported in Section one of this chapter (1985 silos) for the straw bale treatment. It also agrees with the findings of Clark (1987) who reported that, in two experiments, the provision of drainage channels within the grass silage increased effluent volume by 44% in one experiment and by 51% in the other experiment.

Addition of chopped straw to grass at ensiling reduced effluent volume in this trial by 45 and 50% for silos 4 and 6 respectively, a large response considering the extremely wet grass used.

Incorporation of SBP at a rate of 7.6 and 7.3% of grass FW, reduced effluent volume by 62 and 51% for silos 2 and 5 respectively (see Table 4.27). On the basis of the 1986 silages, SBP appeared to give slightly better control of effluent volume than chopped straw. However, the comparison made in 1985 on the basis of 2 silos, (section 1 of this chapter) showed an opposite response

with chopped straw proving slightly superior to the SBP for the reduction of effluent volume.

Composition of Silage Effluent

The dry matter content of the effluent collected from the control silage was 39 gkg^{-1}. This value is in agreement with literature values (Watson and Nash, 1960; Woolford, 1978; Fisher et al, 1981; Paterson and Steen, 1981-82; Lowman et al, 1983). Effluent collected from the chopped straw silage treatments had a dry matter content of 40 and 48 gkg^{-1} for silos 4 and 6 respectively similar to the control. However, effluent collected from the SBP treatments had higher dry matter contents of 69 and 58 gkg^{-1} for silos 2 and 5 respectively (see Table 4.28). The increase in DM content compared to the control for this treatment is presumably due to small particles and soluble materials from the SBP being washed out with silage effluent.

The crude protein contents of the silage effluent are shown in Table 4.28. The CP content of the control silage effluent was 297 gkg^{-1} DM which agrees well with the value reported by Lowman et al (1983). The CP contents of silage effluent collected from chopped straw or SBP silages were generally similar to the CP of the control silage effluent.

Effluent collected from the control silage had a WSC concentration of 339 gkg^{-1} DM. This is similar to that reported in Section one of this Chapter for the control silage effluent, but it is higher than that reported by Patterson and Steen (1981-82). They reported that WSC in silage effluent ranged between 142-286 gkg^{-1} DM. The WSC of the effluent collected from chopped straw and SBP silages were similar to the WSC of the control silage effluent (see Table 4.28).

Losses of OM and BOD in Effluent

Organic matter concentration in effluent (gl^{-1}) and total OM loss (kg/tonne grass) are shown in Table 4.211. Chopped straw proved the most effective for the control of total OM loss in silage effluent. SBP reduced total OM loss in silage effluent compared to the control, but to a lesser extent that the chopped straw. This was due to the increase in OM concentration in silage

effluent when SBP were used (see Figure 4.22). Chopped straw reduced effluent volume by 45 and 50% and total OM loss in effluent by 45 and 38% for silos 4 and 6 respectively. Unlike SBP, chopped straw had no effect on OM concentration of effluent. This agrees well with that reported in Section one of this Chapter and suggests that chopped straw contains little soluble or particulate matter which might be lost in effluent. This view is supported by the work described in experiment 3, Chapter 3, in which straw contained in nylon bags was incubated in the rumen of the sheep. Without rumen incubation, but after prolonged washing in water, only approximately 4% of the straw OM was lost from the bags.

Addition of SBP increased OM concentration in silage effluent by 88 and 57% for silos 2 and 5 respectively (see Figure 4.22). This was expected since a proportion of the high WSC content of SBP (approximately 300 gkg^{-1} DM) is likely to be washed out with silage effluent. Figure 4.22 showed that SBP reduced effluent production by 62 and 51%, but reduced total OM loss in effluent by only 29 and 24% for silos 2 and 5 respectively. The reduction in total OM loss in effluent for SBP was approximately half that measured for chopped straw due to the increased OM concentration in effluent observed for the former absorbent. The use of straw bales had no effect on OM concentration in silage effluent, but increased the total OM loss in effluent by 19% due to the increase in effluent volume caused by this absorbent.

Since the main objective of adding absorbent to grass silage is to reduce the risk of pollution caused by silage effluent, it is essential to investigate the effect of absorbents on effluent biological oxygen demand (see Table 4.212). Of the absorbents tested, only chopped straw reduced the BOD_5 of silage effluent effectively. The changes in BOD_5 in gO_2 per litre of effluent (concentration) or in kgO_2 per tonne of grass (total loss) can be seen clearly in Figure 4.23. Chopped straw reduced the effluent BOD_5 per tonne of grass (total loss) by 35 and 34% for silos 4 and 6 respectively. SBP increased BOD_5 per litre of effluent (concentration) by 151 and 128% for silos 2 and 5 respectively. These increases could be attributed to the loss in effluent of soluble materials from the SBP which would be expected to stimulate the multiplication of the micro-organisms and thus resulted in higher oxygen demand. However, since SBP reduced effluent volume, total BOD_5 per tonne of grass (total loss) for this treatment were only 5 and 10% higher than the

TABLE 4.211

Organic Matter Loss in Silage Effluent

Code	Silo	OM Loss	
		gl^{-1} effluent	kgt^{-1} grass
1	Control	29.2	5.8
2	Molassed Beet Shreds	54.9	4.1
3	Straw Bale	29.5	6.9
4	Chopped Straw	29.2	3.2
5	Molassed Beet Shreds	45.9	4.4
6	Chopped Straw	35.7	3.6

FIGURE 4.22

Effluent from Mini Silos 1986

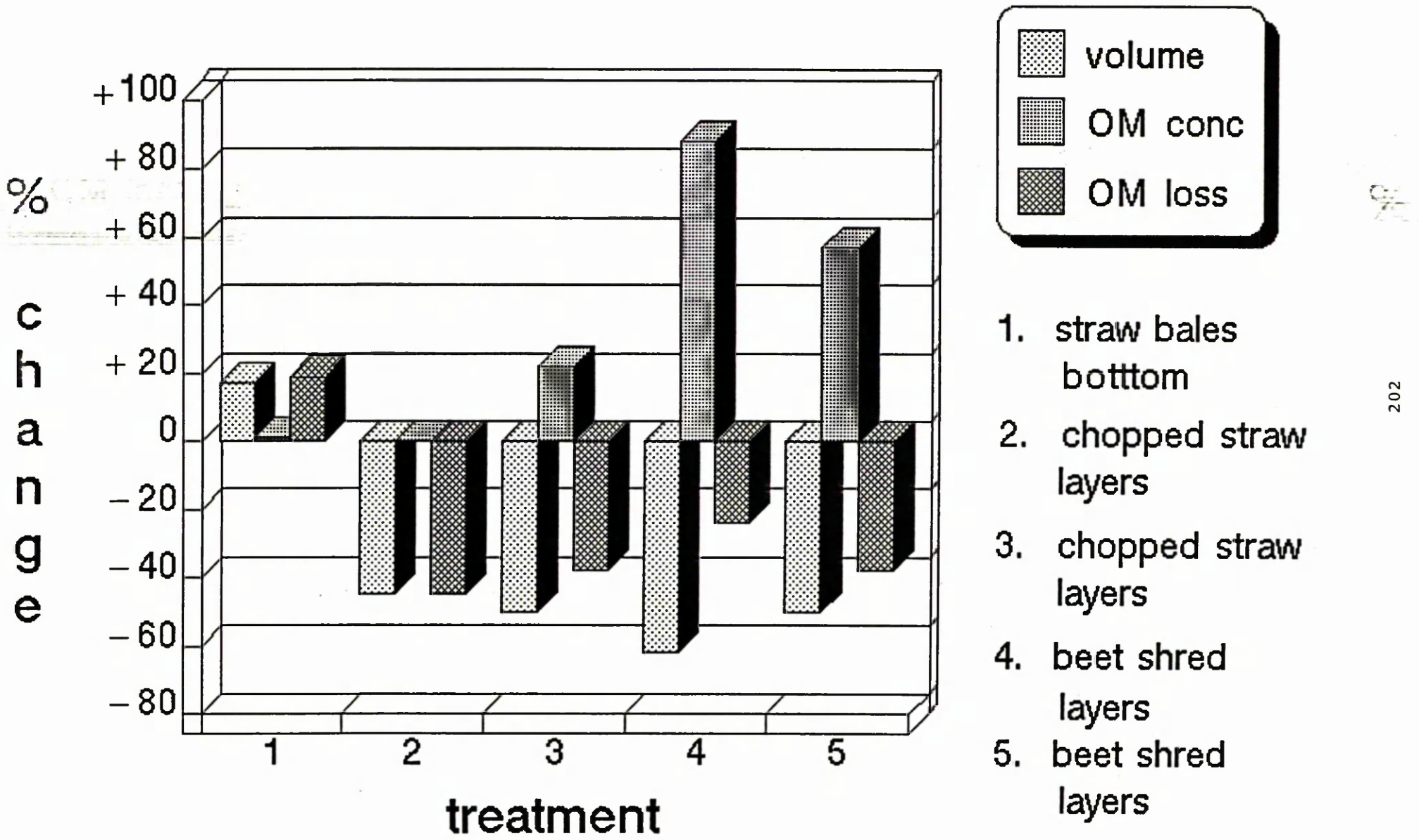


TABLE 4.212

Effect of Adding Absorbents on the Biochemical Oxygen Demand of Silage Effluent

Code	Silo	BOD_5	
		gO_2l^{-1} effluent	kgO_2t^{-1} grass
1	Control	10.5	2.1
2	Molassed Beet Shreds	26.4	1.99
3	Straw Bales	10.5	2.45
4	Chopped Straw	12.5	1.36
5	Molassed Beet Shreds	24.0	2.32
6	Chopped Straw	13.8	1.38

control for silos 2 and 5 respectively (see Figure 4.23). Thus it is essential when using SBP as an absorbent, to incorporate it in sufficient quantity to prevent effluent loss completely. Otherwise, the losses of highly digestible and polluting nutrients may be high and the risk of pollution will be unaffected or even made worse by the use of the SBP.

The straw bales treatment increased BOD_5 per tonne of grass (total loss) by 17% due mainly to the increase in effluent volume for this absorbent. Straw bales should not therefore be used as a method of effluent control. In contrast, the SBP treatment, although having a similar effect on total BOD_5 loss, is potentially superior to straw bales as it does reduce effluent volume. Thus, for SBP it would be possible to add sufficient absorbent totally to prevent effluent production.

The chopped straw treatment proved the most reliable for effluent pollution control. Since there was no increase in BOD_5 concentration in effluent, any reduction in effluent volume represents a beneficial effect on pollution. However, the effect of chopped straw inclusion on silage quality and density may make it a less attractive absorbent than SBP in practice.

CONCLUSIONS

1 Addition of chopped straw as a series of layers gave moderately well-preserved silages similar in fermentation characteristics to the control.

2 Addition of molassed beet shreds as a series of layers slightly improved preservation and fermentation characteristics compared to the control.

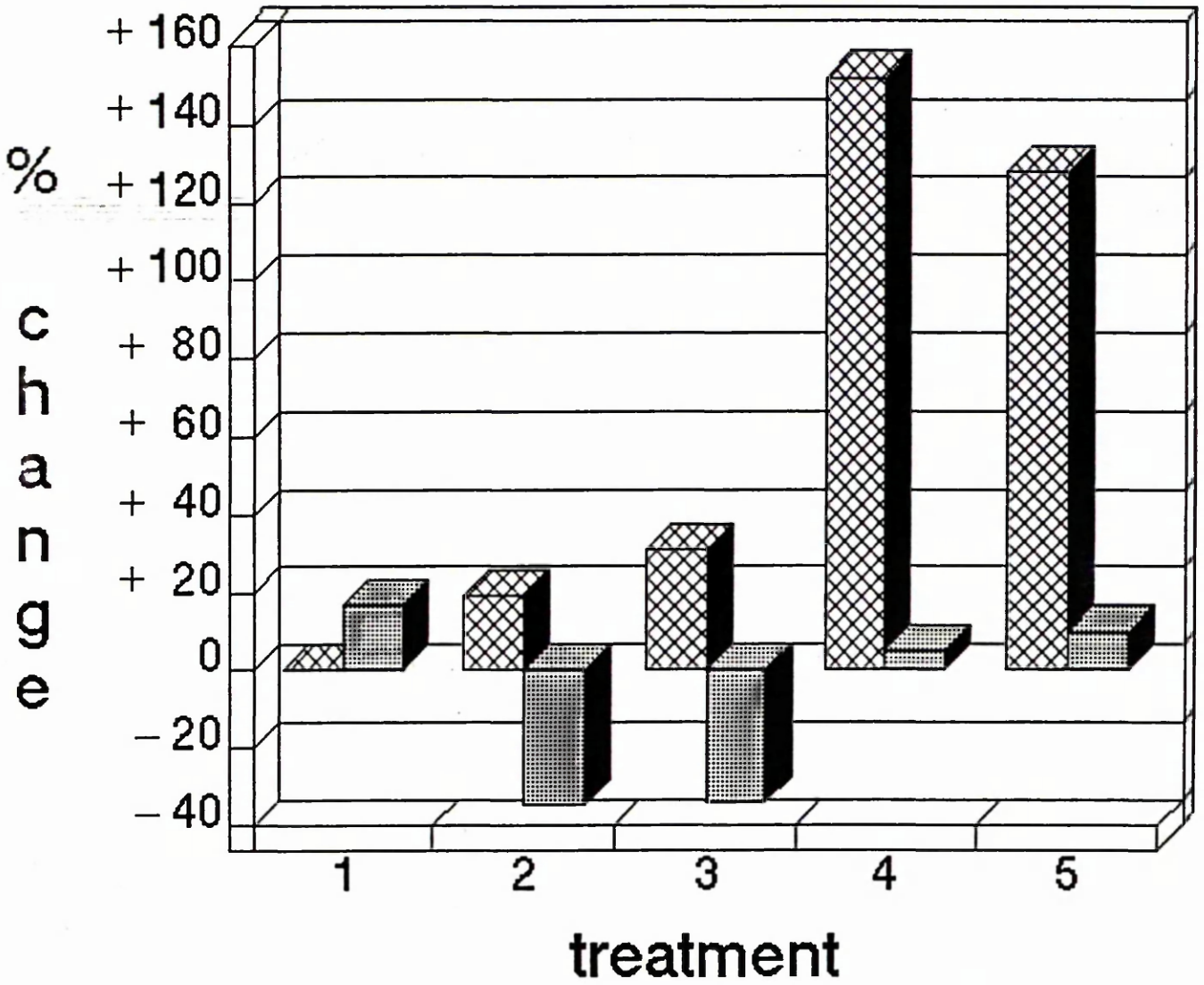
3 Straw bales added to the silo as a bottom layer increased effluent volume by 17% and total OM loss in effluent by 19% compared to the control.

4 Addition of chopped straw reduced effluent volume and total OM lost in effluent by 48% and 42% respectively.

FIGURE 4.23

Mini silos 1986

BOD losses in effluent



Key

conc.

total loss

1. straw bales bottom
2. chopped straw layers
3. chopped straw layers
4. beet shred layers
5. beet shred layers

5 Addition of molassed beet shreds reduced effluent volume by 57%, but total OM lost in effluent by only 27% because of a 73% increase in effluent OM concentration.

6 Chopped straw and molassed beet shreds increased the volume needed to store one tonne of grass by 80 and 22% respectively.

7 Addition of chopped straw to grass at ensiling resulted in a significant reduction in *in vivo* digestibility of OM and energy and in metabolisable energy value.

8 Addition of molassed beet shreds to grass at ensiling did not affect *in vivo* digestibility of OM or energy but the calculated metabolisable energy value was slightly reduced due to a lowering of silage GE content.

SECTION 3

INTAKE AND PERFORMANCE OF CALVES FED THE 1986 EXPERIMENTAL SILAGES

OBJECTIVE

The work described in Section 2 of this Chapter describes the effects of various absorbent treatments on losses from the silos and on silage composition and digestibility. However, before a particular effluent control technique can be recommended for farm application, it is necessary to measure the effects of absorbent inclusion on animal performance and ad libitum intake. Only then will it be possible to make an appraisal of the practicalities and financial implication of mixing absorbents with grass prior to ensiling.

EXPERIMENTAL

Animals

Eighteen Friesian castrated male calves, born over a two week period in September 1986 were used. All calves had been weaned and reared conventionally on a proprietary calf diet. At the start of the experiment on 6 January 1987, their mean liveweight was 129 kg which increased to 170 kg by the end of the 6 week feeding period.

Housing and Management

All calves were weighed and penned individually on concrete floors with sawdust bedding. Additional sawdust was provided daily. Fresh feed was offered twice daily at 0830 and 1630 hrs in plastic feed boxes fitted to the door of each pen. Fresh water was always available. The animals were weighed once a week at 1400 hrs.

Experimental Design

The 18 calves were grouped into three blocks of six on the basis of their

order of reaching 129 kg liveweight and were then randomly assigned within blocks to the three treatments using a randomised block design. The design of the trial is shown in Figure 4.31.

Feeding Routine

Between 8 December 1986 and 5 January 1987, each calf was fed 2.5 kg hay, 1.3 kg barley, 0.15 kg soya bean meal and 0.07 kg mineral mix per day. On 6 January 1987, an acclimatisation period of 11 days was started, in which the above ration was reduced progressively as ad libitum access to the appropriate experimental silage was given. For the last 4 days of this 11 day period, the calves received only the experimental ration described below. The silages were given on an ad libitum basis in two feeds per day at 0830 and 1630 hrs in quantities adjusted to be 10% in excess of the expected daily consumption based on the intake for the previous 4 days. The silages were supplemented with a concentrate mixture consisting of 1 kg barley, 0.2 kg soya bean meal and 0.07 kg mineral mix*. The composition of the barley and soya bean meal is shown in Table 4.31.

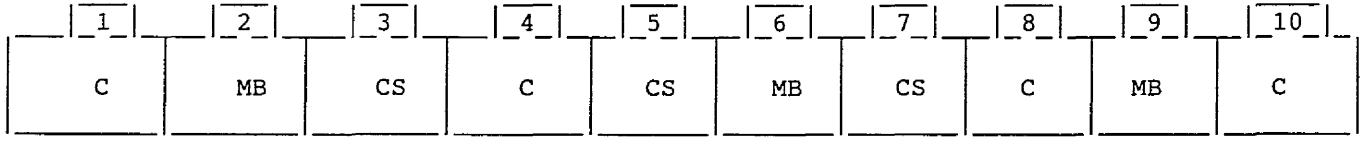
The following silage treatments were tested:

Treatment	Code	Silos
1 Control	C	1 and 3
2 Chopped Straw	CS	4 and 6
3 Molassed Beet Shreds	MB	2 and 5

* Cattle Standard", Scotmin, Maybole, Ayrshire

FIGURE 4.31

Pen Allocation Showing Randomised Design



C = Control

MB = Molassed Beet Shreds

CS = Chopped Straw Silage

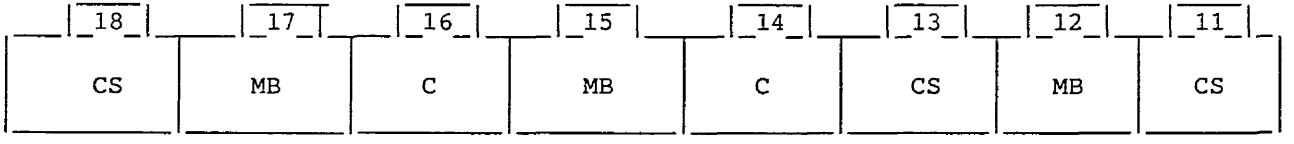


TABLE 4.31

Composition of Barley and Soya Bean Meal

Composition	Barley	Soya Bean Meal
DM (gkg^{-1})	821	867
OM (gkg^{-1} DM)	973	937
CP (gkg^{-1} DM)	90	437
In vitro D-Value (%)	80.3	83.6
ME ($MJkg^{-1}$ DM^{+})	12.5	13.4

+ Calculated from *in vitro* D

Although silo 3 (see Table 4.21, page 179) contained a bottom layer of straw bales, the silage above the bales was treated as control silage for the purposes of this experiment. Examination of the chemical composition and in vitro digestibility of the silage from silo 3 showed that it did not differ significantly from the silage from silo 1.

Calves for each treatment received their morning feed from one silo and their evening feed from the other of the pair in a 50:50 ratio. Thus for example, the control calves received silage from silo 1 in the morning and an equal weight from silo 3 in the evening. Quantities of each silage sufficient for four days were removed from the clamps, weighed into baskets and stored for feeding.

Sampling and Analysis of Feed and Feed Residues

Representative samples were taken from each quantity of silage removed from each silo for DM determination. Feed refusals were weighed daily, sampled, and their DM content was determined on a composite sample accumulated over a period of four days. The daily silage dry matter intakes were calculated from the weights offered and refused.

Statistical Analysis

The data was analysed as a randomised block design. Silage dry matter intake and daily liveweight gains were subjected to the analysis of variance technique to determine statistically significant differences between treatments. Liveweight gains for each calf were calculated by regression of liveweights measured at weekly intervals.

Silage Intake and Animal Performance

Table 4.32 shows the mean daily silage dry matter intakes (SDMI) of the calves on the three treatments. Intake was least for calves offered the chopped straw silage, but the difference from the mean value for the control just failed to reach significance ($P < 0.05$). The SDMI for calves fed the molassed beet shred silage was significantly ($P < 0.05$) higher than for those offered the control or chopped straw silages. Figure 4.32 shows the mean weekly group SDMI over the six weeks of the trial. The increased SDMI of calves fed the beet shred silage was maintained over the entire course of the trial. However, the differences in SDMI between the control and chopped straw was greatest in the first two weeks of the trial and thereafter, intakes for these two silages were similar.

Calves fed the molassed beet shred silage gained weight significantly ($P < 0.05$) faster than those fed the other silages (see Table 4.32). The liveweight gains of calves receiving the control or chopped straw silages were not significantly ($P < 0.05$) different. However, the mean liveweight gain for the latter group (0.86 kgd^{-1}) was significantly lower than the former (0.97 kgd^{-1}) at $P = 0.10$. Figure 4.33 shows the mean liveweights of each group for the three diets over the trial period.

Individual dry matter intakes and liveweight gain (kgd^{-1}) for each animal are shown in Appendix 19. Analysis of variance for silage DM intake and daily liveweight gain are shown in Appendices 20 and 21 respectively.

TABLE 4.32

Mean* Intakes and Liveweight Gains of Calves

Objective	Treatment			SED+
	Control	Chopped Straw Silage	Molassed Beet Shred Silage	
Silage DM Intake (kgd^{-1})	2.27^{a}	2.14^{a}	2.62^{b}	0.07
Liveweight Gain (kgd^{-1})	0.97^{a}	0.86^{a}	1.11^{b}	0.059

* Means in the same line not sharing common subscripts differ significantly ($P < 0.05$).

\+ Standard error of difference between means in the same line.

FIGURE 4.32

SILAGE DRY MATTER INTAKE (SDMI)
(Mean for each treatment group of calves)

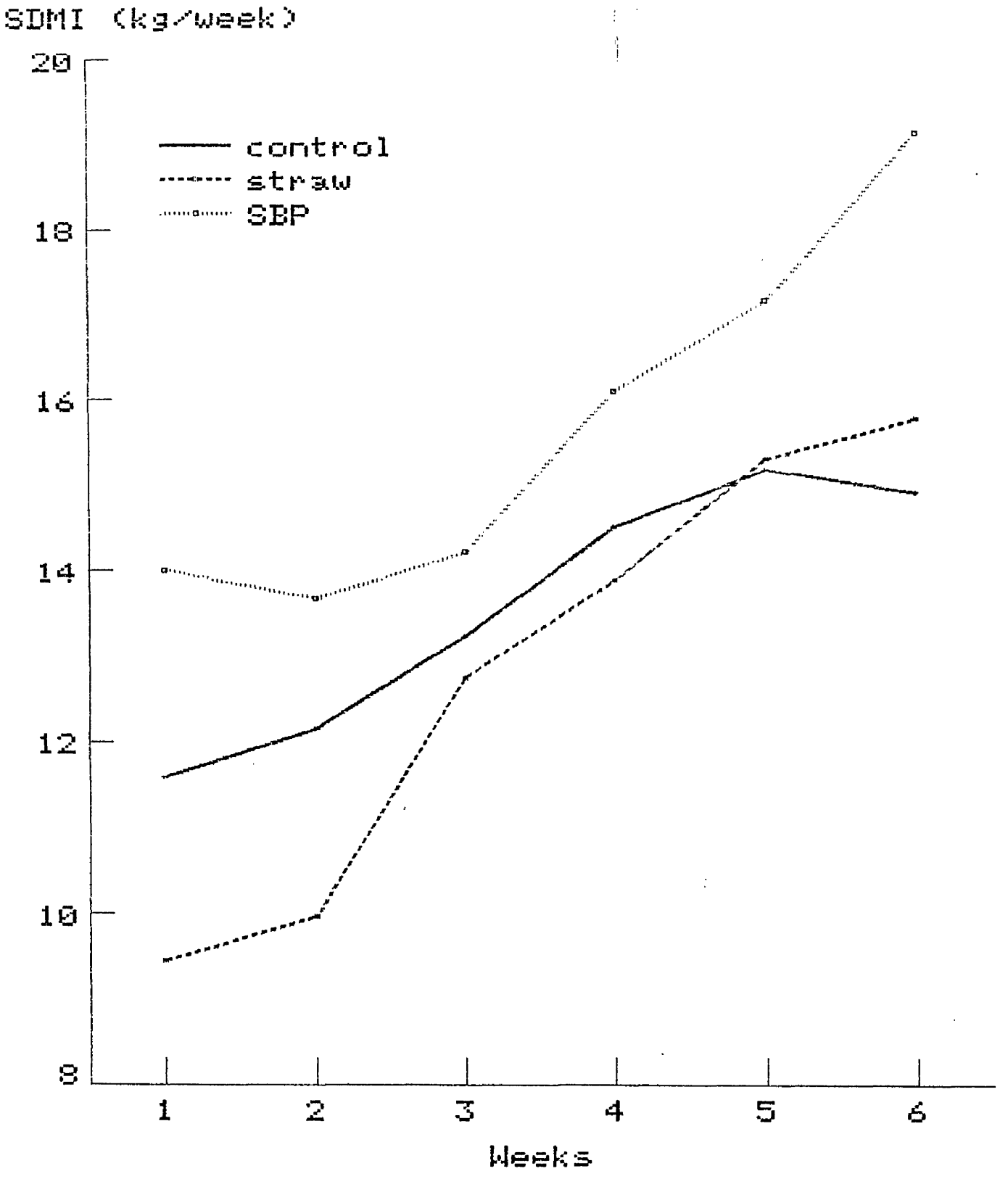
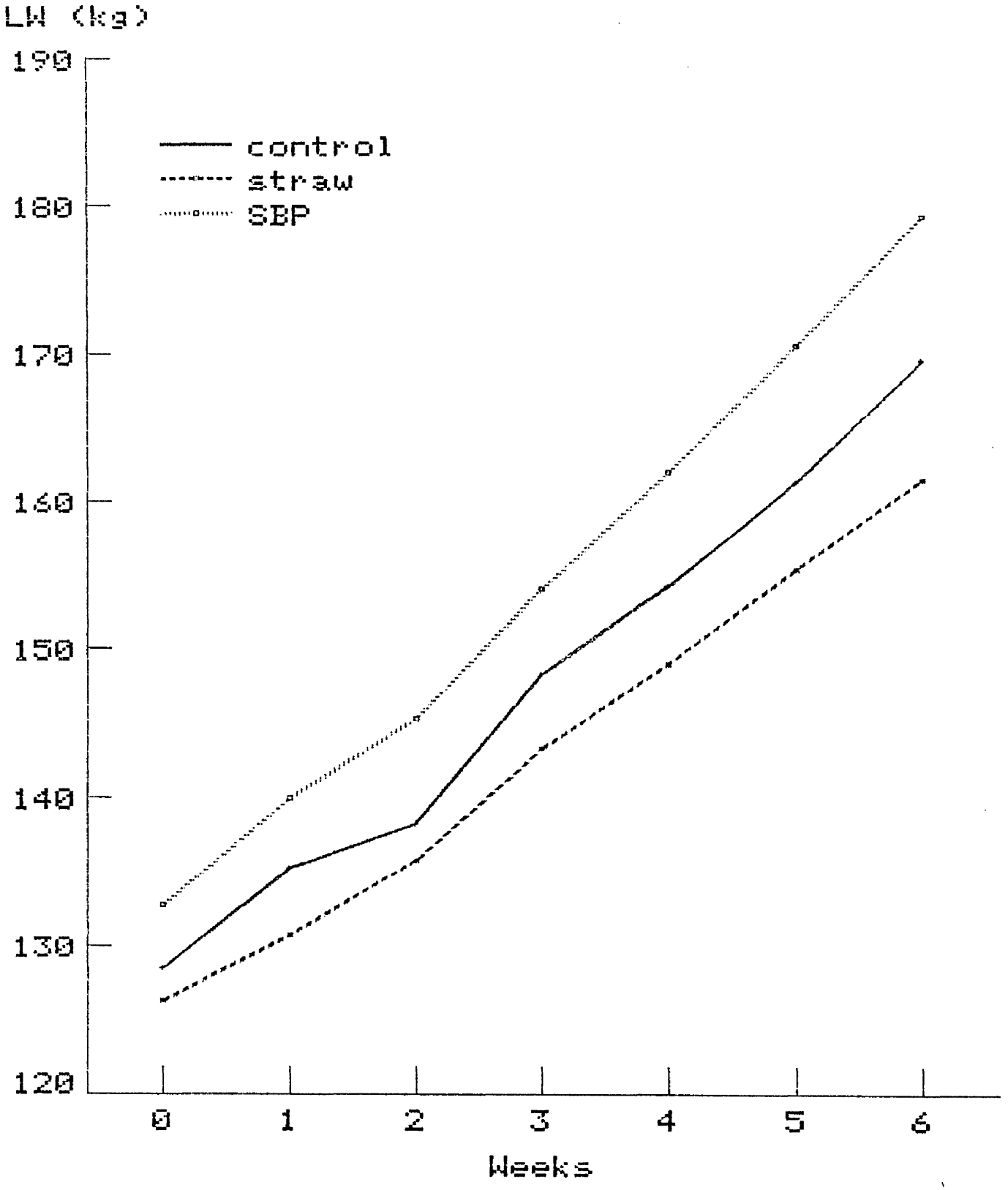


FIGURE 4.33

CALF LIVEWEIGHT (LW)
(Mean for each treatment group of calves)



DISCUSSION

Silage Intake and Performance

The main objective of this trial was to measure the effects of adding chopped barley straw or molassed beet shreds to grass at ensiling on silage dry matter intake and liveweight gain of calves. The main limitation of this trial was the fact that the quantities of silage available restricted both the length of the trial and the number of calves per treatment. The calves were carefully allocated to the 3 blocks on the basis of liveweight. At allocation, the mean liveweight for control, chopped straw and molassed beet shreds were 127.8, 128.5 and 128.5 kg respectively. Clear differences in SDMI and liveweight were already established by the first measurement in week 1 of the trial which followed an 11 day acclimatisation period. It is likely that some of the observed differences between treatments that just failed to reach significance at $P < 0.05$ would have been proved had the supply of silage permitted a longer trial or the use of more calves.

Mean SDMI (kg/calf/day) for each group over the 6 weeks of the trial were 2.27, 2.14 and 2.62 for the control, chopped straw and molassed beet shred silages respectively. Chopped straw inclusion reduced SDMI by only 0.13 kgd^{-1} when compared to the control - a difference which just failed to reach significance ($P < 0.05$). However, this difference was not consistent over the course of the trial. The mean SDMI for the chopped straw silage was considerably lower than the control during weeks 1 and 2 but thereafter, the differences were small. During weeks 5 and 6, SDMI for the chopped straw silage was slightly higher than for the control (see Figure 4.32).

Addition of molassed beet shreds to grass at ensiling resulted in a highly significant ($P < 0.001$) increase in SDMI when compared to the control or chopped straw silages. The mean SDMI of calves fed beet shred silage over the whole trial was 0.35 kgd^{-1} higher than for the control group and 0.48 kgd^{-1} higher than for the chopped straw silage group (see Table 4.32). Inclusion of molassed beet shreds to grass at ensiling had no effect on the digestibility of OM or GE measured *in vivo* with the same calves fed at a fixed level of intake (see Section 2 of this Chapter). There were however, small effects on silage composition due to incorporation of molassed beet shreds and it seems

likely that the increase in SDMI can be attributed to the improved silage fermentation due to inclusion of molassed beet shreds which resulted in silage with a greater palatability. Several studies have found statistically significant relationships between silage intake and fermentation quality (Wilkins et al, 1971; Wilkins et al, 1978; Thomas and Thomas, 1985). Figure 4.32 shows the mean group silage weekly DM intake. Calves fed molassed beet shred silage ate more silage than the others from the beginning of the trial.

Mean liveweight gains for each group over the whole trial were 0.97, 0.86 and 1.11 kgd^{-1} for the control, chopped straw and molassed beet shred silages respectively (see Table 4.32). Although the control group obtained a mean liveweight gain of 0.11 kgd^{-1} higher than the group fed the chopped straw silage, the difference was not significant ($P < 0.05$). However, this depression in liveweight gain due to incorporation of chopped straw at ensiling was considerable and was significant at $P < 0.10$. Furthermore, Figure 4.33 shows that the difference in liveweight gain between the control and chopped straw groups was consistent over the entire period of the trial, even though there was less difference in SDMI between calves in these groups. Thus inclusion of chopped straw reduced animal performance. Nielson (1961), Frank (1982) and Phillips (1983) have measured the effects of adding straw to forages immediately before feeding on performance in dairy cows. The present study differs from these trials since, in the dairy cow trials the straw was not ensiled with the forage and therefore straw inclusion could not affect silage fermentation. The experiments of Nielson (1961) and Phillips (1983) showed that milk production was depressed (although there were increases in cow liveweight) when straw was mixed with silage unless the metabolisable energy value of the mixture was maintained by the use of alkali-treated straw and/or supplementary concentrates. The study of Frank (1982) which continued over 40 weeks of a lactation showed that when barley straw was added to poor quality hay, milk production and liveweight gain was depressed even although the ME values of the straw and hay were similar. Thus the present study supports the general view that the addition of straw to silage or hay depresses animal performance unless compensatory supplementation is provided.

Calves fed the molassed beet shred silage ate more silage DM and gained weight significantly ($P < 0.05$) faster than either the control or chopped straw silage groups. Nevertheless, the liveweight gains recorded for the calves fed

the chopped straw silage diet (0.86 kgd^{-1}) would be considered adequate for many production systems. Steen (1985) in an experiment with calves (initial liveweight 70 kg), fed a well preserved highly-digestible grass silage based diet supplemented with 1.05 or 2.2 kgd^{-1} concentrate which consisted of (gkg^{-1}) 800 ground barley, 125 soya bean meal, 50 molasses and 25 minerals and vitamins. He reported liveweight gains of 0.87 and 1.05 kgd^{-1} for the low and high concentrate diets respectively and concluded that the optimum level of performance for autumn-born calves during their first winter (0.87 kgd^{-1}) can be sustained by a diet of high-digestibility grass silage supplemented with about 1.0 kg of conventional cereal/soya bean meal concentrate. This level of performance was achieved in the present study by calves fed the chopped straw silage and was exceeded by the other groups. Chapple (1985) in a similar feeding trial with calves, fed a silage based diet supplemented with 2 kgd^{-1} concentrate and reported a liveweight gain of 1.0 kgd^{-1} which was lower than the value of 1.11 kgd^{-1} measured in the present trial for calves fed the beet shred silage. At the mid-point of the present experiment, calves fed the beet shred silage (mean liveweight 153 kg) consumed per day 1 kg of barley/soya mixture plus 2.3 kg DM of the silage. Since, on a DM basis, the beet shred silage contained approximately 25% beet shreds, the daily ration could be considered as:

1.7 kg DM grass silage
1.6 kg DM of concentrate (barley + soya + beet shreds)

This allows a comparison to be made with the result of Steen (1985) who used similar calves. Total DM intake (kgd^{-1}) were similar for the two trials (approximately 2.2% of liveweight) but in the present trial, slightly higher liveweight gains were achieved with 0.2 kgd^{-1} less concentrate DM. Since the DOMD of the silage in the trial of Steen (1985) was the same as measured for the control silage in the present study, this suggests that ensilage of mixtures of grass and molassed beet shreds may lead to enhanced efficiency of energy use by the animal compared to efficiencies for feeds mixed immediately before feeding.

The effect of ensiling beet shreds with crops at ensiling on the performance of dairy cows has been reported by Dulphy and Demarquilly (1976). They made two silages from a timothy/red clover sward. The first (control) contained

only the grass/legume which was made from a mixture of the herbage and beet pulp (59 kg/tonne herbage FW). The performance of dairy cows fed the ensiled mixture was compared with a treatment in which the beet shreds were mixed with the control silage immediately before feeding. They found that when beet pulp was added at feeding there was a loss of liveweight of 49 gd^{-1} compared with an increase of 140 gd^{-1} when pulp was added at ensiling. Milk production was higher with pulp added at ensiling than with pulp added at feeding. In a similar experiment, Dulphy and Andrieu (1978) fed dairy cows perennial ryegrass silage made with the addition of 60 kg molassed beet pulp per tonne of grass at ensiling, which was equivalent to 25% of the total ensiled DM. In three trials, they found that addition of beet pulp at ensiling increased daily fat corrected milk production by 0.7 kg per cow and increased liveweight gain by 154 gd^{-1} compared with addition of pulp at feeding.

Calculation of Efficiency of Utilisation of ME for LWG (k_f)

The efficiency of utilisation of ME for gain was calculated to provide a more reliable index of the efficiency of utilisation of dietary energy for liveweight gain than can be achieved by consideration of feed conversion efficiency. Firstly, calculation of k_f allows for the differences in ME value ($MJkg^{-1}$ DM) of the different diets (as calculated from DE measured in vivo with the same calves) and secondly, the separate allowance for the maintenance energy requirement removes the confounding effect due to variation in the proportion of ME intake used for liveweight gain. The main weakness of the calculation of k_f as applied in this trial is that, in the absence of carcass analysis data, it was necessary to predict the net energy values of liveweight gain. The possibility that the treatments affected composition of liveweight gain, in a way not predicted by the ARC (1980) equation, should not be discounted.

The efficiency of utilisation of ME for gain was calculated as follows:

1 The ME values for the different experimental silages were calculated from digestible energy values measured in the in vivo digestibility trial carried out with calves (see Section 2 of this Chapter) using the following equation:

$$ME = 0.81 \times DE$$

2 The energy stored in liveweight gain for each animal was calculated using the ARC (1980) equations (see Appendix 22) which uses the liveweight gain and liveweight to predict the net energy stored.

3 The ME available for liveweight gain was calculated from the following equation:

$$\text{ME available for gain} = \text{ME intake} - \text{ME required for maintenance}$$

ME required for maintenance was calculated from the ARC (1980) equations (see Appendix 22).

4 The efficiency of utilisation of ME for liveweight gain is then calculated as follows:

$$k_f = \frac{\text{energy stored in liveweight gain}}{\text{ME available for liveweight gain}}$$

Where,

k_f = efficiency of utilisation of ME for gain

A further parameter (NEMP) was calculated to compare the animal performance with that predicted from ARC (1980) on the basis of the ME intake.

$$NEMP = \frac{\text{NE stored in measured liveweight gain}}{\text{NE stored in liveweight gain predicted by ARC (1980)}}$$

Table 4.33 shows the mean calculated efficiencies of utilisation of ME for gain (k_f) for different diets. The k_f calculated for the control diet was 0.45. This value is in line with that reported by Beever et al (1984) for a similar silage. Addition of molassed beet shreds to grass at ensiling significantly ($P < 0.05$) increased the calculated k_f value of the diet containing this silage when compared to the control. The k_f value of the chopped straw silage diet was 0.58 which was significantly ($P < 0.05$) higher than that for either the control or beet shred silage diets. Analysis of variance is shown in Appendix 23.

The mean values calculated for NEMP for the animals on different silage diets are shown in Table 4.33. Analysis of variance is shown in Appendix 24. There were significant differences among animals fed different silages. Calves fed the molassed beet shred silage produced significantly ($P < 0.01$) higher values than those fed the control silage. The animals fed the diet containing chopped straw silage gave significantly ($P < 0.001$) higher values than those fed either the control or beet shred silage diets.

The NEMP values provide an indication of how closely the calf performance in this trial fits the model described by ARC (1980). Calves fed the beet shred silage plus barley soya gave liveweight gains which most closely matched the ARC (1980) prediction. This group apparently stored approximately 5% less NE in liveweight gain than would be predicted. This means that the k_f value of 0.49 calculated for this group is only slightly lower than would be predicted from the metabolisability of this diet using the ARC (1980) equation for mixed diets. However, for the calves fed the control silage diet the ARC (1980) model seriously overestimated the liveweight gain that would be achieved. The NE stored in liveweight gain calculated from measured liveweight gain is only 84% of that which ARC (1980) would predict on the basis of measured ME intake. This means that, for the control diet, the calculated k_f values (0.45) is considerably lower than that which ARC (1980) predicts using the equation for mixed diets. For calves fed the diet containing the chopped straw silage, NE stored in liveweight gain exceeded the ARC (1980) prediction by 20%. The k_f value calculated for this group (0.58) was therefore considerably greater than that predicted from the ARC (1980) equation.

TABLE 4.33

Mean* Calculated Efficiencies of Utilisation of ME for Liveweight Gain (k_f) and the Calculated Values for NEMP[+] for the last Four Weeks of the Trial

Treatment	k_f	NEMP
Control	0.45^a	0.84^a
Chopped Straw Silage	0.58^b	1.2^b
Molassed Beet Shred Silage	0.49^c	0.95^c
SED[°]	0.020	0.034

* Mean in the same column not sharing common subscripts differ significantly ($P < 0.05$)

[+] $$\text{NEMP} = \frac{\text{NE stored in measured liveweight gain}}{\text{NE stored in liveweight gain predicted by ARC (1980)}}$$

[°] Standard error of difference for means in the same column.

The trial therefore shows large discrepancies for some diets between observed performance and that predicted by ARC (1980). An explanation could be that the energy value of a unit weight of gain was affected by dietary treatment in a way not predicted by ARC (1980). Relative differences in gut fill between diets could be a major source of these differences. Carcass analysis or calorimetric studies would help to explain the nature of the discrepancies between actual and predicted performance. The weight of gut contents as a proportion of total liveweight may have varied for the different diets. The diet containing chopped straw might be expected to lead to a greater weight of gut contents per unit liveweight than for the other diets. Liveweight gain was estimated by regression of liveweight against time and this may have led to an overestimate of carcass gain for the straw silage relative to the others. The ARC (1980) model assumes a single linear relationship between liveweight and empty body weight for all diets. In the case of diets for which gut contents exceed the proportion of liveweight predicted by this relationship, the gain in empty body weight calculated from measured liveweight gain will be exaggerated. This may explain the high values of k_f and NEMP calculated for the chopped straw diet.

Table 4.34 shows the approximate daily intake of the dietary components during the fourth week of the trial. For calves fed the chopped straw diet, the straw represented only approximately 17% of total DM intake. It seems unlikely therefore, that the weight of gut contents as a proportion of liveweight would be so much greater than for calves fed the control diet as to explain the large differences in k_f and NEMP.

Thomas and Thomas (1985) reviewed measurements of efficiency of utilisation of metabolisable energy for maintenance (k_m), for liveweight gain (k_f) and for lactation (k_l). Measured values of K_m, k_f and k_l are generally lower for all-silage diets than for mixed diets. Determined k_f values for growing cattle fed silage diets were 0.09 or 17.3% of the value, calculated using the ARC (1980) relationships. However in the present trial, silage was not fed alone (see TAble 4.34) and the work of Thomas and Chamberlain (1982b) and Beever et al (1984) showed that k_f values were increased when silage diets were supplemented with barley. The k_f value for the control diet in the present study (0.45) was low compared to the value of 0.54 measured by Beever et al (1984) for a silage diet containing 28% barley on a DM basis. In the present

TABLE 4.34

Approximate Intakes of Dietary Components During the Fourth Week of the Trial (kg DM/calf/day)

Treatment	Grass Silage	Ensiled Chopped Straw	Ensiled Molassed Beet Shreds	Barley + Soya	Total DM Intake
Control	2.11	-	-	1.00	3.11
Chopped Straw	1.57	0.52	-	1.00	3.09
Molassed Beet Shreds	1.79	-	0.6	1.00	3.39

study, addition of either molassed beet shreds or chopped straw to the grass at ensiling improved the calculated k_f values even though a barley supplement was provided for all diets.

It is difficult to explain the apparent improvement in k_f values when absorbents were ensiled with the grass. The improvement in k_f values when silage diets are supplemented with rapidly fermentable energy sources may be partly attributed to improved efficiency of microbial protein synthesis in the rumen due to the synergistic effect of supplying both structural and non-structural carbohydrate (as described by Offer et al, 1978 and Mathers and Miller, 1981). In addition, the inclusion of rapidly fermentable carbohydrate would decrease the rumen acetate: propionate ratio which according to Blaxter and Wainman (1964) and Daccord (1970) would lead to an ~~reduced~~ increased efficiency of utilisation of ME for liveweight gain. The work of Ørskov et al (1966), Hovell and Greenhalgh (1972) and Hovell et al (176) suggests that the acetate:propionate ratio has little effect on k_f. Another possible mechanism for the increase in k_f when barley is fed with silage is the possibility that barley supplementation increases absorption of energy as glucose at the expense of VFA. Stokes and Thomas (1978) have related the increase in k_f as concentrate proportion of the diet is increased to increased uptake of glucose from the small intestine. Also the heat of digestion (including heat of fermentation) may be reduced when barley is included in a diet at the expense of structural carbohydrate. Thus Osuji et al (1975) showed that the heat of digestion was reduced by physical processing of a grass diet.

None of these mechanisms provide an explanation for the increase in k_f when absorbents were ensiled with the grass. Incorporation of chopped straw or molassed beet shreds would not be expected to have the same effects as barley on any of the parameters described. The problem requires further, more detailed research using calorimetric techniques.

Financial Appraisal

A margin over feed costs (£/calf) was calculated by estimation of the total feed costs and the value of liveweight gain measured during the six weeks of the trial as follows:

1 Cost of Feed

Feed	Cost £t^{-1} FW
Grass Silage	15
Barley	102
Soya Bean Meal	150
Mineral Mix	350
Chopped Barley Straw	30
Molassed Beet Shreds	100

2 Table 4.35 shows the feed intakes and costs per calf per 6 weeks.

3 Table 4.36 shows the total cost of feed, the total gain and the value of gain (£) over the 6 weeks of the trial.

The total feed cost was greatest for the molassed beet shred treatment due to the higher total intake achieved and the cost of the molassed beet shreds (£100/tonne). The total feed cost was £17.95 for the molassed beet shred diet compared to £15.97 for the control and £14.01 for the chopped straw diet. The value of the gain was however, greater for the molassed beet shred diet (£69.90), intermediate for the control (£61.05) and was least for the chopped straw diet (£54.15). Consequently, the margin over feed cost for the molassed beet shred diet was £11.81 and £6.87 greater than for the chopped straw and control diets respectively (see Table 4.36).

Research work reported in Chapter 3 (experiment 2b) using drum silos, demonstrated the possibility of producing well-fermented silages from grass and molassed beet shreds without a silage additive. It is likely that, if molassed beet shreds are used, a saving on the cost of additive could be made. Had Add-F not been used in this trial for the molassed beet shred treatment with no effect on silage quality, this would represent a saving of £1.36 over the 6 weeks (assuming cost of Add-F is £2.50 per tonne of grass).

TABLE 4.35

Feed Consumption and Costs per Calf per Six Weeks

Treatment	Feed	Dry Weight (kg)	Fresh Weight (kg)	Cost (£)
Control	Silage	95.3	627	9.41
	Barley	34.5	42	4.28
	Soya Bean Meal	7.3	8.4	1.26
	Mineral Mix	-	2.9	1.02
Chopped Straw	Grass Silage	67.4	443	6.65
	Chopped Straw	22.5	26.6	0.80
	Barley	34.5	42	4.28
	Soya Bean Meal	7.3	8.4	1.26
	Mineral Mix	-	2.9	1.02
Molassed Beet Shreds	Grass Silage	82.5	543	8.14
	Molassed Beet Shreds	27.5	32.5	3.25
	Barley	34.5	42	4.28
	Soya Bean meal	7.3	8.4	1.26
	Mineral Mix	-	2.9	1.02

TABLE 4.36

Total Feed Cost and Value of Gain (£) per Calf per 6 Weeks

Treatment	Total Feed Cost (£)	Total Gain (kg)	Value of* Gain (£)	Margin Over Feed Cost (£)
Control	15.97	40.7	61.05	45.08
Chopped Straw	14.01	36.1	54.15	40.14
Molassed Beet Shreds	17.95	46.6	69.90	51.95

* Assuming £1.50/kg gain.

It is essential to stress that the financial evaluation described above applies only to this trial, which was of only a small scale, and continued for only a short period. The conclusions require to be tested in a large scale trial over a longer period. For a 30 week trial, the improvement in margin per calf could be as much as £41 due to incorporation of molassed beet shreds. However, a more valid comparison would be to use a control treatment in which the calves receive the same quantity of beet shreds fed without being ensiled with the grass. Such a trial would provide an estimate of the economics of providing effluent control by incorporation of molassed beet shreds.

CONCLUSIONS

1 Addition of chopped straw to grass at ensiling reduced liveweight gain in calves.

2 Addition of molassed beet shreds to grass at ensiling significantly increased silage DM intake and liveweight gain in calves.

3 Addition of either absorbent to grass at ensiling increased the calculated efficiency of utilisation of metabolisable energy for liveweight gain.

CHAPTER FIVE

GENERAL DISCUSSION

The organic constituents of silage effluent are rapidly decomposed by micro-organisms when released into streams and rivers using up large amounts of oxygen in the process. This is reflected in the very high BOD values recorded for silage effluent (12,000-90,000 ppm), which shows it to be a much more powerful pollutant than other agricultural wastes. Thus, when fish deaths occur from silage effluent entering a watercourse, the cause of death is usually from oxygen depletion. The high BOD value of silage effluent makes it unacceptable without pre-treatment to local authorities for disposal in public sewers, or to the River Authorities for discharge into rivers or streams. For safe disposal, the BOD value should be reduced to a level of about 20 ppm (Ministry of Agriculture, Fisheries and Food, 1973) which could only be achieved by a full-scale treatment plant which would be too expensive for an ordinary grassland farm. Consequently, disposal must be achieved on the farm without expensive treatment and without any discharge to watercourses. This reinforces the need to reduce silage effluent to the absolute minimum in the conservation process.

Unfortunately, current trends in silage making (as listed below) which are aimed at the achievement of maximum animal production per unit area of grassland, all serve to increase effluent production:

- Use of earlier maturing, more succulent grass varieties
- High fertiliser application rates
- Early cutting for high digestibility
- Direct cutting
- Precision chopping
- Use of acid and enzyme additives

- Use of heavier tractors for rolling

- Provision of drainage pipes along the sides of silos

In addition, the total quantity of silage produced in the UK seems likely to increase for the following two reasons. Firstly, dairy farmers will attempt to overcome the reduction in farm income caused by the imposition of quotas on milk production by producing more milk from grass rather than concentrate feeds. Secondly, there is accumulating evidence that grass and animal production per unit area of land is increased when grass is cut for conservation rather than directly grazed (Kay, 1987).

A major problem which limits safe disposal of silage effluent is the integrity of clamp silos on many farms. As many as 90% of the farm silos in the West of Scotland leak to some extent (Johnston, 1987). The construction of leak-proof silos is difficult and expensive and any programme of repair or replacement of existing silos will take many years, during which time many silos will deteriorate further.

The River Purification Boards are in action to prevent watercourses being polluted by silage effluent. A report on the 1985 survey of water pollution incidents caused by silage effluent in England and Wales has shown a sharp increase over the previous year from 573 incidents in 1984 to 1006 in 1985 (ADAS, 1985). Much of the increase was due to leaks from silos, collection systems and storage tanks (see Table 5.1). In 1985, silage effluent became the most important source of agricultural pollution in England and Wales, forming 30% of total incidents and 40% of total serious pollution incidents (ADAS, 1985). The 1986 edition of the Water Authorities Association report "Water Pollution from Farm Waste in England and Wales" (ADAS, 1986) suggests that up to half Britain's dairy farmers - much the worst offenders - are either polluting rivers or risk doing so. Pollution incidents in 1986 increased in number by approximately one third in Devon and Cornwall and by nearly one half for Somerset, Dorset and Wiltshire compared to numbers for 1985. Although silage effluent is not the only source of agricultural pollution, it has played an important part in the pollution of rivers in dairy farming areas. Nearly half of the rivers in Devon and Cornwall have been

TABLE 5.1

Pollution Incidents caused by Silage Effluent in England and Wales in 1985 (From ADAS 1985)

Cause of Pollution	Pollution Incidents	Serious Pollution Incidents
Inadequate Effluent Storage	277	59
Leaking Silos	320	69
Leaking Effluent Stores/Drains	409	82
TOTAL	1006	210

downgraded by the Water Authorities between 1980 and 1985 due to their increased pollution.

In the wetter North Western parts of the UK, particularly Western Scotland and Northern Ireland, the problem of effluent pollution is likely to be more severe than in the country as a whole. Approximately 80% of the silages analysed at the West of Scotland Agricultural College during the years 1984-1987 had a DM content of less than 200 gkg^{-1}. Such silages would have produced large volumes of effluent and many pollution incidents. In 1985, inspectors of the Clyde River Purification Board visited 200 dairy farms during June, July and August, of which 105 were found to be causing pollution by leakage of silage effluent.

The actual incidence of pollution by silage effluent is likely to be much greater than indicated by the number of official warnings and prosecutions. Many pollution incidents are undetected and River Boards are reluctant to prosecute farmers who make a serious attempt to prevent pollution even if their efforts prove unsuccessful. Indeed, under the terms of the Control of Pollution Act 1974, Part 2, a farmer who has caused pollution may use in his defence the claim that he has followed "good agricultural practice". This may explain why the numbers of prosecutions (and the fines imposed) have declined in 1986 compared to 1985, even though the number of pollution incidents has increased (ADAS, 1985 and 1986). The evidence suggests that current "good agricultural practice" is frequently inadequate for avoiding pollution although it may perhaps be used as a legal defence. What is required is a reliable strategy for avoiding effluent pollution which could then be enforced.

A farmer who has a silage effluent pollution problem has the following options. He could:

1 Stop Making Silage

The farmer would need to conserve grass for winter feeding as hay. However, the advantages of silage over hay making under UK climatic conditions, in terms of animal production and profitability, are well known to the farmer and very few would accept this option voluntarily.

2 Resite the Silo in a place away from Watercourses

Any programme for building a new silo would be expensive and no convenient suitable site may be available close to stock buildings.

3 Make the Silo Leak-proof and provide Effluent Storage Tanks of adequate size

This option would be expensive and frequently difficult to achieve. It may require complete rebuilding of the silo, although remedial action such as the use of asphalt coating (Johnston, 1987) may be possible in some cases.

4 Increase the Grass Wilting period to reduce Effluent Production

This option would be the most attractive to the farmer who faces a pollution problem, since it requires no financial outlay. However, in the wetter parts of the UK, it is impossible always to achieve the grass DM level (minimum 250 gkg^{-1}) necessary to avoid effluent pollution. In many years, the farmer would pay the penalty of increased field losses and poor silage fermentation due to delayed filling of the clamp.

5 Use Absorbents

The farmer could add absorbent materials to prevent effluent production. Although no capital silo rebuilding cost would be incurred, the farmer would need to purchase the absorbent well in advance of feeding. Also, the choice of absorbent and level of application would need to be made with great care so as to achieve satisfactory pollution control and animal performance.

A River Purification Board has the duty and power to force any farmer causing pollution due to silage effluent, to adopt one of the options listed above. In many cases, agricultural advisory organisations (ADAS in England and Wales and SAC in Scotland) would be consulted. It is important therefore, for the advisory services to know in detail how to overcome the problem of silage effluent. For example, if wilting is the chosen preventative method, estimations of grass DM at ensiling and a knowledge of target DM levels to prevent effluent will be needed. Alternatively, if an absorbent is to be used, it is important to know which absorbent to use, the appropriate rate of

addition and what the consequences may be for effluent production, silage quality and animal performance.

The work described in this thesis has evaluated the effect of adding absorbents to grass at ensiling on the following aspects:

1 Effluent volume and composition

2 Silage fermentation and composition

3 Silage digestibility, intake potential and feeding value

4 The silo volume required per unit weight of grass

It may be argued that comparisons of different absorbents would be best carried out using farm-scale silos. However, the problems of obtaining an homogeneous supply of grass and a sufficient number of silos meant that the initial assessment of absorbents should be carried out using small scale experimental silos. Drum silos of 200 l capacity were used to compare absorbents (experiments 1 and 2a) and to measure the relationship between grass DM, level of SBP and effluent production (experiment 2b). A disadvantage of using drum silos was that, for grass of DM content greater than 150 gkg^{-1}, no effluent collected in the base of the drum although in a farm-scale silo considerable effluent loss would occur. This difference can be attributed to the lower pressure applied to the silage in the drum silo. The wine press technique was used to simulate farm-scale conditions, but it should be remembered that it measures volumes of juice expressed from silage after fermentation rather than effluent freely drained from a silo in the days immediately following filling. Nevertheless, the use of drum silos allowed a wide range of absorbents to be screened and showed chopped barley straw, vitaferm and molassed beet shreds to be the most effective controllers of effluent. This conclusion is consistent with the results obtained for chopped straw and molassed beet shreds when tested in the "mini pit" silos (Chapter 4).

The volume of effluent measured by the wine press technique (l/tonne grass) are slightly lower than those reported for farm-scale silos. However, the drum experiment (2b) combined with the wine press technique yielded an important relationship (see equation (3), Chapter 3, page 113). This allows the calculation of the effluent volume expected (l/tonne grass) for any given grass DM and SBP concentration. Table 5.2 shows a comparison between the volumes of effluent predicted using equation (3) and those measured using the "mini pit" silos. The volumes of effluent collected for each level of beet shreds (l/tonne grass) were generally similar to those predicted using equation (3) for the appropriate levels of beet shreds and grass DM. Thus the relationship observed using drum silos and the wine press technique appears to yield a valid estimate of effluent production at least on the 10 tonne "mini pit" scale. However, the volumes of effluent measured in "mini pit" silos for the control silages were slightly lower than the values reported for large scale farm silos. Farm scale trials, using molassed beet shreds as an absorbent, are therefore needed to test the validity of equation (3) in practice, although evidence suggests that it should serve as a useful interim relationship.

The work described in Chapter 4 using "mini pit" silos evaluated the effects of different absorbents on effluent losses from grass silage and on silage quality and feeding value. Silage densities for the control silages made in the "mini pit" silos were similar to the values reported by Johnston et al (1985) for farm scale silos. This suggests that the consolidation achieved in the "mini pit" silos was similar to that for large scale silos and therefore that the effects of adding absorbent on silage fermentation reported in this work are likely to reflect those which would be found in farm scale silos, provided rapid filling and efficient sealing is achieved. However, the effluent volumes measured in the "mini pit" silos were slightly lower compared to literature values for farm scale silos (Bastiman, 1976; Patterson and Walker, 1980). A likely explanation for the difference is the lower height (1.5 m) of the "mini pit" silos compared to the farm scale silos (3-4 m). This would result in lower pressures being applied to the grass in the bottom of the "mini pit" silos than for the larger scale silos, even though similar silage densities were achieved. In spite of this difference, the 10 tonne "mini pit" silos should serve as a reliable model for the farm scale silo, at least for comparative purposes.

TABLE 5.2

Comparison between Measured and Predicted* Effluent Volumes for the Silages Containing Molassed Sugar Beet Shreds Made in "Mini Pit" Silos

Grass DM (gkg^{-1})	SBP Level (% grass FW)	Effluent Measured (l/tonne grass)	Effluent Predicted* (l/tonne grass)
149	6	71	45
127	7.6	75	82
127	7.3	97	87

* Using $V = (37.8 - 0.1725\ DM - 0.9022\ SBP)^2$ (3)

Where,

V = effluent volume (lt^{-1} grass FW) measured at 33 kg/dm^2

DM = grass DM gkg^{-1}

SBP = level of molassed beet shreds (% grass FW)

Chopped barley straw and molassed beet shreds proved most effective for the control of effluent loss. The results for straw bales were of great practical importance as this is a common technique used by farmers. Straw bales increased effluent loss (l/tonne grass) slightly when compared to the control in both 1985 and 1986 trials. Moreover, the effluent-soaked bales deteriorated rapidly when exposed to air and were unpalatable to sheep, thus creating a solid disposal problem for the farmer without reducing the effluent volume produced. Further, straw bales have the potential to allow penetration of air into the silo. The use of straw bales in grass silos should be actively discouraged by advisory organisations.

The purpose of adding absorbent to the silo is not just to reduce effluent volume, but particularly to reduce the total OM lost in silage effluent as only the latter leads to reduced pollution risk and less wastage of nutrients. The work reported in Chapter 4 shows that the addition of Viton straw cubes had only a small effect on effluent volume, but increased the total OM loss and BOD_5 per tonne of grass by approximately 34% and 112% respectively when compared to the control. Thus Viton straw cubes should not be used as a silage effluent absorbent because, although a slight reduction in effluent volume was obtained, there was a large increase in effluent OM concentration and total OM lost in effluent. Thus the use of Viton straw cubes increases pollution risk and nutrient loss.

Molassed beet shreds have proved effective in reducing effluent volume, but again this reduction in volume did not lead to a large reduction in total losses of either OM or BOD_5 per tonne of grass as effluent OM concentration was increased. Molassed beet shreds proved superior to Viton straw cubes as absorbents in that the reduction in effluent volume was greater for the shreds, whilst the increase in effluent OM concentration was less. The absorbent nature of beet shreds suggests the possibility of avoiding OM loss in effluent (and hence pollution risk) totally by adding sufficient shreds to prevent effluent loss completely. However, chopped straw proved the best controller of the total OM loss and hence pollution risk since chopped straw inclusion greatly reduced effluent volume without causing an increase in effluent OM concentration. Thus any level of chopped straw use will reduce the total OM loss per tonne of grass and hence, lower the risk of pollution from a silo.

The results of the 1985 and 1986 trials using "mini pit" silos (Chapter 4) show that molassed beet shreds should not be used as a means of controlling pollution from grass silos unless sufficient shreds are added completely to prevent effluent loss. The drum silo trial (experiment 2b), Chapter 3, established the relationship:

$$SBP_{(0)} = 41.9 - 0.191\ DM \qquad (4)$$

Where,

$SBP_{(0)}$ = level of beet shreds (% grass FW) required to produce no effluent

DM = grass dry matter (gkg^{-1})

However, if equation (4) is to be applied in practice, it is necessary to develop a rapid method for the estimation of grass dry matter which could be used as a silo is filled. The use of microwave ovens may provide an approximate estimation of grass DM. Alternatively, the development of an instrument similar to the modified wine press described in Chapter 3, might provide a rapid method of estimation, for a particular crop, of the level of beet shred addition required. With suitable calibration, measurement of the volume of juice expressed from a standard weight of grass at standard pressure could allow calculation of the required beet shred levels. Another possibility, which removes the need for weighing grass or measuring juice volumes, would be to measure the pressure (using a built-in load cell) needed to cause any loss of juice from the sample. Again, appropriate calibration would be required.

Equation (4) indicates that levels of beet shreds (kg/tonne grass FW) needed to prevent effluent loss for grass of DM content 120, 140, 160 and 180 gkg^{-1} are approximately 190, 150, 110 and 80 respectively. These beet shred levels represent about 60%, 50%, 40% and 30% of resulting grass + absorbent mixtures on a DM basis respectively. This suggests that molassed beet shreds are not an appropriate absorbent unless grass DM is 160 gkg^{-1} or higher which means that some wilting will usually be required. For grass of less than 160 gkg^{-1}

DM, layered chopped straw is the most suitable absorbent as, unlike molassed beet shreds, effluent OM concentration is not increased by this treatment. The risk of pollution would be reduced by chopped straw even if the level used was inadequate to prevent effluent production completely.

The effect of adding chopped straw or molassed beet shreds to grass at ensiling on silage digestibility was evaluated both in vitro and in vivo (see Sections 1 and 2, Chapter 4). For silage made in 1985, the in vitro evaluation showed that addition of chopped straw reduced silage IVOMD from 0.667 to 0.591 and the estimated ME ($MJkg^{-1}$ DM) from 9.5 to 8.4, whereas addition of SBP increased IVOMD from 0.667 to 0.720 and the estimated ME ($MJkg^{-1}$ DM) from 9.5 to 10.1. The in vivo evaluation showed that chopped straw inclusion reduced OMD from 0.683 to 0.625 and estimated ME ($MJkg^{-1}$ DM) from 10.82 to 9.81, whereas inclusion of SBP increased OMD from 0.683 to 0.717 and estimated ME ($MJkg^{-1}$ DM) from 10.8 to 11.1. For silages made in 1986, the OMD and estimated ME values for both chopped straw and SBP silages followed the same pattern as described for silages made in 1985. An exception was that ME of the SBP silage (calculated from DE measured in vivo) was lower than that for the control due to the lower GE of the SBP silage. In general, the OMD values obtained for the grass + absorbent mixtures suggested a simple additive relationship between the OMD values of the components of the mixture.

The feeding trial reported in Section 3 of Chapter 4 showed that chopped straw inclusion reduced silage DM intake and calf liveweight gain, although the reduction just failed to reach significance ($P < 0.05$) when compared to the control. However, the liveweight gain achieved for the chopped straw diet was considerably higher than would be predicted using the ARC (1980) equations. Thus the calculated efficiency of utilisation of ME for liveweight gain (k_f) was significantly higher for the chopped straw silage than that for the control.

Molassed beet shred inclusion resulted in a significant ($P < 0.05$) increase in silage DM intake and liveweight gain when compared to the control. Moreover, the efficiency of utilisation of ME for liveweight gain of SBP diet was significantly ($P < 0.05$) higher than the control, although the increase was smaller than observed for chopped straw.

The possible reasons for the apparent improvement in k_f have been discussed in Section 3 of Chapter 4. The main weakness is that, in the absence of calorimetric or carcass analysis data, the changes in k_f could be due to altered carcass composition, especially gut fill. However, the apparent increases in k_f when absorbents were ensiled with grass were considerable and merit further investigation, especially since other workers (Dulphy and Demarquilly, 1976; Dulphy and Andrieu, 1978) have shown improved animal performance due to mixtures being ensiled together rather than the components being mixed immediately prior to feeding. Should detailed investigation confirm these findings, it would make the use of low digestibility absorbents such as chopped straw more attractive, as the lowered ME value of the silage would be partially offset by the increased efficiency of ME utilisation.

The financial appraisal based on this short term calf trial reported in Section 3, Chapter 4, showed that the investment in molassed beet shreds may be repaid in terms of additional liveweight gain. A disadvantage of using the absorbents in silage making is that the farmer would need to buy them in advance and store them during the winter period to be used the following spring and summer. This has negative implications for cash flow and borrowing requirements for the farm. However, if a proven system for using absorbents can be established, in which effluent loss is prevented, the need for other silage additives avoided and an improvement in grass energy utilisation is achieved, then the cost of using absorbents could well be justified. For a particular farmer facing prosecution over effluent pollution, absorbents could be a cheaper and more productive alternative to the construction of a new silo and effluent collection tanks.

The research area described in this thesis is now at the stage when large scale investigations are needed to give a proven system for application by the farmer. A long term feeding trial using dairy cows would permit assessment of the practical difficulties, production consequences and the financial implications of using absorbents. The relationships described for drum silos and 10 tonne "mini pit" silos must be tested in farm scale trials. The practical difficulties of incorporating absorbents must be examined and overcome. Relatively dense materials such as molassed beet shreds could be applied to a clamp silo by the use of a fertiliser spreader fitted to a tractor during rolling of the grass at ensilage. Less dense materials such as

chopped straw present practical problems for incorporation. The volume of silo needed to store a given weight of grass is greatly increased (by up to 76% at 6% FW) and the material is difficult to store and handle. The most promising method might be to develop a machine which could chop big bales of straw and blow the material through a delivery pipe into the clamp.

Since sufficient absorbent could be added to prevent effluent loss completely, it may not be necessary to ensile grass + absorbent mixtures in conventional walled clamps with effluent tanks. Silage would be made on any firm level based creating an unwalled clamp. An addition possibility may be to introduce the absorbent into grass as it is baled into large round bales. This would allow the baling of grass crops of much lower DM content than normally recommended for this technique.

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APPENDIX 1

Analysis of Variance of Absorbent Efficiency
With and Without Formic Acid Treatment

Source of Variation	DF	SS	MS	F	Significance
Absorbents	8	43206.8550	5400.8569	463.536	***
Additives	1	510.4013	510.4013	43.806	***
Absorbent + Additive	8	2521.7750	315.2219	27.054	***
Error	54	629.1775	11.6514		
Total	71	46868.2087			

APPENDIX 2

OM Degradability (%) for Control and Treated Straw

Treatment	Soaking Period (Weeks)	Sheep							
		A		B		C		D	
		Rumen Incubation Times (Hrs)							
		24	48	24	48	24	48	24	48
Control	0	47.25	60.68	50.79	60.12	40.53	49.13	48.20	61.48
		48.16	61.69	46.82	60.20	42.69	56.69	43.73	58.62
Treated	0	46.27	61.28	48.54	61.25	42.98	51.30	45.30	60.09
		45.51	59.96	43.80	61.01	40.81	49.36	46.95	60.90
Control	2	46.32	54.11	44.33	55.56	40.87	59.16	43.96	61.05
		45.98	54.28	45.23	55.67	43.47	54.47	46.59	55.16
Treated	2	47.83	60.97	42.42	54.40	48.98	59.77	48.98	59.77
		49.63	54.01	50.97	61.73	46.06	61.22	45.48	60.35
Control	4	46.64	62.97	45.48	62.39	49.27	53.35	44.90	62.39
		50.72	63.27	44.02	60.35	35.86	55.98	47.52	61.52
Treated	4	46.94	59.02	45.27	59.41	37.14	53.71	43.90	60.42
		48.63	59.91	47.97	62.71	36.10	60.66	49.06	62.37
Control	6	41.98	53.27	44.44	52.02	47.73	55.40	46.48	55.11
		49.83	50.25	43.44	51.18	43.91	56.26	46.09	54.93
Treated	6	48.88	58.31	44.34	52.28	43.35	60.93	46.51	57.94
		45.55	61.75	46.96	55.42	34.69	57.41	50.23	57.31
Control	8	40.91	56.92	39.20	58.84	41.23	58.23	40.87	60.14
		47.12	56.40	44.36	56.13	37.50	53.20	49.89	60.12
Treated	8	43.70	57.00	39.96	58.26	45.88	56.81	48.04	60.42
		42.49	59.18	42.18	57.26	47.77	55.13	47.33	62.05

APPENDIX 3

RE Values of Effluent Soaked Straw

Soaking Period (Weeks)	24 (hrs) Rumen Incubation Time							
	Sheep							
	A		B		C		D	
0	-1.4	-2.2	-0.27	-5.0	1.37	-0.8	-0.67	0.99
2	1.68	3.48	-2.4	6.2	6.81	3.89	3.71	0.21
4	-1.74	-0.05	0.52	3.2	-5.43	-6.47	-2.31	2.85
6	2.98	-0.36	0.9	3.0	-2.47	-11.13	0.23	3.95
8	-0.32	-1.53	-1.8	0.4	6.52	8.41	2.66	1.95
	48 (hrs) Rumen Incubation Time							
	A		B		C		D	
0	0.1	-1.23	1.09	0.85	-1.61	-3.55	0.04	0.85
2	0.68	-0.19	-1.22	6.12	2.96	4.41	1.67	2.25
4	-4.1	-3.2	-1.96	1.34	-0.96	6.00	-1.54	0.42
6	6.6	10	0.68	3.82	5.10	1.58	2.92	2.29
8	0.34	2.5	0.78	-0.23	1.10	-0.59	0.29	1.92

APPENDIX 4

Analysis of Variance for RE Values for Effluent Soaked Straw

Source of Variation	DF	SS	MS	F	Significance
Sheep	3	4.3982	1.4661	0.168	NS
Incubation Time	1	10.3320	10.3320	1.183	NS
Week of Soaking	4	151.1195	37.7799	4.324	**
Sheep + Incubation Time	3	7.5278	2.5093	0.287	NS
Sheep + Week of Soaking	12	175.4130	14.6178	1.673	NS
Incubation Time + Week of Soaking	4	82.7588	20.6897	2.368	NS
Error	52	454.2904	8.7364		
Total	79	885.8398			

APPENDIX 5

The *in vivo* Digestibilities of the Absorbents

OBJECTIVE

To measure the digestibilities of the following absorbents.

1 Viton Straw Cubes

2 Chopped Barley Straw

3 Molassed Beet Shreds

4 Viton Straw Cubes which have been stored in the bottom of the silage

5 Straw Bale which have been stored in the bottom of the silage

EXPERIMENTAL

Animals

Six Suffolk wether sheep (average liveweight 55 kg), born spring 1984. Each sheep was housed in a metabolism crate, fitted with a slatted floor and provided with a detachable feed box at the front with a removable plastic bucket for drinking water.

During the trial period, each sheep was fitted with a faecal collection harness to which a polythene faceces collection bag was attached.

Experimental Diets

Each absorbent was fed with a standard complete diet Ruminant A in a ratio of 50:50 dry matter basis, supplemented with 8 g/day urea solution and 15 g/day mineral mix (Sheep Standard Mix, Scotmin, Maybole, Ayrshire). The quantities

of feed were estimated to provide the maintenance ME requirement plus 10%.

The composition of diet Ruminant A was as follows:

DM (g kg^{-1})	847
OM (g kg^{-1} DM)	903
In vivo D-Value (%)	59.5*
ME (MJ kg^{-1} DM)	9.7*
GE (MJ kg^{-1} DM)	18.3

Equilibration and Collection

An equilibration period of 10 days was given to introduce the animals to each absorbent followed by six days faecal collection. Faeces were removed from the collection bags daily at 0900 hrs and the fresh weight of faeces was recorded and the three days collection was stored in a sealed plastic bucket at 5°C. At the end of each three days collection, the total faeces were weighed and thoroughly mixed using a food mixer. Two representative samples were taken for drying and subsequent analysis.

* Previously measured in Sheep

APPENDIX 6

Silage Digestibility - Calf Trial (1985)

Analysis of Variance of Organic Matter Digestibility

Source of Variation	DF	SS	MS	F	Significance
Calf	11	7578.889	688.9899	2.284	NS
Diet	5	23849.4548	4769.8910	15.812	**
Period	2	1062.1886	531.0943	1.761	NS
Diet + Period	10	4777.7020	477.7702	1.584	NS
Error	7	2111.6546	301.6649		
Total	35	39379.8889			

APPENDIX 7

Silage Digestibility - Calf Trial (1985)

Analysis of Variance of ED

Source of Variation	DF	SS	MS	F	Significance
Calf	11	6403.4722	582.1338	5.440	*
Diet	5	15932.7062	3186.5413	29.779	***
Period	2	2114.4309	1057.2155	9.880	**
Diet + Period	10	4886.6488	488.6649	4.567	*
Error	7	749.0469	107.0067		
Total	35	30086.3056			

APPENDIX 8

Silage Digestibility - Calf Trial (1985)

Analysis of Variance of ME

Source of Variation	DF	SS	MS	F	Significance
Calf	11	1.9056	0.1732	6.436	*
Diet	5	4.1412	0.8282	30.768	***
Period	2	0.5302	0.2651	9.848	**
Diet + Period	10	1.2097	0.1210	4.494	*
Error	7	0.1884	0.0269		
Total	35	7.9752			

APPENDIX 9

Silage Digestibility - Calf Trial (1985)

Apparent Digestibility Values of Experimental Silages

Calf No	Diet	OMD	ED
23	A	0.696	0.662
9	A	0.679	0.676
21	A	0.699	0.692
29	A	0.662	0.653
3	A	0.690	0.682
22	A	0.668	0.664
26	B	0.713	0.704
21	B	0.712	0.697
32	B	0.645	0.634
29	B	0.727	0.703
3	B	0.701	0.692
17	B	0.659	0.641
9	C	0.633	0.635
32	C	0.615	0.623
37	C	0.629	0.621
3	C	0.627	0.635
17	C	0.618	0.635
7	C	0.628	0.624
23	D	0.608	0.616
21	D	0.629	0.616
37	D	0.646	0.649
17	D	0.648	0.641
7	D	0.622	0.619
4	D	0.634	0.631
23	E	0.673	0.680
26	E	0.692	0.677
32	E	0.670	0.653
7	E	0.682	0.673
4	E	0.644	0.634
22	E	0.703	0.684
26	F	0.728	0.717
9	F	0.720	0.717
37	F	0.694	0.675
29	F	0.738	0.719
4	F	0.729	0.721

APPENDIX 10

Input of Nutrients from Grass and Absorbents

Nutrient	Treatment					
	A	B	C	D	E	F
DM (kg)	622	843	841	805	862	798
OM (kg)	549	739	756	706	776	709
CP (kg)	112	118	125	112	125	129
WSC (kg)	46	52	50	49	50	103
DOM (kg)	382	491	489	469	498	531
ME (MJ)	6099	7798	7767	7443	7906	8327

APPENDIX 11

Output of Nutrients from Silage and Absorbents

Nutrient	Treatment					
	A	B	C	D	E	F
DM (kg)	481	633	647	632	697	630
OM (kg)	430	566	569	543	638	558
CP (kg)	87	85	67	86	93	99
WSC (kg)	7.1	9.3	7.2	7.0	11.3	8.2
DOM (kg)	294	369	356	343	383	400
ME (MJ)	5208	6315	6345	6276	6344	6988

APPENDIX 12

Output of Nutrients in Effluent

Nutrient	Treatment					
	A	B	C	D	E	F
DM (kg)	31.4	40.0	6.8	27.2	24.7	16.1
OM (kg)	21.7	27.8	4.5	20.8	16.1	11.9
CP (kg)	8.2	6.1	1.2	5.8	6.9	4.2
WSC (kg)	11.5	6.5	2.4	6.4	9.6	4.0

APPENDIX 13

Input of Nutrients in Absorbents

Nutrient	Treatment					
	A	B	C	D	E	F
DM (kg)	0	232	198	224	226	204
OM (kg)	0	200	188	193	215	185
CP (kg)	0	7.9	8.7	7.6	9.9	22.3
WSC (kg)	0	6.79	2.4	6.5	2.7	59.2
DOM (kg)	0	116	94	112	107	167
ME (MJ)	0	1813	1465	1750	1672	2512

APPENDIX 14

Output of Nutrients in Absorbents Stored Under Silages

Nutrient	Treatment	
	Viton Straw Cubes B	Straw Bale E
DM (kg)	193	246
OM (kg)	182	232
CP (kg)	7.5	13.8
WSC (kg)	2.4	2.2
DOM (kg)	103	108
ME (MJ)	1642	1636

APPENDIX 15

Analysis of Variance of *in vivo* Organic Matter Digestibility (1986 Trial)

Source of Variation	DF	SS	MS	F	Significance
Diet	2	81772.330	40886.1650	136.226	***
Error	15	4502.0150	300.1343		
Total	17	86274.3450			

APPENDIX 16

Analysis of Variance of *in vivo* Energy Digestibility (1986 Trial)

Source of Variation	DF	SS	MS	F	Significance
Diet	2	82889.2744	41444.6372	192.752	***
Error	15	3225.2367	215.0158		
Total	17	86114.5111			

APPENDIX 17

Analysis of Variance of ME (1986 Trial)

Source of Variation	DF	SS	MS	F	Significance
Diet	2	30.7960	15.3980	273.257	***
Error	15	0.8453	0.0564		
Total	17	31.6413			

APPENDIX 18

Apparent *in vivo* Digestibility Values of the Experimental Silages (1986 Trial)

Calf No	Diet	OMD	ED
28	Control	0.764	0.753
24	Control	0.776	0.764
23	Control	0.775	0.764
20	Control	0.803	0.788
15	Control	0.779	0.761
32	Control	0.753	0.742
16	Chopped Straw Silage	0.658	0.639
37	Chopped Straw Silage	0.607	0.599
14	Chopped Straw Silage	0.621	0.612
31	Chopped Straw Silage	0.656	0.630
21	Chopped Straw Silage	0.646	0.634
25	Chopped Straw Silage	0.618	0.606
34	Molassed Beet Shred Silage	0.775	0.763
18	Molassed Beet Shred Silage	0.775	0.764
30	Molassed Beet Shred Silage	0.794	0.781
26	Molassed Beet Shred Silage	0.774	0.759
29	Molassed Beet Shred Silage	0.795	0.780
22	Molassed Beet Shred Silage	0.765	0.751

APPENDIX 19

Individual Calf DM Intakes and Liveweight Gains

Diet	Calf No	DM Intake (kg d^{-1})	Liveweight Gain (kg d^{-1})
Control	28	2.49	0.92
	24	2.04	0.98
	23	2.49	1.03
	20	1.91	0.87
	15	2.48	1.15
	32	2.18	0.89
		----	----
	Mean	2.27	0.97
Chopped Straw Silage	16	2.03	0.75
	37	2.23	0.90
	14	2.05	0.83
	31	1.91	0.85
	21	2.29	0.90
	25	2.35	0.90
		----	----
	Mean	2.14	0.86
Molassed Beet Shred Silage	34	2.74	0.91
	18	2.12	1.01
	30	2.95	1.26
	26	2.48	1.09
	29	2.66	1.14
	22	2.75	1.23
		----	----
	Mean	2.62	1.11

APPENDIX 20

Analysis of Variance of Daily Dry Matter Intakes (kg)

Source of Variation	DF	SS	MS	F	Significance
Diet	2	4.3891	2.1945	24.703	***
Week	5	10.4333	2.0867	23.488	***
Diet + Week	10	1.1751	0.1175	1.323	
Error	90	7.9955	0.0888		
Total	107	23.9930			

APPENDIX 21

Analysis of Variance of Daily Liveweight Gains (kg)

Source of Variation	DF	SS	MS	F	Significance
Diet	2	0.1902	0.0951	8.872	**
Error	15	0.1608	0.0107		
Total	17	0.3511			

APPENDIX 22

Part of program used to calculate kf and NEMP values for the calf feeding trial (equations from ARC 1980).

```
MD=MEI/DMI:rem M/D of the ration
NEM=(.53*((WT/1.08)^.67))+.0043*WT:REM NE REQ FOR MAINT
EVG=(4.1+.0332*WT-.000009*WT*WT)/(1-.1475*LWG):REM NE OF 1KG LWG
NEAG=EVG*LWG:REM NE OF LWG MEASURED
KM=.019*MD+.503:REM EFF. UTILISATION ME FOR MAINT.
KP=.0424*MD+.006:REM EFF. UTILISATION ME FOR LWG AT L=2
P=KM*LOG(KM/KP):B=KM/(KM-KP)
R=B-1-(B/EXP((MEI*P)/NEM))
NEPG=R*NEM:REM NE PREDICTED FOR LWG
LWP=NEPG/(4.1+.0332*WT-.000009*WT*WT+.1475*NEPG)
NER=NEAG/NEPG:REM NE ACTUALLY STORED / NE PREDICTED
MEM=NEM/KM:REM NE REQ. FOR MAINT
MEP=MEI-MEM:REM ME AVAILABLE FOR LWG
PKF=NEAG/MEP:REM CALCULATED KF
```

APPENDIX 23

Analysis of Variance of Efficiency of Utilisation of ME for Liveweight Gain (k_f)

Source of Variation	DF	SS	MS	F	Significance
Diet	2	0.2162	0.1081	21.904	***
Week	3	0.0486	0.0162	3.283	*
Diet + Week	6	0.0249	0.0041	0.841	
Error	60	0.2962	0.0049		
Total	71	0.5859			

APPENDIX 24

Analysis of Variance of DMD Values

Source of Variation	DF	SS	MS	F	Significance
Diet	2	1.6079	0.8040	59.982	***
Week	3	0.1276	0.0425	3.173	*
Diet + Week	6	0.0638	0.0106	0.793	
Error	60	0.8042	0.0134		
Total	71	2.6035			