CONSERVED FORAGE AS A BUFFER FEED FOR DAIRY COWS

BY

CLIVE JULIAN CHRISTIE PHILLIPS

Crichton Royal Farm,
The West of Scotland Agricultural College.

A thesis submitted in September, 1983, to the Faculty of Science of the University of Glasgow for the degree of Doctor of Philosophy

TABLE OF CONTENTS

ACKNOWLEDGEMENTS ix

ABBREVIATIONS x

GLOSSARY xi

SUMMARY xii

CHAPTER 1. BUFFER FEEDING IN CONJUNCTION WITH GRAZED HERBAGE 1

1.1 Limitations of grazed herbage 1

1.1.1 Herbage availability 1

1.1.1.1 Herbage allowance 1
1.1.1.2 Effect of a reduction in herbage intake on animal production 4

1.1.2 Herbage digestibility 6

1.1.3 Herbage dry matter content 8

1.1.4 Herbage contamination 11

1.1.5 Seasonal effects on milk production 15

1.1.5.1 Spring herbage 15
1.1.5.2 Autumn herbage 17

1.2 Effects of offering conserved forage with herbage on DM intake and production 22

1.2.1 Grass silage 22

1.2.1.1 Restricted herbage + silage compared with *ad libitum* herbage 22

1.2.1.1.1 DM intake 22
1.2.1.1.2 Dairy cow production 25

1.2.1.2 Restricted herbage + silage compared with restricted herbage 29

1.2.1.2.1 DM intake 29
1.2.1.2.2 Dairy cow production 29

1.2.1.3 UME from silage compared with grazing areas 31

1.2.2 Maize silage 34

1.2.2.1 DM intake 34
1.2.2.2 Dairy cow production 36

1.2.3 Hay 37

1.2.3.1 Hay offered *ad libitum* with herbage compared with *ad libitum* herbage 37

1.2.3.2 Hay offered *ad libitum* with herbage compared with restricted herbage 39

1.2.4 Straw 41

1.2.5 Conclusions 44

CHAPTER 2. BUFFER FEEDING IN CONJUNCTION WITH GRASS SILAGE AS THE BASIC FORAGE 45

2.1 Restricting the allowance of silage 45

2.1.1 Possible mechanisms of a silage restriction 45

2.1.2 The effect of restricted energy intake on milk production and liveweight change 46

2.2 Offering conserved forage with silage 48

2.2.1 Hay 48

2.2.2 Straw 50

2.2.3 Alkali-treated straw 51

CHAPTER 3. EXPERIMENT 1 THE EFFECTS OF OFFERING HAY TO DAIRY COWS SET-STOCKED AT A HIGH AND A LOW RATE 53

3.1 Introduction 53

3.2 Material and methods 54

3.2.1 Design 54

3.2.2 Dairy cow management and measurements 55

3.2.3 Fields and feed management 57

3.2.4 Statistical analysis 60

3.3 Results 61

3.3.1 Weather 61

3.3.2 Herbage height 61

3.3.3 Feed composition 65

3.3.4 Feed and nutrient intake 68

3.3.5 Behaviour 75

3.3.5.1 Hay feeding 75

3.3.5.2 Grazing 75

3.3.6 Milk yield and composition 80

3.3.7 Liveweight gain and condition score gain 85

3.3.8 Yield level 85

3.4 Discussion 89

3.4.1 Results 89

3.4.1.1 Hay feeding 89
3.4.1.2 Stocking rate 93

3.4.2 Experimental techniques 95

3.4.2.1 Herbage intake 95
3.4.2.2 Grazing behaviour 98
3.4.2.3 Herbage height measurement 100

3.5 Summary 101

CHAPTER 4. EXPERIMENT 2 THE EFFECT OF OFFERING SILAGE TO SET-STOCKED DAIRY COWS IN THE EARLY PART OF THE GRAZING SEASON 102

4.1 Introduction 102

4.2 Material and methods 103

4.2.1 Design 103

4.2.2 Dairy cow management and measurements 104

4.2.3 Fields and feeds management 105

4.2.4 Statistical analysis 107

4.3 Results 108

4.3.1 Weather 108

4.3.2 Herbage height 108

4,3.3 Feed composition 110

4.3.4 Feed intake 110

4.3.5 Cow behaviour 114

4.3.6 Animal production 120

4.3.7 Animal type 123

4.3.8 Coefficients of variation 126

4.3.9 Residual effects 127

4.4 Discussion 128

4.4.1 Animal production 128

4.4.2 Feed intake 130

4.4.3 Cow behaviour 133

4.4.4 Animal type 135

4.4.5 Residual effects 136

4.5 Summary 137

CHAPTER 5. EXPERIMENT 3 THE EFFECT OF OFFERING SILAGE TO SET-STOCKED DAIRY COWS IN THE LATE PART OF THE GRAZING SEASON 138

5.1 Introduction 138

5.2 Material and methods 139

5.2.1 Dairy cow management and measurements 139

5.2.2 Fields and feeds management 140

5.2.4 Statistical analysis 141

5.3 Results 141

5.3.1 Weather 141

5.3.2 Herbage height 142

5.3.3 Feed composition 142

5.3.4 Feed intake 142

5.3.5 Cow behaviour 147

5.3.6 Animal production 155

5.3.7 Coefficients of variation 155

5.4 Discussion 160

5.4.1 Animal production 160

5.4.2 Feed intake 163

5.4.3 Grazing behaviour 165

5.5 Summary 166

CHAPTER 6. EXPERIMENT 4 THE EFFECT OF A RESTRICTION OF SILAGE DM INTAKE AND THE PROVISION OF HAY AS A BUFFER FEED ON DAIRY COW PRODUCTION 168

6.2 Material and methods 169

6.2.1 Design 169

6.2.2 Dairy cow and feed management 169

6.2.3 Dairy cow and feed measurements 171

6.2.4 Statistical analysis 171

6.3 Results

6.3.1 Feed composition 172

6.3.2 Feed intake 172

6.3.3 Animal production 175

6.3.4 Nutrient intake and output 178

6.3.5 Treatment effects in the first six days of each period 178

6.3.6 Variation in feed intake and milk yield 180

6.3.7 Residual effects 180

6.3.7.1 Days 1-6 of each period 180
6.3.7.2 Days 15-21 of each period 182

6.4 Discussion 182

6.4.1 The effect of offering hay 182

6.4.2 Restricting silage DM intake 184

6.4.3 The sequence of response to underfeeding and offering hay 185

6.4.3.1 Underfeeding 185
6.4.3.2 Hay feeding 186

6.4.4 General considerations 186

6.5 Summary 188

CHAPTER 7. EXPERIMENT 5 THE EFFECT OF RESTRICTION OF SILAGE DM INTAKE AND THE PROVISION OF STRAW OR AMMONIA-TREATED STRAW AS A BUFFER FEED ON DAIRY COW PRODUCTION 189

7.1 Introduction 189

7.2 Materials and methods 190

7.2.1 Design 190

7.2.2 Dairy cow and feed management 191

7.2.3 Dairy cow and feed measurements 193

7.2.4 Statistical analysis 193

7.3 Results 193

7.3.1 Feed composition 193

7.3.2 Feed intake 195

7.3.3 Animal production 197

7.3.4 Nutrient intake and output 197

7.3.5 Variation in feed intake and milk yield 200

7.3.6 Residual effects 200

7.4 Discussion 200

7.4.1 Restricting the silage ration 200

7.4.2 Straw treatment 202

7.4.3 The effect of straw or treated straw on animal production 204

7.4.4 Energy balance 206

7.5 Summary 206

CHAPTER 8. EXPERIMENT 6 THE EFFECT OF RESTRICTION OF SILAGE DM INTAKE AND THE PROVISION OF STRAWMIX AS A BUFFER FEED ON DAIRY COW PRODUCTION 208

8.1 Introduction 208

8.2 Material and methods 209

8.2.1 Design 209

8.2.2 Dairy cow and feed management 209

8.2.3 Dairy cow and feed measurements 211

8.2.4 Statistical analysis 212

8.3 Results 213

8.3.1 Feed composition 213

8.3.2 Feed intake 213

8.3.3 Feeding behaviour 213

8.3.4 Animal production 217

8.3.5 Nutrient intake and output 217

8.3.6 Effect of transition from restricted to *ad libitum* silage 222

8.4 Discussion

8.4.1 Restricting the silage ration 222

8.4.2 Offering strawmix as a buffer feed 225

8.4.3 Differences between cows and heifers 226

8.5 Summary 228

CHAPTER 9. GENERAL DISCUSSION 229

9.1 Buffer feeds with grazed herbage 229

9.2 Buffer feeds with a silage-based diet 235

9.3 The effect of increasing farm stocking rates and of offering a buffer feed on profitability 238

APPENDICES 242

LIST OF REFERENCES 260

ACKNOWLEDGEMENTS

The author is indebted to the Principal and Council of The West of Scotland Agricultural College for the provision of the research facilities and to the trustees of the Dr William Stewart Scholarship for the provision of finances.

The author is also grateful to:

Dr J D Leaver for his advice and guidance throughout the course of this work.

Mr D P Arnot and Dr D Reid for statistical advice and help.

Mr H Ferns for milk analysis and Mr R H Alexander and Miss Mary McGowan for feed analysis.

Dr J S Chalmers and the other Animal Production Specialists at the Crichton Royal Farm for advice and assistance.

The Field Officers at the Crichton Royal Farm for assistance in the experimental recording.

Mr D Webster and the farm staff for the care and management of the animals.

Mrs J McCallay for her accurate typing of the thesis.

Finally, but not least, my wife Alison for her help and support.

ABBREVIATIONS

ADAS	Agricultural Development and Advisory Service.
ARC	Agricultural Research Council.
CP	Crude protein.
CV	Coefficient of variation.
DAFS	Department of Agriculture and Fisheries for Scotland.
DANI	Department of Agriculture for Northern Ireland.
DM	Dry matter.
DMD	Dry matter digestibility.
EHF	Experimental Husbandry Farm.
K	Potassium.
MAFF	Ministry of Agriculture, Fisheries and Food.
ME	Metabolizable energy.
MMB	Milk Marketing Board.
N	Nitrogen.
NA	Not available.
NIRD	National Institute for Research into Dairying.
NSD	No significant difference.
OMD	Organic matter digestibility.
P	Phosphorus.
RDP	Rumen-degradable protein.
SED	Standard error of the difference.
UDP	Undegradable protein.
UME	Utilized metabolizable energy.

GLOSSARY

Heifer: a cow up to the end of the first lactation.

Residual effects: the effect of treatment in the previous period on the treatment means.

Social facilitation: the adjustment of the voluntary feed intake of a gregarious animal as a result of the presence of animals with a different intake potential.

Support energy: the total input of energy (in the form of fuels, electricity, fertilizers, feedstuffs, machinery and buildings) to a farming product.

Synergistic effect: increased voluntary feed intake when two feedstuffs are offered compared with either feedstuff offered alone.

Utilized Metabolizable Energy: the total output of metabolizable energy from grazed or conserved swards over the whole, or a defined part of, the grazing season/conservation period (expressed as gigajoules ha^{-1}).

SUMMARY

1) The literature concerning the reasons for and the effects of a restriction of the forage intake of dairy cows (grazed herbage in summer, grass silage in winter), and the effects of providing additional conserved forage as a buffer feed, is reviewed.

2) In a 24 week experiment with grazing dairy cows the effects of stocking rate and the provision of hay as a buffer feed were examined. Herbage intake was restricted by stocking cows at a higher rate and during inclement weather. Offering hay increased total DM intake and milk yield but had no effect on milk composition. Details of grazing behaviour (in particular grazing and ruminating times) were obtained at monthly intervals.

3) A second experiment examined the response to a buffer feed of silage during the early part of the grazing season. Silage was offered either after morning milking, or indoors overnight at a restricted level or *ad libitum*. Offering silage had no effect on total DM intake, slightly reduced milk yield but increased milk fat content. The behaviour of the cows was recorded both indoors and at pasture and showed that grazing times were depressed by offering silage.

4) A similar experiment examined the response to a buffer feed of silage in the late grazing season. Offering silage increased total DM intakes which increased animal production, particularly when silage was offered overnight *ad libitum*. Similar grazing behaviour studies to the previous experiment were carried out.

5) In a winter feeding regime an initial changeover experiment with three week periods examined the effects of restricting the silage

ration and of offering hay as a buffer feed. Restricting silage intake primarily resulted in loss of live weight and offering hay increased total DM intake and milk yield.

6) A second changeover experiment, also with three week periods, examined the effects of a greater restriction of silage intake, and of offering straw or ammonia-treated straw as a buffer feed. Restricting silage intake resulted in loss of live weight and reduced milk production. The intakes of straw or ammonia-treated straw were too low to restore forage DM intakes and consequently were of little value in increasing animal production.

7) A final experiment in a winter-feeding regime examined the effects of a longer-term restriction of silage intake, and the provision of a nutritionally-formulated strawmix as a buffer feed. Restricting the silage ration resulted in loss of live weight compared to cows offered *ad libitum* silage. Provision of strawmix as a buffer feed to restricted silage restored forage DM intakes to *ad libitum* levels but did not prevent loss of live weight, although it was of some benefit in improving milk composition.

8) The effect of offering a buffer feed in reducing the daily variation in forage DM intakes and milk yields is also studied in these experiments. In addition, the differences between cows and heifers in their response to forage restrictions are examined, in particular the effect on ingestive behaviour.

The effects of restricting forage intake and of offering buffer feeds on farm stocking rate are considered - farm stocking rate can be increased by restricting forage intake, and loss of milk production averted by the provision of a purchased buffer feed.

CHAPTER 1. BUFFER FEEDING IN CONJUNCTION WITH GRAZED HERBAGE

1.1 LIMITATIONS OF GRAZED HERBAGE

1.1.1 Herbage availability

1.1.1.1 Herbage allowance

Herbage allowance for rotationally grazed dairy cows has generally been found to be asymptotically related to herbage DM intake (Van der Kley, 1956; Gordon *et al*, 1966; Hijink, 1978). Meijs (1981a) however found little evidence of curvilinearity with relatively high yielding cows. Variation in response is mainly due to the different intake potential of the cows, different cutting heights above ground level in herbage allowance and intake determinations and confounding effects of herbage quality.

As herbage allowance declines grazing time and rate of biting generally increase and bite size decreases (Jamieson and Hodgson, 1979; Le Du *et al*, 1979). Rotationally grazed cows do not increase their grazing time at low herbage allowances as much as continuously grazed cows (Jamieson and Hodgson, 1979), although grazing time is particularly increased in the final day of a rotation (Meijs, 1981a). Grazing time is significantly related to milk yield (Brumby, 1959), but cows are reluctant to graze for more than 10 hours day^{-1} on temperate pastures (Waite *et al*, 1951; Meijs, 1981b), although grazing times in excess of 12 hours day^{-1} have been recorded on tropical pastures (Smith, 1955; Stobbs, 1974). To sustain maximum herbage intake even at high herbage allowances a high yielding dairy cow must graze for 9 hours day^{-1} or more, and there would appear to be little opportunity to increase grazing time at low herbage allowance (Meijs, 1981b). High yielding dairy cows will therefore require a greater herbage allowance to sustain maximum herbage intake than low yielding dairy cows (Figure 1.1).

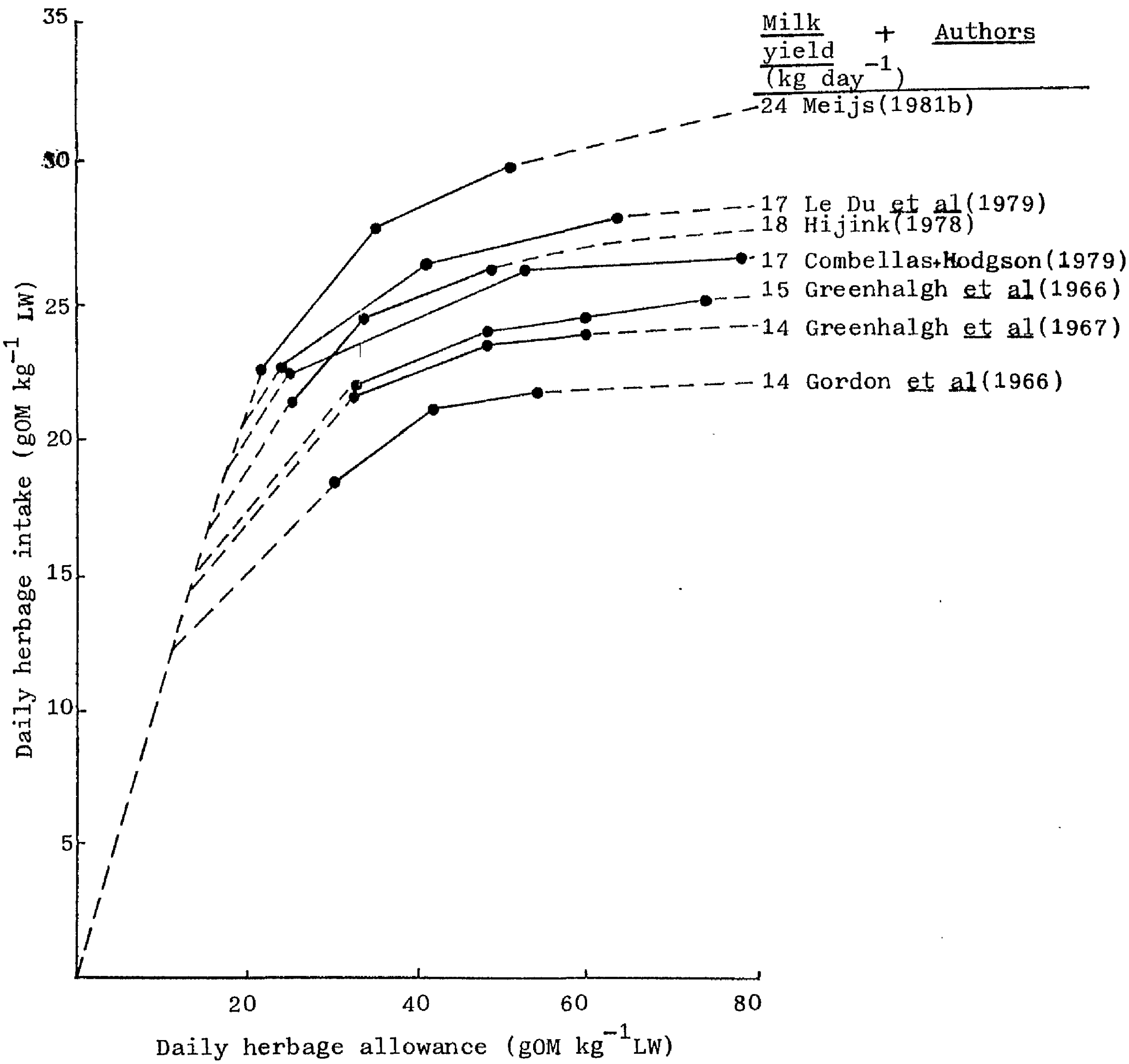


Figure 1.1 Effect of mean daily milk yield on the relationship between daily herbage allowance (g OM kg^{-1} LW) and daily herbage intake (g OM kg^{-1} LW)

Method of calculation:

Herbage allowance and intake data for Combellas and Hodgson (1979), Gordon *et al* (1966), Greenhalgh *et al* (1966, 1967) and Le Du *et al* (1979) were extracted from Le Du *et al* (1979). The data of Hijink (1978) and Meijs (1981b) was incorporated without adjustment for variation in cutting height above ground level; the small amount of concentrates fed in these two trials (1.5 and 1.3 kg OM day^{-1} respectively) was assumed to be additive to herbage intake. Milk yield quoted is the mean daily milk yield of the various herbage allowances.

Variation in herbage allowance will be manifested either as differences in herbage height or density. Sward height may be the best practical measure of herbage allowance, although variation in sward density and uniformity will restrict its usefulness (Leaver, 1982). The herbage intake and milk production of dairy cows has been found to be depressed below a sward height of 7 cm for a continuously grazed sward (density 437 kg OM ha^{-1} cm^{-1}) and 9 cm for a rotationally grazed sward (density 400 kg OM ha^{-1} cm^{-1}) (Le Du *et al*, 1979; 1981). Similar results have been obtained with calves (Baker *et al*, 1981a,b). The lower critical herbage height on continuously grazed swards is probably attributable to higher herbage densities than rotationally grazed swards.

Herbage density may be as low as 45 kg DM ha^{-1} cm^{-1} for a tropical sward (Stobbs, 1973) or 150 kg DM ha^{-1} cm^{-1} for the first year of a continuously grazed, perennial ryegrass ley (Leaver, 1982). On these swards bite size will be low (Stobbs, 1973), and herbage intake is depressed unless grazing time and biting rate can be increased to compensate. In such circumstances ease of prehension may be increased at mean sward heights above 9 cm, thereby allowing biting rate to be increased. Hodgson *et al* (1977) found that the maximum intake of a low density tropical pasture was at a sward height of 40-45 cm.

Herbage intake may be regarded as the product of grazing time, bite size and biting rate (Jamieson, 1975). If one parameter is restricted eg bite size with low density pastures or grazing time with high intake-potential dairy cows, the animal attempts to compensate by increasing one or both of the other parameters. In these circumstances a mean sward height greater than 9 cm may be beneficial in increasing ease of prehension and hence biting rate.

1.1.1.2 Effect of a reduction in herbage intake on animal production

The results from 34 experiments from 24 publications (see Appendix 1) in which cut or grazed herbage was offered *ad libitum* and at a certain proportion of *ad libitum* are shown in figure 1.2. Data was not included where the digestibility of the ingested herbage differed at the two levels of intake.

The % reduction in herbage intake was significantly correlated with % reduction in milk yield, fat yield and milk protein content. Although a reduction in herbage intake almost invariably increased milk fat content, the two factors were not significantly correlated. From the regression equations it can be seen that a 10% reduction in herbage intake will result in a 5.6, 4.5 and 1.5% reduction in milk yield, fat yield and protein content respectively. The duration of each treatment was only stated in 18 experiments and averaged 71 days. Greenhalgh *et al* (1967) found the difference in milk yield kg^{-1} herbage OM intake at two herbage allowances was 44% higher when cows were on treatment for 70 days compared with 7 days.

It was not possible to relate the effects of a reduction in herbage intake on liveweight change due to insufficient data. Where rate of liveweight change was reported it was invariably reduced at the restricted herbage intake, and this reduction was greater in short-term than long-term experiments (cf Greenhalgh *et al*, 1966 and Greenhalgh *et al*, 1967). The actual loss of liveweight, however, is independant of the duration of the restriction where this is greater than approximately 2 weeks, although a greater restriction increases the amount of liveweight lost (Le Du and Newberry, 1981). Thus in the short-term cows are able to buffer variation in feed intake by

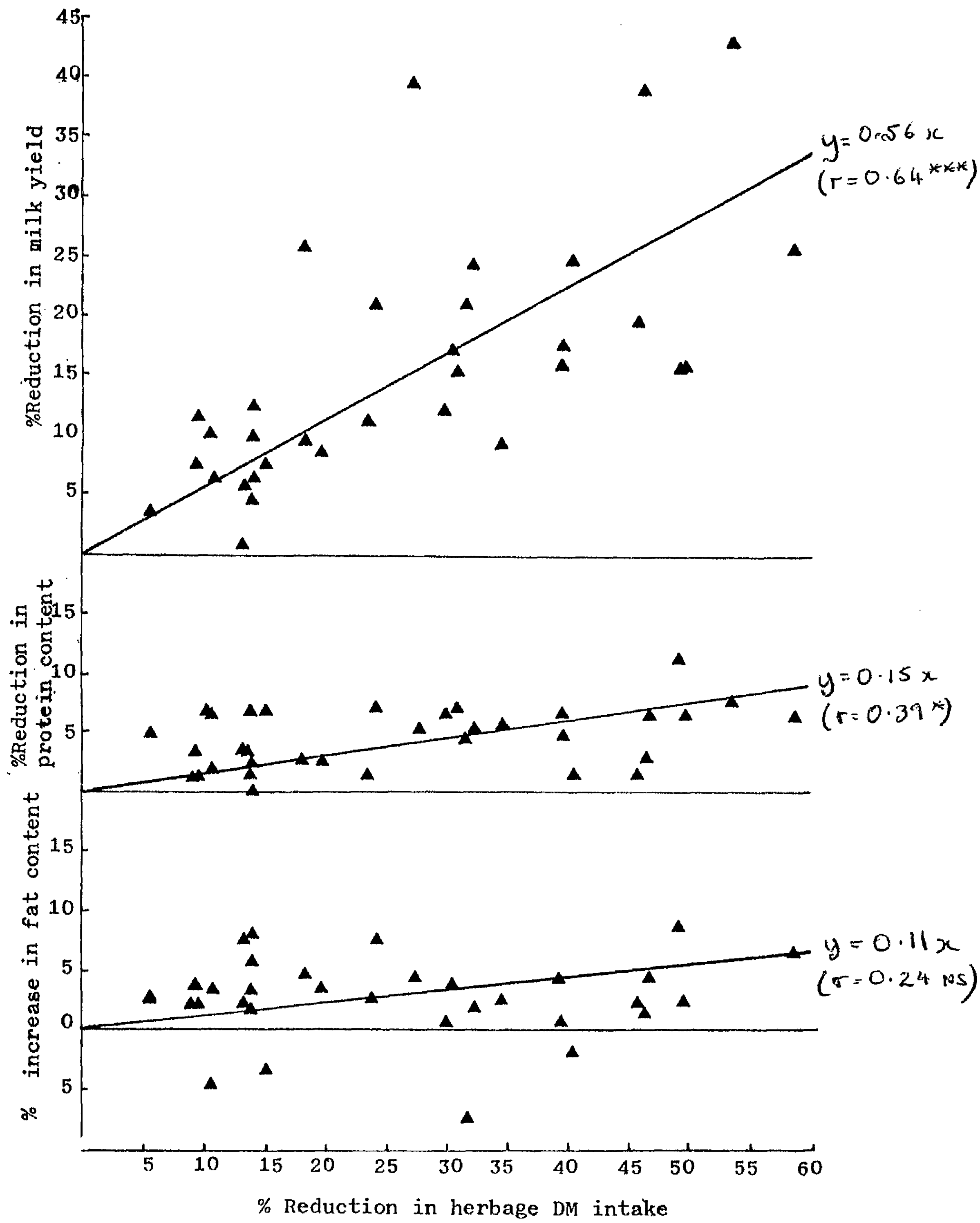


FIGURE 1.2

Effect of a reduction in herbage DM intake on milk yield and milk fat and protein content liveweight change (Broster, 1980), but if the restriction is for more than this length of time there will be some loss in milk production.

Another likely source of variation is the level of milk yield. Cows in late lactation and cows with a low milk yield potential tend to partition extra ME intake towards liveweight change. For example, a cow giving 40 kg milk day^{-1} may have double the response in milk yield and half the response in liveweight change of a cow giving 20 kg milk day^{-1} (Broster, 1980).

1.1.2 Herbage digestibility

Sward digestibility may vary both within and between periods of the grazing season (Dent and Aldrich, 1968). Typical values for a well stocked pasture in spring, summer and autumn are 740, 690 and 710 g kg^{-1} D value respectively (Holmes, 1980). However Baker (1980) and Le Du *et al* (1981) found that a perennial ryegrass sward, continuously grazed by dairy cattle at a high stocking rate, ranged from 750 g kg^{-1} OMD from turnout until the end of May to 600-650 g kg^{-1} OMD by the end of the grazing season in October.

The degree to which cattle can select herbage of higher digestibility than that on offer will vary with the stage of growth of the pasture and the homogeneity of the botanical composition (Chenost and Demarquilly, 1982). Cattle have been found to select herbage on average 40-60 g kg^{-1} higher in digestibility than the sward on offer (Hardison *et al*, 1954; Jamieson, 1975; Le Du *et al*, 1981). Autumn herbage tends to be of lower digestibility and have a higher proportion of dead matter than spring herbage (Corbett *et al*, 1966; Jones *et al*, 1982 particularly at low stocking rates (Baker, 1980). Thus at equivalent herbage availabilities there is greater scope for cattle to be selective on autumn herbage, which will tend to minimize the difference in digestibility between autumn and spring herbage (Figure 1.3).

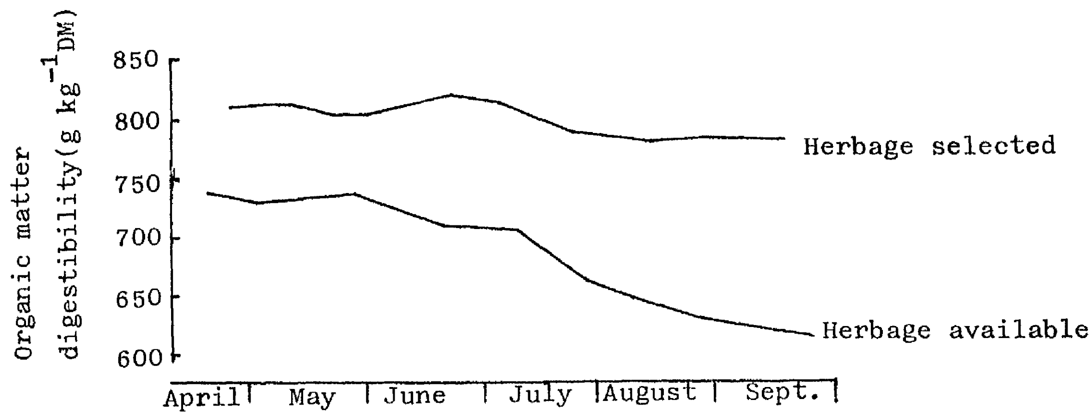


Figure 1.3 THE OMD OF HERBAGE SELECTED AND OF THE AVAILABLE HERBAGE (From Le Du *et al*, 1981)

If herbage availability declines as the season advances, or is restricted throughout, the cows will have little opportunity for selection in autumn, and the digestibility of the ingested sward and herbage intake will fall. Thus, where herbage availability is adequate, no relationship between the digestibility of the sward and herbage intake has been found (Hutton, 1962a, b; Hutton *et al*, 1964; Greenhalgh and Runcie,1962; Curran and Holmes, 1970). Where herbage availability is restricted or declines through the season, herbage intake is related to sward digestibility (Corbett *et al*, 1963; Holmes *et al*, 1972). Corbett *et al* (1963) estimated that a 100 g kg^{-1} decline in herbage digestibility would decrease herbage DM intake by 3%.

It is unlikely that the relatively small differences in herbage digestibility between spring and autumn pastures account for a large proportion of the observed differences in intake, even if herbage availability is restricted. In support of this, where spring and autumn herbage (Corbett *et al*, 1963) or dried grass (Lonsdale and Tayler, 1971) of the same digestibility were offered to cattle *ad libitum*, the DM intake of autumn herbage was 11% less than spring herbage.

Where herbage is restricted in autumn, and cattle are unable to select herbage of a higher digestibility than the sward, the decline in herbage digestibility in autumn may adversely affect animal output. Curran and Holmes (1970) found that, although the herbage digestibility at different times in the grazing season was not significantly related to the herbage intake of dairy cows, it was significantly related to milk yield and liveweight change. Under such circumstances, therefore, animal output is likely to be reduced even more than would be expected from the decline in herbage intake.

1.1.3 Herbage dry matter content

The DM content of herbage is a product of the amount of surface water on herbage and the DM content of the herbage itself. Thus the DM content of herbage is inversely correlated with rainfall (Castle, 1972; Castle and Watson, 1973), and in Great Britain rainfall tends to increase in the latter part of the grazing season, the accumulation of surface water at this time effectively reducing the DM content of the herbage (Holmes and Lang, 1963).

Several authors have concluded that there is no effect of DM content *per se* on the DM intake of herbage (MaClusky, 1955; Holmes and Lang, 1963), hay (Hillman *et al*, 1958; Campling and Balch, 1961; Thomas *et al*, 1961) and alfalfa silage (Moore *et al*, 1960; Thomas *et al*, 1961). In these instances the DM content of the feedstuff was not reduced to a very low level. At very low DM contents the DM intake of zero-grazed herbage is depressed (Duckworth and Shirlaw, 1958a; Davies, 1962; Halley and Dougall, 1962; Sonneveld, 1965; Rohr and Kaufmann, 1967; Verite and Journet, 1970; Wilson, 1978), and the same effect has been reported for silage (Dodsworth and Campbell, 1953).

Estimates of the critical DM content below which herbage DM intake is depressed range from 180-260 g kg^{-1} for beef cattle (Duckworth and Shirlaw, 1958a, b) and for sheep (Davies, 1962; Wilson, 1978). With dairy cows Verite and Journet (1970) estimated the critical DM as 180 g kg^{-1}, and DM intake of fresh herbage was significantly related to DM content (range 120-220 g kg^{-1}) by the equation $y = 9.7 + 0.021 x$ ($r = 0.91^{**}$), where y = herbage intake (kg DM day^{-1}) and x = DM content (g kg^{-1}).

It has been demonstrated that the addition of water in a balloon into the rumen will depress intake, whereas the addition of water *per fistulam* will have no effect or actually increases the intake of hay (Campling and Balch, 1961; Thomas *et al*, 1961; Moore *et al*, 1960) or lucerne chaff (Davies, 1962). It would appear therefore that the reduction in herbage intake at very low DM is not an effect of water in the rumen but is a behavioural limitation. Duckworth and Shirlaw

(1958 a, b) found that at low DM contents the rate of intake of fresh cut herbage increases due to an increased rate of biting and eating time, but rate of DM intake decreases. This was probably due to the inability of the cows to satisfy their nutrient demands rather than any palatability effect. Bite size (derived from intake measurements and number of bites day^{-1}) measured in g freshweight $bite^{-1}$ was increased by 66%, but bite size measured in g DM $bite^{-1}$ was decreased by 19%.

In the grazing situation high rainfall and the resulting low DM content of the herbage appear to have an adverse effect on herbage DM intake. This may be due to low rate of biting because of the difficulty in prehending herbage of low DM content (Combellas *et al*, 1979). Grazing time is not usually effected by moderately wet weather, although the periodicity of grazing during the day is affected (Hancock, 1953; Ruckebusch and Bueno, 1978). However, very inclement weather may reduce the grazing time of cattle by almost one hour per day (Hinch *et al*, 1982), whereas grazing times may increase when cattle graze wet herbage compared with dry herbage (Wardrop, 1953; Waite *et al*, 1951). Clearly the effect of rainfall on grazing time is a balance between the inability of cattle to eat sufficient DM with very low DM herbage and the reluctance of cattle to graze in high rainfall.

Large effects on animal output have been recorded in inclement weather. Marsh (1975) found the reduction in daily liveweight gain of grazing beef cattle in autumn compared with spring was only 10% when the autumn was very dry (23 mm rain) compared with 48% when the autumn was wet (148 mm rain). In grazing experiments with dairy cows Sjollema (1950) reported a fall in milk fat production of approximately 50 g cow^{-1} day^{-1} during wet, stormy weather.

1.1.4 Herbage contamination

Cattle defaecate on average 12 times a day (Table 1.1), with some variation due to herbage DM intake (MaClusky, 1960) and mean daily temperature (Hancock, 1950). Mean area of faecal deposits in Table 1.1 was 0.07 m^2, which would theoretically result in 6% of the pasture area being covered by faeces by the end of the grazing season at a stocking rate of 4 cows ha^{-1}. This assumes no deposits overlap (Petersen *et al* (1956) estimated the incidence of this to be very small) and no faecal deposits disappear over the season. Rate of disappearance of faecal deposits increases with increasing rainfall and decreasing DM content of the faeces (Weeda, 1967; MAFF, 1969a). Formation of a crust in dry weather prevents rain eroding the deposit and consequently disappearance rate tends to be faster in autumn than in summer (Weeda, 1967). Faeces have been found to cover 2-4% of the pasture area by September (Arnold and Holmes, 1958; Greenhalgh and Reid, 1968).

If the faecal disappearance is rapid and stocking rate is not greatly reduced in autumn, peak herbage rejection will occur in the summer (Tayler and Rudman, 1966; Weeda, 1967; MAFF, 1969b). Otherwise herbage rejection will increase linearly (MaClusky, 1960) or curvilinearly (MAFF, 1969a; Brockington, 1972) over the grazing season. The area of herbage rejected in a sward generally decreases with increasing stocking rate (Arnold and Holmes, 1958; Greenhalgh and Reid, 1968; MAFF, 1969a) and, on average, a faecal deposit will cause an area

Table 1.1 Faecal Contamination of Pasture and Associated Effects

Author	Relative stocking rates	Deposition rate (deposits day^{-1})	Defaecation area (m^2)	Disappearance rate (days $deposit^{-1}$)	Peak herbage rejection %	Peak herbage rejection Month	Rejection area / deposit area
Johnstone-Wallace and Kennedy (1944)		12	0.062				
Petersen *et al* (1956)		12	0.093	255			3
Arnold and Holmes (1958)	High Low				15 26		
Norman and Green (1958)				280			5.8
MaClusky (1960)		12.5	0.050		35	Mid-summer	6
Tayler and Rudman (1966)					23	July	
Weeda (1967)		10.7		150 (summer) 40 (autumn)	23	July	
Greenhalgh and Reid (1968)	High Low				23 34		8 12
MAFF (1969a)	High Low			147	89 29	Aug/ Sept	
MAFF (1969b)	High Low				15 29	July	
MacDiarmaid and Watkin (1972)		13.9	0.074	55 (spring) 80 (summer)			
MEAN		12.2	0.070	144	30		6.2

6 times its own area to be rejected. This is initially because of smell (Marten and Donker, 1966; MacDiarmaid and Watkin, 1972) and later because the herbage is more mature than the rest of the sward (Broom *et al*, 1975). This rejected herbage will act as a partial buffer to variation in grazed herbage availability, since cattle will consume this herbage when there is none other available (MAFF, 1969a).

It has been difficult to estimate experimentally the effect of herbage rejection on herbage intake. Greenhalgh and Reid (1968) found herbage DM intake in the autumn was 9% less on a contaminated pasture than a clean pasture; Holmes *et al* (1971) found the difference was 7% over the whole grazing season. In both experiments increased dead matter content and decreased density of the clean sward may have reduced intake in this treatment. Brockington (1972), recognising the limitations of Greenhalgh and Reid's data, formulated a model using their data and others and concluded that herbage intake would be reduced by 15% in autumn at a high stocking rate.

There are two possible reasons for the reduction in herbage intake - the reduction in grazed area in a contaminated sward may restrict herbage availability, alternatively herbage intake may be intrinsically depressed at all stocking rates by the smell of the faecal deposits. The fact that Greenhalgh and Reid (1968) and Reed (1978) found that the depression in herbage DM intake in autumn was unrelated to stocking rate suggests the latter explanation. However, Boswell (1971) found that at very low stocking rates contamination had no effect on herbage intake, but at moderate stocking rates intakes from clean swards were 30% higher than contaminated swards. Conceivably at very low stocking rates the influence of smell is reduced as the chance of grazing in the proximity of a faecal deposit is reduced and therefore both explanations probably apply.

Recent applications of slurry to pasture result in greater depressions in herbage DM intake of between 12 and 32% (Reid *et al*, 1972; Broom *et al*, 1975; Pain and Broom, 1978). In support of the theory that herbage intake is intrinsically depressed by the smell of faecal deposits, Pain and Broom (1978) found that slurry reduced the acceptability of a sward, with a lower rate of intake and longer walking time.

Several methods have been investigated to overcome the reduction in herbage intake due to faecal contamination. Conditioning cows to eat rejected herbage by feeding hay sprayed with dilute slurry (MAFF,1968 Garstang & Mudd, 1971) or by grazing cattle on recently manured pastures (Reid *et al*, 1972), met with little success. Using a chain harrow to disperse faeces and accelerate decomposition has not been successful. Reid *et al* (1972) found that this had no effect on herbage intake and wet faeces were not adequately dispersed; Weeda (1967) found that although grazing was more even, herbage yield was reduced by 14% due to sward damage, and MAFF (1969c) found no effect on the proportion of the herbage rejected. Marten and Donker (1964) found that spraying rejected herbage areas with molasses greatly increased the consumption of these areas, but MAFF (1968) found that cows licked off the molasses and left the herbage. Topping the pasture in late season will reduce the proportion rejected if herbage contamination is high (MAFF, 1969c).

1.1.5 Seasonal effects on milk production

1.1.5.1 Spring herbage

Seasonal effects on milk production represent an amalgamation of the factors discussed previously.

Cows grazing spring herbage generally show an increased milk yield and SNF content, but a decreased milk fat content compared with the previous winter feeding regime (Rook, 1961; Walsh, 1969; Gardiner and McGann, 1968; Fisher, 1979). Several extreme cases were reported in the first half of this century with milk yield increased by up to 75%, and milk fat content falling from 35 g kg^{-1} to below 20 g kg^{-1} (McClymont, 1950). In some cases this was associated with severe scouring and depraved appetite. Rook and Rowland (1959) found the yield of total solids was increased by 42% after turnout where cows had been on a low energy winter ration, but only 11% where cows had been on a high energy winter ration. It is difficult to evaluate the effects on liveweight change since the change in the level and type of nutrient intake after turnout causes a major change in rumen microflora and retention time. Normally the reduction in gut contents causes rapid weight loss for 2-3 days after the onset of spring grazing, followed by a gradual recovery over the next 2-3 weeks (Balch and Line, 1957). Theoretically the high proportion of propionate in the ruminal VFA with spring herbage would be expected to increase the partition of metabolites towards liveweight gain at the expense of milk production (Ørskov *et al*, 1968).

A few authors have not obtained the usual effects on milk production probably due to the absence of a change in fibre or energy level of the diet (eg Waite *et al*, 1960).

The normal effects arise as a result of quantitative changes in the levels of dietary fibre and energy. In the rumen increased energy supply causes an increased VFA concentration, and the low fibre level results in a decreased ratio of acetate to propionate, similar to that obtained with cows suffering from "low fat milk syndrome" (Rook, 1964). It has been established that depression of milk fat in cows suffering from low fat milk syndrome arises from a reduced ratio of acetate and butyrate to propionate in the rumen and an increased overall level of propionate (Annison *et al*, 1974). This is generally due to a concentrate:forage imbalance on a winter feeding regime. Intraruminal infusions of acetate and butyrate increase milk fat but propionate decreases it (Thomas and Rook, 1977). In addition, there is a simultaneous increase in lipase activity in fat deposits, with a decrease in lipase activity in the mammary gland (Opstvedt *et al*, 1967).

The changes in ruminal VFA levels are caused both by a lack of long fibre, as has been demonstrated with ground roughage (Campling and Milne, 1972) and also by rapid carbohydrate digestion, which reduces the pH of the ruminal contents below the optimum for cellulolytic bacteria (Osbourn, 1980). With perennial ryegrass the content of water-soluble carbohydrate has been found to be inversely related to the proportion of acetate in the rumen (Bath and Rook, 1961), although no close correlation has been found between herbage species (Bath *et al*, 1962).

Depression of ruminal pH from 6.6 to 6.0 by the addition of maize meal to chopped dried grass decreased the rate of cellulolytic digestion by 57% (Osbourn *et al*, 1969). The pH of the ruminal contents of cows fed leafy Italian ryegrass was 5.6 compared with 6.0 for mature Italian ryegrass (Bath *et al*, 1962).

The depression in milk fat content can be alleviated by offering herbage of greater maturity that has a higher crude fibre content (Figure 1.4).

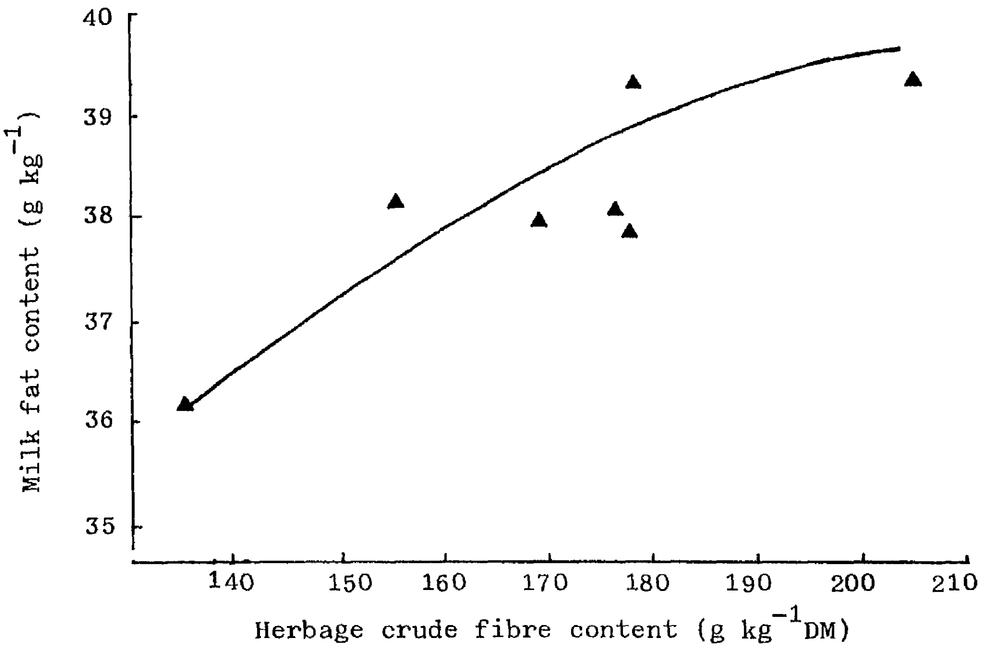


Figure 1.4 Effect of crude fibre content of herbage on milk fat content (from Hildebrandt, 1958)

1.1.5.2 Autumn herbage

The decline in *ad libitum* herbage intake of rotationally-grazed, lactating cows with autumn herbage compared with spring herbage has been found to be 11% (Corbett *et al*, 1963) and 19% (Stehr and Kirchgessner, 1976). With continuously-grazed dairy cows Baker *et al*, (1980) found that herbage intake was 7% less in the last third of the grazing season compared with the first third. Le Du *et al* (1981), in three experiments where herbage height was kept constant throughout the season, found that herbage DM intake of continuously-grazed dairy cows was 14 and 13% higher in mid grazing season than in early or late grazing season respectively.

The principle reasons for the reduced intake and animal production of autumn herbage compared with spring herbage have been discussed by Reed (1978) and Scott *et al* (1976). The main factors proposed are faecal contamination and sward chemical composition. In addition, decreased herbage DM content and availability and declining day length in autumn may be implicated.

In the commercial situation the reduction in herbage intake in the autumn could be even greater. Farmers attempt to maintain constant herbage availability, despite seasonal varation in growth rate by conserving forage in the spring and using the aftermath later in the season to reduce stocking rates (Holmes, 1980). However, because the proportion of the land used for conservation is often too small, stocking rate is not reduced sufficiently and herbage availability declines in the autuumn.

Grazing pressure has a greater effect on animal production in the autumn than in the spring (Jamieson, 1975; Reed, 1978) for two reasons. Firstly, as the season progresses the proportion of the sward as dead matter increases from approximately 10% in spring to 40% in autumn (Le Du *et al*, 1981). Secondly by the end of the grazing season the proportion of the sward rejected due to faecal deposits may be 30% (Section 1.1.4). Thus, even if herbage availability is the same in autumn as in spring, the proportion of herbage that is acceptable to the cow may be less than 50% in autumn. Both herbage dead matter proportion and rejection of contaminated herbage are increased by inadequate stocking rates in spring (Baker, 1980), thereby increasing the importance of a sufficient reduction in stocking rate in autumn. Furthermore, if herbage is restricted the opportunity for selection is reduced and the resulting low digestibility of ingested herbage will further reduce animal production.

Although herbage availability may amplify differences in herbage intake and animal production between autumn and spring, differences are still observed under *ad libitum* herbage conditions (Corbett *et al*, 1963) and with identical, restricted intakes of dried grass (Lonsdale and Taylor, 1971), suggesting that other factors are involved.

It is well established that the feeding value of autumn herbage for liveweight gain is substantially below that of spring herbage of the same digestibility (Blaxter *et al*, 1971; Corbett *et al*, 1966; Beaver *et al*, 1975, 1977). For example Lonsdale and Taylor (1971) found that the liveweight gain of beef cattle was 20% less with autumn-dried grass compared with spring-dried grass of the same digestibility. However, the decrease in milk production with autumn-dried grass compared with spring-dried grass is less than 5% (Campling and Holmes, 1958; Holmes, 1956; Gordon, 1974). In addition Corbett *et al* (1963) found no difference in milk yield per unit of DOMI between autumn and spring grazed herbage. These differing responses may arise from changing the partition of metabolites from liveweight gain to milk production, which occurs when the proportion of acetate in the ruminal VFA increases (Ørskov *et al*, 1968). Typical ratios of acetate to propionate for autumn and spring herbage are 66:18 and

59:22 respectively (Bath and Rook, 1961). Thus the overall efficiency of utilization of ME is probably reduced as much in dairy cows as in growing ruminants in autumn, although the transfer of metabolites means that this difference is not evident when milk production alone is studied.

The reasons for the decreased efficiency of ME utilization of autumn herbage compared with spring herbage is unclear. Work by Ørskov and McDonald (1980) suggests that the proportion of ruminal acetic acid *per se* has little effect on the efficiency of utilization of ME for liveweight gain. Corbett *et al* (1966) postulated that the retention time of autumn herbage in the rumen is longer than spring herbage because of the low water soluble carbohydrate content (Waite and Boyd, 1953; Waite, 1965) and the correspondingly low fermentation rate. Rumen retention time is closely related to voluntary intake (Thornton and Minson, 1973) and greater efficiency may ensue in spring herbage as a result of an increased proportion of nutrients escaping rumen fermentation and being digested in the small intestine (Reed, 1978) and a lower maintenance requirement for ruminal microorganisms (Buttery and Lewis, 1982). In support of this Beever *et al* (1975) found the proportion of the nitrogen intake reaching the small intestine as amino-acid was reduced by 20%, and the energy lost in the rumen increased by 30%,with autumn compared with spring herbage.

Of a more unpredictable nature is the reduction in animal output that can occur as a result of prolonged periods of inclement weather and the resulting low DM content of the herbage. In fine weather cows may compensate to some extent for low herbage DM content by increasing grazing time and biting rate. In periods of prolonged rainfall, such as frequently occur in autumn, cows are unwilling to graze and herbage DM intake is reduced.

It has been suggested that declining day length in autumn may modify grazing behaviour and appetite (Decaen and Journet, 1966; Reed, 1978; Baker, 1980). Cattle prefer to graze in daylight (Hancock, 1953), possibly as a vestigial defence mechanism, and declining daylength increases the proportion of daylight hours spent grazing (Tayler, 1953). In addition under certain circumstances cattle will only graze at night time in well-lit nights (Hancock, 1953). However, since up to 30% of the grazing time in temperate regions is at night in the autumn (Hancock, 1953), and in many reported instances grazing time is the same or higher in the autumn than in summer (Johnstone-Wallace and Kennedy, 1944; Hancock, 1950; Waite *et al*, 1951; Wardrop, 1953) it is concluded that the effect of declining daylength in autumn on grazing time is minimal. However, there may be hormonal influences - milk yield is increased when cows are exposed to 16 hours artificial light compared with natural daylength of 10.5 hours (Peters *et al*, 1978, 1981). It is unclear whether extending the natural autumnal daylength of 12 hours would increase milk yield. In addition Decaen and Journet (1966) report that long daylength in midsummer caused a reduction in milk fat content but it is more likely that this was caused by high temperatures.

It has been observed that the grazing behaviour of dairy cows (Castle *et al*, 1950) and beef cattle (Tayler, 1953) can be disturbed by flies in the autumn in Great Britain. In Canada beef cattle had an 18% higher liveweight gain when fitted with ear tags impregnated with insecticide (Haufe, 1982). However in Great Britain, it has been observed that fly counts on cattle are not as high as those observed in Canada, and it is unlikely that production is greatly impaired (Hughes, J, unpublished results).

1.2 EFFECTS OF OFFERING CONSERVED FORAGE WITH HERBAGE ON DM INTAKE AND PRODUCTION

1.2.1 Grass silage

1.2.1.1 Restricted herbage + silage compared with *ad libitum* herbage

1.2.1.1.1 DM intake Where herbage intake is restricted and silage offered *ad libitum* the silage DM intake is dependant upon the level of pasture restriction (Hutton and Parker, 1966) and the silage quality (Percival, 1955; Bryant, 1978) (Table 1.2). When herbage is greatly restricted offering silage *ad libitum* will decrease total DM intake relative to *ad libitum* herbage intake unless the silage is of high intake characteristic. This reduction in total DM intake is probably due to the low energy content and nitrogen retention of silage relative to fresh herbage.

Silage alone has a considerably lower DM intake compared with *ad libitum* herbage - the decrease in total DM intake ranges from 11% with high quality silage to 29% with low quality silage. Combinations of herbage and silage also result in depressions in total DM intake relative to *ad libitum* herbage, except where good quality silage is included at low levels in the diet (Rogers, 1979). Mean substitution rate (kg herbage DM kg silage DM^{-1}) in table 1.2 is 1.17. However combinations of herbage and silage generally result in higher total DM intakes than the intake of the separate forages would predict (figure 1.5) (Miller *et al*, 1965). This "synergistic effect" has

Table 1.2 The effect of inclusion of silage with restricted herbage on DM intake relative to *ad libitum* herbage

Herbage/silage combinations

Author	Restricted Herbage intake (% of *ad lib*)	Silage *ad libitum* intake (kg DM day^{-1})	Change in total DM intake with silage (%)	Substitution rate (kg herbage DM kg silage DM^{-1})	Silage quality CP (DMD) $g\ kg^{-1}$
Miller *et al* (1965)	28	7.3	-10.2	1.17	Low 137
Bryant and Donnelly (1974)	64	2.5	-15.0	1.71	150
Bryant (1978)	30	8.8	-7.0	1.11	Wilted (740)
	33	7.8	-11.0	1.21	Direct cut (750)
Rogers and Porter (1978)	59	5.2	-1.5	1.04	High, wilted
	38	7.4	-5.3	1.09	
Rogers (1979)	63	4.1	+4.0	0.90	High, wilted
	39	5.9	-1.0	1.02	
Rogers and Robinson (1980b)	39	7.9	-2.2	1.04	Wilted (660)
	33	6.5	-18.7	1.38	High moisture (630)
MEAN	43	6.3	−6.8	1.17	
Silage vs herbage					
Miller *et al* (1965)	0	8.4	-28.8		Low 137
Rogers (1979)	0	8.8	-11.1		High
Rogers and Robinson (1980b)	0	12.1	-9.7		Wilted (660)
	0	10.2	-23.9		High moisture (630)
MEAN	0	9.9	−18.4		

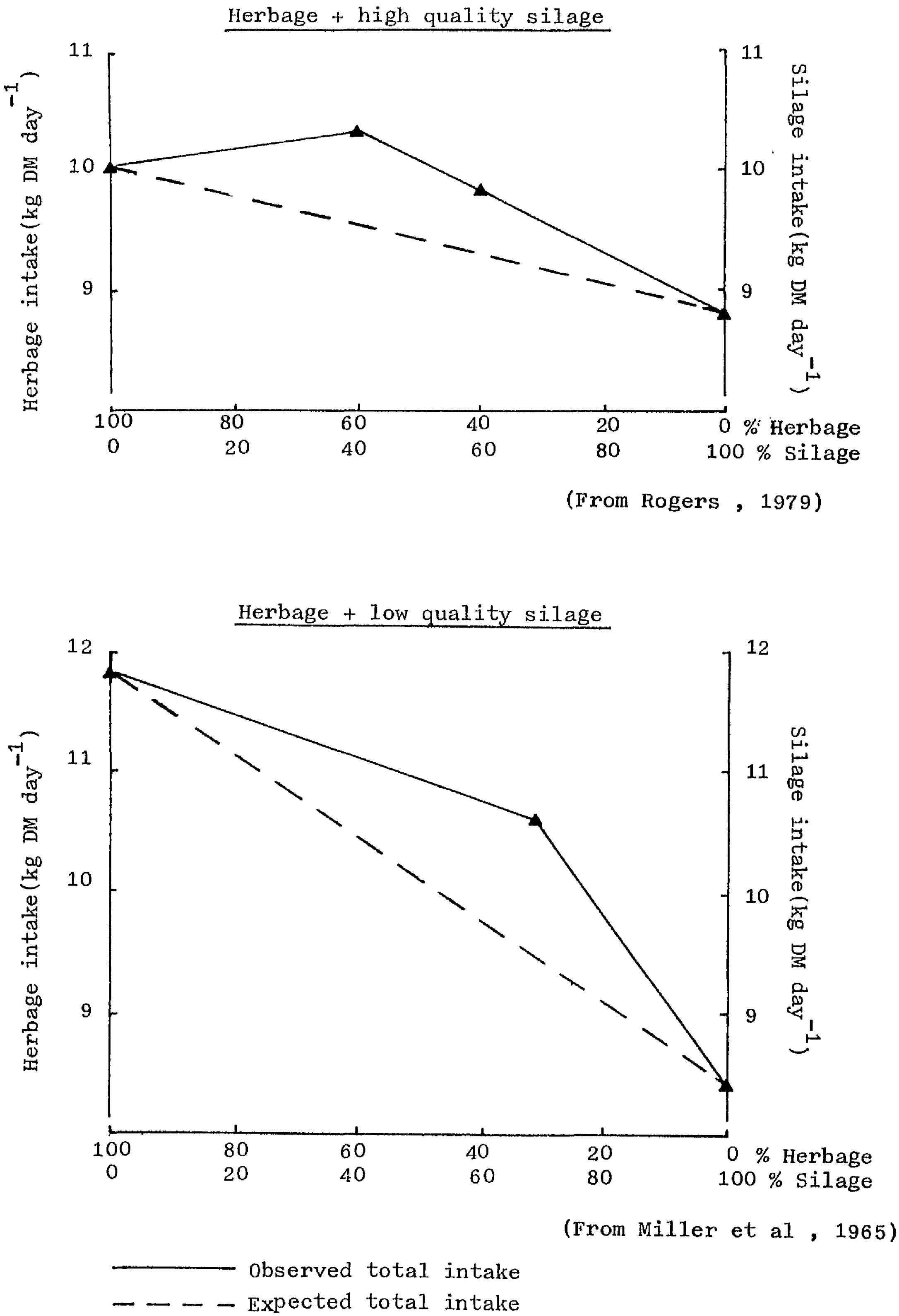


Figure 1.5 Observed and expected total DM intakes with herbage/silage combinations

also been observed with silage and hay (Coppock *et al*, 1974) and two dissimilar silages (Miller *et al*, 1965). No effect, however, was found by Rogers and Robinson (1980b) when a restricted herbage allowance was supplemented with a low DM silage of low intake characteristic. It is likely that the synergistic effect is due to the provision of a nutrient that is deficient in one feed (eg protein in silage, fibre in spring herbage) but in surplus in another (eg crude protein in herbage, fibre in silage). Conceivably the intake drive of the cow may also be increased when more than one forage is offered.

<u>1.2.1.1.2</u> <u>Dairy cow production</u> Where silage is of lower or similar quality to herbage, inclusion of silage in the diet generally results in a depression in milk yield relative to *ad libitum* herbage (table 1.3). Where silage is of higher quality than pasture, Bryant (1978) found that milk yield was increased when silage was included in the diet.

The effects of inclusion of silage on the fat content of the milk are varied but tend to be inversely related to the effect on milk yield (table 1.3). Where silage is of better quality than herbage, fat content is decreased (Bryant, 1978; Rogers and Robinson, 1980b), otherwise there is little change or it is slightly increased. The inclusion of silage in a pasture-silage diet increases the degree of saturation of the milk fatty acids (Rogers, 1980) which increases the keeping quality of the milk (Keen and Kroger, 1975).

Table 1.3 The effect of inclusion of silage with restricted herbage on milk production relative to *ad libitum* herbage

Author	Silage *ad libitum* intake (kg DM day^{-1})	% change with silage: Milk yield	Fat content	Protein content	Fat yield	DMD (g kg^{-1}): Silage	Herbage
Miller *et al* (1965)	7.3	-24	+11		-15	Low	
Hutton and Parker (1965)	2.5	- 9	+ 3	+ 1.1	- 7	670	
Hilderbrand (1958)	3.8	- 7	+ 2		- 5		
Bryant and Donnelly (1974)	2.8	-11	+ 5		- 3	700	670
Hutton and Douglas (1975)	3.1				- 3	720	770
Bryant (1978)	6.1	+11	- 6	- 2.8	+ 3	Direct cut 700	640
	8.3	+14	0	- 1.7	+ 2	Wilted 730	640
Rogers and Porter (1978)	5.2	0	- 4	- 0.3	- 3	Wilted	
	7.4	- 1	- 6	- 0.7	- 9	High	High
Rogers (1979)	4.1	0	- 2	0	- 2	Wilted	
	5.9	- 5	- 3	- 0.3	- 6	High	High
Bryant (1979)	36% total DM intake	-13	+ 1	- 5.7	- 9	Wilted	
Rogers and Robinson (1980b)	6.5	- 3	-11	- 8.0	-13	High moisture 630	620
	7.9	+ 3	- 4	+ 1.1	0	Wilted 660	620
Thomas *et al* (1980)	3.7	+ 2	- 6	+ 2.6	- 3		
MEAN	5.4	- 3.0	- 1.3	- 1.3	- 2.8		

Table 1.3 continued

Author	Silage *ad libitum* intake (kg DM day^{-1})	% change with silage				DMD (g kg^{-1})	
		Milk yield	Fat content	Protein content	Fat yield	Silage	Herbage
Silage only							
Miller *et al* (1965)	8.4	-38	+ 3		-37	Low	–
Rogers (1979)	8.8	-13	- 5	- 0.9	-17	Wilted High	High
Rogers and Robinson (1980b)	12.1	- 3	- 9	- 2.4	-16	Wilted 660	620
	10.2	0	-13	-11.2	-21	High moisture 630	620
MEAN	9.9	-13.6	- 6.2	- 4.8	-22.5		

The reduction in total DM intake when silage was included in the diet caused reductions in milk yield and milk fat yield that were similar to changes caused by restriction of herbage intake (section 1.1.1.2) (appendix 2).

Protein content tends to be reduced by including silage in the diet. This probably arises both from the reduction in total DM intake and the low protein content and nitrogen retention of silage compared to fresh herbage. Increasing the cutting interval of fresh herbage greatly reduces the nitrogen content (Ashford and Troelsen, 1965; Wilkins *et al*, 1981). Ensiling herbage reduces nitrogen retention by ruminants, and the reduction in total DM intake of silage compared with herbage reduces nitrogen intake (Grenet and Demarquilly, 1983). Dietary protein supply to the tissues is thus enhanced in fresh herbage diets, which will result in increased uptake by the mammary gland and increased non-protein-nitrogen content of the milk (Thomas, 1980). The magnitude of the depression in milk protein content when silage is included in the diet depends on the quality of the silage offered (Bryant, 1978; Rogers and Robinson, 1980a).

The effect of inclusion of silage on liveweight change is poorly documented. Reductions in liveweight gain of between 0.3 and 0.8 kg day^{-1} have been reported by Miller *et al* (1965), Bryant and Donnelly (1974) and Rogers (1979), but silage has been reported to increase liveweight gain where pasture is of lower quality (Bryant, 1978).

1.2.1.2 Restricted herbage + silage compared with restricted herbage

1.2.1.2.1 DM intake When herbage allowance is restricted, offering silage as a buffer feed will decrease herbage DM intake but increase total DM intake relative to intake at the restricted level (Hutton and Parker, 1965; Moate, *et al*, 1980; Rogers and Robinson, 1980a). Substitution rates can be calculated to relate the intake of herbage DM at restricted allowances to silage DM intake. Moate (1980) found that substitution rate (kg herbage DM kg^{-1} silage DM) decreased as the restriction of pasture increased (0.21 at low pasture allowance, 0.39 at high pasture allowance). There was little effect of level of silage offered on substitution rate (0.28 at 3 kg DM day^{-1}, 0.32 at 6 kg DM day^{-1}), although this is likely to depend on the degree of pasture restriction.

1.2.1.2.2 Dairy cow production Results from cows offered a restricted herbage ration with *ad libitum* silage are shown in table 1.4. Offering silage tended to increase milk yield and fat yield, decrease milk fat content and had small, variable effects on milk protein content. The increases in milk yield and fat and protein content when silage was offered were less than would be expected from offering additional herbage (section 1.1.1.2), which is contrary to what was found when silage and herbage were compared with *ad libitum* herbage (section 1.2.1.1.2). This is probably explained by the short duration of experiments in table 1.4 (mean 40 days) and the greater degree of restriction (57% of *ad libitum* intake) compared with herbage as a supplement (68% of *ad libitum* intake) in section 1.1.1.2. Both of these factors would increase tissue mobilization at the restricted herbage level, thus reducing

Table 1.4 The effect of silage as a buffer feed to restricted herbage on milk production and efficiency

Author	Silage DM intake ($kg\ day^{-1}$)	% change with silage					Efficiency (g milk fat kg^{-1} silage DM)	DMD ($g\ kg^{-1}$)	
		Total DM intake	Milk yield	Fat content	Protein content	Fat yield		Silage	Herbage
Wheeler *et al* (1972)*	2.2	NA	+11	0	NA	+ 6	10	Low	
Hutton and Douglas (1975)*	3.1	+26	NA	NA	NA	+ 9	19	720	770
Pankhurst & McGowan (1978)	2.0	+47	+54	-19	-6.2	+25	25	630	710
Rogers and Porter (1978)	5.2	+63	+21	- 8	+4.2	+14	14		
	7.4	+130	+33	-11	+6.0	+17	11		
Bryant (1978)	6.1	+67	+48	- 8	-0.6	+40	20	Direct cut 700	640
	8.3	+75	+44	- 2	-1.7	+34	17	Wilted 730	640
Bryant (1979)	≅4.0	+100	+10	- 1	+1.3	+ 9	≅20		
Rogers and Robinson (1980a)	4.0	+50	+11	- 4	+0.6	+11	10	600	630
	8.0	+130	+21	- 7	+1.2	+22	10		
Moate *et al* (1980)	3.0	+52	+ 8	+ 4	-0.3	+ 9	15	630	720
	6.0	+120	+16	- 7	+2.3	+ 7	11		
	3.0	+26	+15	-10	+2.3	+ 5	12		
	6.0	+43	- 1	- 4	-0.7	- 7	0		
Rogers (1979)	4.1	+72	+33	+ 2	+1.2	+24	22	High	
MEAN	5.2	+75	+24.1	- 5.7	+0.7	+15.7	14.4		

* Excluded from mean because of incomplete results.

the effect of a silage supplement on milk production. In a review of short-term feeding experiments in Australia, McGowan (1980) found no substantial differences in efficiency of milk fat production between silage and herbage as a supplementary feed to herbage.

It has not been possible to examine in detail the effects of offering silage as a buffer feed on liveweight change relative to restricted herbage due to the paucity of information and short duration of some trials. Bryant (1978) and Rogers (1979) reported a reduction in liveweight loss when silage was offered. In addition it has not been possible to fully evaluate stage of lactation effects on the efficiency of silage as a buffer feed. McGowan (1980) reported that mid-late lactation cows were only 4% less efficient than early lactation cows in the conversion of herbage as a buffer feed into milk fat.

Comparing different methods of feeding silage with pasture, Wallace and Parker (1966) concluded that there was no difference in intake or production between cows offered silage in a covered yard overnight, or cows allowed to consume a week's ration of silage then turned out to pasture for the remainder of the week. Feeding the silage in the field without a trough increased silage wastage to 23% compared to 5% when fed indoors.

1.2.1.3 Utilized metablizable energy (see glossary) from silage compared with grazing areas

Although feeding silage in large amounts will entail some losses in animal production relative to *ad libitum* herbage, if high levels of grassland utilization are to be achieved some losses in individual cow performance must be sustained (McMeeken and Walshe, 1963; Gordon, 1981). Offering conserved forage as a buffer feed will reduce grassland utilization compared with a restricted herbage ration (Stockdale *et al*, 1981), unless stocking rates are increased to utilize the extra herbage available.

A potential benefit of offering silage with restricted herbage is increased UME output ha^{-1} from silage compared with grazed herbage (Van Keuren *et al*, 1966). Decreasing the cutting frequency of herbage increases yields of DM (figure 1.6) and ME (Chestnutt *et al*, 1977; Wilkins *et al*, 1981), especially at high levels of nitrogenous fertilizer.

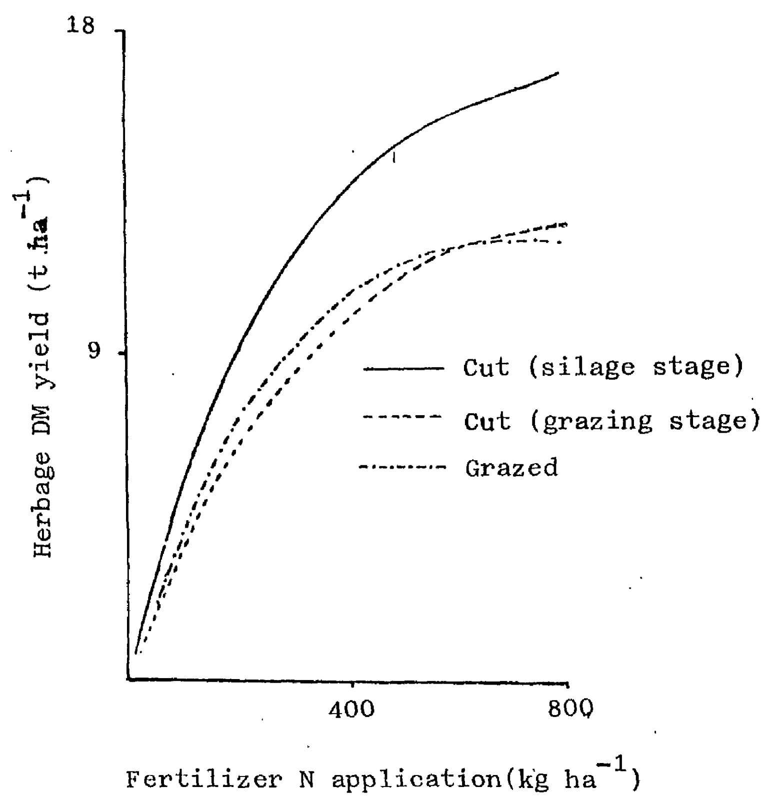


Figure 1.6 Effect of cutting stage on herbage DM yield at various levels of nitrogen fertilizer (from Richards, 1977)

Increases in UME ha^{-1} will be less than increases in DM yield ha^{-1} because of the lower ME content of silage compared with herbage.

Under experimental conditions differences in UME output are not always apparent. Applying a UME calculation (MAFF *et al*, 1975) to an experiment by Castle and Watson (1978), where land was grazed or ensiled, produced UME outputs of 87 and 89 GJ ha^{-1} respectively. Farmers, however, tend to understock their grazing land in spring, and a farm survey has shown that ensiled areas produced approximately 17 GJ ha^{-1} more than grazed areas (Walsh, 1982). In addition, Hopkins (1983) estimated that only 65% of the available ME from grazed herbage on dairy farms in England and Wales is utilized.

Losses from grazed swards are mainly due to contamination, poaching and herbage senescence (Stuth *et al*, 1981) and are commonly around 25% under experimental conditions (Doyle *et al*, 1982). Losses are decreased at low herbage allowances and when silage aftermaths are gradually released (Stuth *et al*, 1981; Doyle *et al*, 1982). Losses from ensiled wilted herbage under good management range from 10% (Moisey, 1981) to 21% (Wilkinson, 1981). With wilted silage the decrease in digestibility associated with wilting (about 20 g kg^{-1} DM) is balanced by the increase in gross energy content due to in-silo losses, with little resulting change in digestibility as a result of the conservation process (Wilkinson, 1981).

If silage comprises a major part of the diet the maintenance requirement of the cows - 10-20% higher for grazing cows than housed cows (NRC, 1978) - will be reduced. However, the support energy used for making silage compared with grazing herbage is greater by between 9% (direct cut silage, no additive) and 61% (wilted silage, with additive) (White *et al*, 1983). Although silage costs almost twice as much as grazed herbage when it is the basal forage in the diet (Lazenby and Doyle, 1981), the cost of making additional silage to feed in the summer will be confined to the variable rather than fixed costs (Van Keuren *et al*, 1966).

1.2.2 Maize silage

Inclusion of maize silage into summer feeding could not only act as a buffer to variation in herbage intake but also has potential benefits of increased output ha^{-1}, a more balanced seasonal work pattern and reduced risk of crop failure due to the spread of harvesting dates (Phipps, 1978). Maize silage also has a consistently high energy content but low crude protein, mineral and vitamin content and is therefore a suitable nutritional complement to herbage with its variable energy content and high crude protein content.

1.2.2.1 DM intake

Inclusion of maize silage in a herbage based diet up to approximately 33% of total DM intake generally increases total DM intake (Hutton, 1975) (table 1.5), despite the slightly lower energy content of maize silage. This may be due to more rapid digestion compared with herbage (Bryant and Donnelly, 1974). At higher proportions of maize silage in the diet the crude protein content of the diet is limiting, and rumen microbial population falls with a corresponding decrease in total DM intake.

Table 1.5 The effect of inclusion of maize silage in a herbage diet on intake and production

	Maize silage intake		Substitution rate	% change in				Change in lwt gain	Maize silage relative to herbage		Notes
	kg DM	% of diet	(kg herbage DM kg^{-1} maize silage DM)	Total DM intake	Milk yield	Fat content	Protein content	(kg d^{-1})	CP content (g kg^{-1})	ME* (MJ kg^{-1} DM)	
Bryant & Donnelly (1974)	3.1	25	0.87	+ 4.3	+ 4.4	- 3.3	0	-0.36	-89	-0.2	
	8.1	75	1.18	-10.0	-16.1	- 2.2	-3.9	+0.10			
Hutton and Douglas(1975)	3.3	24	0.82	+ 4.5	0	NA	NA	NA	NA	-1.8	Fat-corrected milk yield
Hijink (1978) 1972	4.8	35	1.40	-12.7	- 8.2	+ 2.8	- 4.0	-0.16	-119	-0.8	) Restricted maize
1973	4.9	34	1.02	- 2.1	- 7.5	- 3.7	- 3.2	-0.03	-147	-0.2	) silage overnight
1974	2.1	14	1.00	0	0	- 2.4	- 4.2	-0.09	-127	-0.6	) Maize silage
1975	3.6	24	0.92	+ 2.0	0	0	- 4.7	+0.17	-147	-0.2	) offered according to herbage availability
Hijink *et al* (1981)	2.0	14	0.76	+ 3.7	NA	NA	NA	NA	NA	NA	
	4.0	27	0.75	+ 7.0							
Davison *et al* (1982)	4.0	32	NA	NA	+ 7.0	- 2.7	0	+0.23	- 73	NA	No protein supplement
	5.4	43			+16.1	-11.7	-3.2	+0.47			Protein supplement

* Calculated from MAFF (1975)

In the experiments of Hijink (1972-3) (table 1.5) maize silage was offered overnight at a restricted level, and total DM intake was depressed by the limitation on herbage intake during the day. Cows housed overnight and grazed during the day (8-8.5 hours) are restricted to a maximum herbage intake of 10-11 kg herbage DM day^{-1} under good grazing conditions (Hijink, 1978) and will spend up to 75% of their time outside grazing (Vik, 1956). If supplementary feed is offered overnight the intake drive during the day is reduced, and herbage intake is further reduced.

Substitution rates of herbage DM for maize silage DM are equal to or less than 1.0 with some evidence of higher substitution rates at higher levels of supplementation (Bryant and Donnelly, 1974). Substitution rates are approximately 0.30 and 0.15 higher than concentrates and dry beet pulp respectively offered under the same circumstances (Hijink, 1978).

1.2.2.2 Dairy cow production

In the experiments of Hijink in 1972-3 (table 1.5) milk yields were depressed by the restriction of maize silage and herbage intake. Otherwise milk yield was only depressed when maize silage was included at 75% of the total diet. Both milk fat and protein content were depressed by inclusion of maize silage. Offering a protein supplement will increase milk protein yields but have no effect on milk fat yields. This may be mediated through increased milk yields and decreased milk fat content, rather than increased milk protein content (Davison *et al*, 1982).

1.2.2.3 Buffer feeding

The results of Hijink (1978) suggest that maize silage is generally eaten in preference to grazed herbage, which will restrict its use as a buffer feed. In addition, if large quantities are included in the diet total DM intake will fall. However, if herbage is restricted, offering maize silage at a low level eg access for 1 hour day^{-1}, will increase milk yield and liveweight gain (Seath and Elliott, 1950; Davison *et al*, 1982). Further increases in milk protein yield may be obtained by inclusion of a protein supplement.

The use of maize silage will only be economic if high crop yields ha^{-1} are achieved - a factor which precludes its use in the northern parts of Great Britain. In addition, it must be stored for 6-12 months before it can be used with summer grazing.

1.2.3 Hay

The use of hay at pasture has generally been as a means of increasing DM intake when herbage is restricted, and to increase the intake of fibre after turnout in spring.

1.2.3.1 Hay offered *ad libitum* with herbage compared with *ad libitum* herbage

Where herbage is available *ad libitum*, offering hay as a supplement has little effect on total DM intake (table 1.6), and the substitution rate of herbage DM for hay DM is approximately 1.0 (King and Stockdale, 1981; Stockdale *et al*, 1981). The reduction in herbage intake when hay is offered as a supplement will reduce pasture utilization unless stocking rates are increased (Stockdale *et al*, 1981).

Table 1.6 Hay offered *ad libitum* with herbage compared with *ad libitum* herbage

	Hay intake kg DM day^{-1}	Substitution rate kg herbage DM kg hay DM^{-1}	% change with hay					Hay relative to herbage		Efficiency g milk fat kg silage DM^{-1}
			Total DM intake	Milk yield	Fat content	Protein content	Fat yield	CP g kg^{-1}	ME* MJ kg DM^{-1}	
Seath and Miller (1947)	2.3	NA	NA	-0.4	NSD	NA	NSD	NA	NA	NA
Parker (1966)	1.4	NA	NA	+7.4	0	+2.5	+6.1	NA	little difference	18
King and Stockdale (1981)†	5.8	1.03	-1.2	+0.3	-7.2	+1.6	-2.7	-0.6	+0.7	- 2
Stockdale *et al* (1981)†	3.8	0.93	+1.9	-9.5	+2.3	-3.1	-5.2	-45	-1.5	-10
Spring herbage										
Castle *et al* (1960)	1.4	NA	NA	-1.0	+3.7	-1.8	+2.7	-107	NA	14
Walsh (1969)	1.9	NA	NA	-1.4	+7.7	-0.6	+6.2	-120	NA	14

* Predicted from MAFF (1975)

† Mean of several treatments

After turnout the intake of fibre is low (McClymont, 1950), but cows will only eat small quantities of hay where *ad libitum* herbage is available (Castle *et al*, 1960; Walsh, 1969). This still results in appreciable increases in milk fat content and fat yield with only slight reductions in milk yield and milk protein content (see table 1.6). In these circumstances hay is used as efficiently for milk fat production as when offered as a supplement to restricted herbage (table 1.7) - 14 g milk fat kg hay DM^{-1}. Cows can be encouraged to eat more hay by offering it indoors overnight (Parker, 1966) or possibly by increasing the palatability of the hay eg by the addition of molasses.

Offering hay at other times in the grazing season produces variable results compared with *ad libitum* herbage (table 1.6) - where hay is of lower quality then herbage, milk fat yield and protein content are decreased. Hay offered as a mid-day supplement in hot weather has little or no effect on milk production (Seath and Miller, 1947; Seath *et al*, 1955).

1.2.3.2 Hay offered *ad libitum* with herbage compared with restricted herbage

Offering hay as a supplement to restricted herbage increases total DM intake (table 1.7) especially at low herbage availabilities. Substitution rate decreases as herbage availability declines (Eldridge and Kat, 1980). The intake of hay is greater where the hay is of good quality (King *et al*, 1977) and is increased by inclement weather - Walsh (1969) found that hay intake increased from 0.3 kg DM day^{-1} to 1.6 kg DM day^{-1} during inclement weather. Hay can be either fed in the field or in a feeding passage. When

Table 1.7 Hay offered *ad libitum* with herbage compared with restricted herbage

	Herbage allowance	Hay intake kg DM day^{-1}	Substitution rate kg herbage DM kg^{-1} hay DM	% change with hay: total DM intake	% change with hay: milk yield	% change with hay: fat content	% change with hay: protein content	% change with hay: fat yield	Hay relative to herbage: CP g kg^{-1}	Hay relative to herbage: ME† MJ kg^{-1} DM	Efficiency g milk fat kg^{-1} silage DM
Parker (1966)	4 hours grazing	5.1	NA	NA	+36.8	- 9.4	+2.7	+20.0	NA	Little difference	13
	8 hours grazing	3.5	NA	NA	+26.1	- 6.5	+5.3	+17.7	NA	Little difference	14
Wilhelms & Grainger (1978)	NA	3.2	0.16	+32.1	NA	NA	NA	+10.4‡	NA	-3.6	16
Eldridge & Kat (1980)	Low	1.7	0.14	+21.6	NA	NA	NA	NA	NA	-1.4	NA
	High	1.9	0.66	+ 9.8	NA	NA	NA	NA	NA	+0.5	NA
King & Stockdale (1981)	62% of *ad lib* intake	5.8	0.11	+54.0	+34.0	-13.6	-3.3	+17.9	-0.6	+0.7	12
Stockdale *et al* (1981)	77% of *ad lib* intake	6.9	0.29	+40.4	+20.4	+ 1.3	+4.3	+12.2	-62	-1.2	14

† Predicted from MAFF (1975)
‡ FCM yield

offered in racks in the field wastage can be high, especially where hay is of low quality and there is a high degree of selection (King *et al*, 1977). In addition the field may become poached around the rack.

The effects on milk yield and production in table 1.7 reflect the increased total DM intake when hay is fed. Milk yields, milk protein content and milk fat yields were generally increased and milk fat content decreased by offering hay. Hay was used with the same efficiency as silage offered with restricted herbage (see table 1) - 14 g milk fat kg hay DM intake^{-1}. Where hay and silage have been made from the same swath, hay is of equivalent (Morrison and Deal, 1952) or slightly higher (Rogers, 1969) feeding value to silage when used as a pasture supplement. Hay may be preferred for feeding in small quantities because it does not deteriorate, whereas silage must be removed from the pit at a reasonable rate to prevent surface deterioration.

1.2.4 Straw

Straw, with its high gross energy and low crude protein content, has mainly been investigated as a buffer to intensively fertilized pastures with a high crude protein content. It has been offered with *ad libitum*, rather than restricted, herbage and has been fed either alone or mixed with a high energy, low protein supplement such as molasses (Hildebrandt, 1958) or potato flakes (Sjollema, 1950).

Straw intakes are increased where pasture has received a high level of nitrogen fertilization (Campling *et al*, 1958; Leonhard-

Kluz *et al*, 1979) and therefore has a high crude protein and low crude fibre content (Arnold and Holmes, 1958). An overriding factor may be the DM content of the herbage - straw intakes are low in dry weather but increase during wet weather (Arnold and Holmes, 1958).

Offering straw with *ad libitum* herbage has only small effects on milk production (table 1.8). Milk yields are slightly decreased, milk fat content increased and milk protein content unaffected.

Inclusion of molasses does not greatly increase straw intake and only small increases in milk fat content are obtained (Hildebrandt, 1958) - usually when the crude fibre content of the herbage is less than 200 g kg^{-1} DM. Further addition of acetic acid greatly increases intake but decreases milk yield (Hildebrandt, 1958). High intakes and beneficial effects on milk fat production have been recorded where straw treated with sodium hydroxide (Leonhard-Kluz *et al*, 1979) or mixed with potato flakes (Sjollema, 1950) has been offered as a supplement to *ad libitum* herbage.

Improvements in liveweight gain have been reported for cows offered straw at pasture (Arnold and Holmes, 1958; Hildebrandt, 1958; Horne and Barber, 1971), but in the absence of major effects on milk production it is likely that most of this improvement was due to increases in gut contents (Arnold and Holmes, 1958).

Table 1.8 Offering straw and straw-based feeds with herbage compared with *ad libitum* herbage

	Grazing system	Straw supplement	Supplement DM intake kg day^{-1}	% change with straw: Milk yield	Fat content	Protein content	Fat yield
Sjollema (1950)	Unrestricted	Straw +	5†	NA	NA	NA	+ 8.7
		potato flakes	3†	NA	NA	NA	+ 4.0
Hildebrandt (1958)	Unrestricted	Straw + molasses (30% of straw DM)	0.9	-0.9	+0.3	NA	+ 0.2
		" + sodium acetate (7% DM) + acetic acid (4% DM)	3.3 (restricted)	-4.9	+2.0	NA	- 3.1
Arnold and Holmes (1958)	Continuous and strip grazing 225 kg N ha^{-1}	Barley straw	2.2‡	-1.7	+3.6	0	+ 1.8
Campling *et al* (1958)	Continuous + clover	Oat straw	0.09	#-2.6	+2.6	0	- 0.2
	Continuous + nitrogen 238 kg ha^{-1}	Oat straw	0.23				
Leonhard-Kluz *et al* (1979)	Zero grazing 720 kg n ha^{-1}	Wheat straw	3.4‡	-1.4	+3.1	+1.9	+ 1.6
		Sodium hydroxide treated wheat straw	3.4‡	+5.0	+6.2	-0.3	+11.5

† kg freshweight
‡ assumed DM content 860 g kg^{-1}
# % change with high straw intakes

1.2.5 Conclusions

When conserved forage is offered with *ad libitum* herbage the intake of the conserved forage will be low if it is of low quality eg straw, but can form a major part of the diet for better quality feeds eg silage. However, the quality of the conserved forage is usually lower than herbage and for this reason total DM intake is depressed. This reduces milk yield and often milk protein content and has small, variable effects on milk fat content. An exception is spring herbage of high digestibility where offering hay increases milk fat content and fat yield.

Where conserved forage is used to supplement a restricted herbage ration, total DM intakes are increased and substitution rates are lower than with *ad libitum* herbage. Substitution rates are slightly greater at high levels of supplementation and are generally higher than for concentrates offered under the same circumstances (Hijink, 1978). As a result of the substitution of conserved forage for herbage, pasture utilization is reduced unless stocking rates are increased. When herbage is restricted offering hay or silage increases milk yield and sometimes milk protein content but decreases milk fat content. Overall the yield of milk fat and protein are increased.

A further benefit of offering grass or maize silage is the increased UME output hectare^{-1} compared with grazed herbage.

CHAPTER 2

BUFFER FEEDING IN CONJUNCTION WITH GRASS SILAGE AS THE BASIC FORAGE

2.1 RESTRICTING THE ALLOWANCE OF SILAGE

2.1.1 Possible mechanisms of a silage restriction

Silage DM intake may be restricted for a variety of reasons, not all of which are intentional on the part of the farmer. The most important is insufficient conservation, although this may be precipitated by high stocking rates.

The high herbage growth rate in spring enables surplus herbage to be conserved, but climatic variables will determine the quantity and quality of feed conserved. Later in the grazing seasons the rainfall is even more variable (Garwood *et al*, 1977), and the proportions of conserved and grazed herbage may vary according to herbage availability (Illius and Lowman, 1983). The use of forage planning guides (Dodds and Galt, 1981) and computer prediction models (Spedding, 1983) will increase the amount of silage conserved in years of high herbage availability, and this will have the effect of increasing variation in the annual amount of silage conserved. Coefficient of variation of annual herbage yield in England has been recorded as 24% (Garwood *et al*, 1977).

In certain circumstances insufficient forage conservation may be overcome by turning cows out early in the spring but the more usual practice is to restrict silage intake. This may be implemented in a passage feeding system by reducing the silage allowance cow^{-1} or simply by making the cows consume all the silage offered. Leaving the manger empty for 4-5 hours day^{-1} will reduce intake by approximately 6% (Coppock, 1977). In addition restricting the available feeding space cow^{-1} may reduce intake - Friend *et al* (1977) found that restricting manger width from 0.50 to 0.25 m cow^{-1} reduced DM intake by 13% but Reynolds and Campling (1981) found that having 50% more cows than mangers did not affect silage DM intake even when access was restricted to 7 h day^{-1}.

In a self-feeding system silage intake may be restricted by reducing either the time of access to the feed face or the width of face cow^{-1} (Leaver and Yarrow, 1977) or by positioning a movable barrier in front of the feed face (Chalmers, 1980).

In a competitive situation silage DM intake is related to dominance (Reynolds and Campling, 1981) and the coefficient of variation of intakes may be increased. In addition the rate of silage DM intake is generally increased (Reynolds and Campling, 1981).

2.1.2 The effect of restricted energy intake on milk production and liveweight change

Restricting the energy intake of dairy cows usually results in a decrease in milk yield and milk protein and lactose content (Dawson and Rook, 1972) provided the concentrate:forage ratio remains constant. Under these circumstances there is usually little change in the milk fat content (Fisher *et al*, 1975). If concentrate intake is reduced, however, milk fat content increases (Rook and Line, 1961; Astrup *et al*, 1980; Carstairs *et al*, 1981) unless the crude fibre content of the diet is limiting (Gordon and Forbes, 1971).

If the concentrate;forage ratio is increased at the same time as energy intake declines, as occurs when silage intake is restricted, milk fat content is usually decreased (Ekern, 1972; Mahanna, 1980). In addition, there may be some decline in milk yield and milk protein and lactose content.

Liveweight gain is generally reduced by lowering the energy intake (Gordon and Forbes, 1970). During moderate underfeeding most of the initial restriction of energy intake is partitioned towards a reduction in live weight until a basal level of body fat is reached (Neilson *et al*, 1983). After this milk production is adversely affected. Severe underfeeding or inanition produces an immediate drop in milk yield (Smith *et al*, 1938), possibly because there is a maximum rate of body tissue mobilization.

Cows in the initial stages of lactation usually utilize body reserves rapidly to compensate for reduced appetite and following this underfeeding may produce large reductions in milk production. The level of fat reserves is therefore crucial in determining the response of the dairy cow to a period of undernutrition. If energy intake is reduced by restricting silage intake the change in concentrate:forage ratio may cause extra energy to be partitioned to liveweight change at the expense of milk production, due to changes in the activity of the enzymes involved in lipid metabolism (Ekern and Vikmo, 1979).

It is unclear whether the efficiency of utilization of ME is increased during underfeeding (Van Soest, 1963). Although it is unlikely that the efficiency of utilization of ME for liveweight gain or milk production could vary (ARC, 1980) the maintenance requirement could conceivably be reduced due to a lower metabolic rate or a reduced micro-organism population of the rumen.

2.2 OFFERING CONSERVED FORAGE WITH SILAGE

2.2.1 Hay

The effects of offering hay as a supplement to grass silage on total DM intakes and milk production are shown in table 2.1. In these experiments different levels of hay DM intake were achieved by offering it in set proportions of milk yield or live weight. Other experiments in Norway (Breirem *et al*, 1959) have demonstrated little benefit in terms of milk yield of offering hay with AIV silage (low pH silage with acid additive).

Offering low quality hay with *ad libitum* silage has little effect on milk yield or composition (Nicholson and Parent, 1957; Retter and Castle, 1982 - experiment 1), although it may increase total DM intake. Medium and high quality hay will increase total DM intake and milk yield but may reduce milk fat content (Retter and Castle, 1982).

Chopping hay does not improve its nutritional value and may reduce intake compared with long hay (Castle *et al*, 1981). However, grinding hay will increase intake and the digestibility of the hay (Castle *et al*, 1981).

Table 2.1 Hay supplementation of grass silage offered *ad libitum*

		Intake (kg DM day^{-1})		Digestibility† (g kg^{-1} DM)		Total DM	Milk yield	Milk composition (g kg^{-1})	
		Silage	Hay	Silage	Hay	intake	(kg day^{-1})	Fat	Protein
Nicholson and Parent (1957)		8.8	-	Moderate	-	11.8	12.9‡	44.2	-
		7.6	1.5	"	Low	11.9	12.7‡	44.0	-
		6.6	2.9	"	"	12.6	12.7‡	44.1	-
		5.7	4.3	"	"	13.1	12.8‡	44.5	-
Keener *et al* (1958)		14.2	-	-	-	14.2	-	-	-
		12.5	1.6	-	-	14.1	-	-	-
Castle *et al* (1981)		7.2	1.8	698	597	14.1	18.5	38.4	33.4
		7.7	1.2*	"	594	14.0	18.6	38.4	33.0
		7.9	2.1**	"	619	15.1	19.6	39.5	33.3
Retter and Castle (1982)	(1)	10.5	-	598	-	12.8	17.7	35.2	26.3
		9.8	0.8	"	580	12.8	17.1	36.1	26.1
		9.0	1.6	"	"	13.0	18.1	35.5	26.5
	(2)	8.8	-	646	-	11.0	14.1	38.2	29.4
		7.5	1.8	"	653	11.4	15.3	34.7	29.2
		6.4	3.6	"	"	12.2	16.2	35.8	28.8
	(3)	11.8	-	683	-	12.7	15.0	39.0	33.0
		8.3	3.9	"	628	13.1	15.4	38.8	33.5
		8.2	4.1	"	700	13.1	15.8	37.1	33.4

† Digestible organic matter in the dry matter ‡ Fat-corrected milk yield * Chopped ** Ground

These results do not support the view that some hay is necessary for the correct functioning of the rumen (Helminen, 1979), but hay can be beneficial in increasing intake and milk production. In these experiments it is likely that DM intake was increased by the synergistic effect (Coppock *et al*, 1974) of increased intake when two feeds are offered compared with one. If silage is of poor quality or of low intake characteristic (eg low DM silage, Dodsworth and Campbell, 1953) it is likely that hay will be of more benefit. In addition, if silage conservation is insufficient and intake is restricted, hay could be useful as a buffer feed (Retter and Castle, 1982). A benefit of making both hay and silage is that the spread of harvesting is increased (Breirem *et al*, 1959), which will reduce peak labour requirements and distribute the risk of inclement weather affecting the harvest more evenly over the season.

The benefits of offering hay with maize silage as the basic forage have been adequately demonstrated (Logan *et al*, 1968; Waldern, 1972; Holter *et al*, 1973; Grieve *et al*, 1980) but are beyond the scope of this review.

2.2.2 Straw

The potential advantages of replacing silage with straw in the ration of dairy cows are mainly economic rather than nutritional. Inclusion of straw will increase annual stocking rates if straw is readily available as a byproduct of cereal production (MAFF, 1969d; 1982). Even if straw has to be purchased the cost per unit of ME is considerably less than that of silage or hay (Butler, 1981). However straw is of low digestibility, in particular cellulose digestibility is low due to the high lignin content of the cell walls (Frank, 1982).

Voluntary intake of straw is low, even when the crude fibre content of the diet is low, and especially in early lactation. This has led to cows going off their feed in early lactation when straw is the basic forage (MAFF, 1969d) and also a low fat milk syndrome at this time (Frank, 1982). These problems are increased by the large variation in the acceptability of straw to dairy cows (Frank, 1982). Incorporation of the straw into a complete diet mix will increase intake, as will milling and pelleting, but the latter will be of little use in overcoming low fat milk problems (Amir *et al*, 1970).

These nutritional problems demonstrate that it is unwise to compare feed costs MJ^{-1} ME. In general straw should only replace some of the silage or hay in the diet in mid to late lactation if it is less than one third of the cost of the basic forage (Frank, 1982).

2.2.3 Alkali-treated straw

Alkaline treatment of straw, usually with ammonia or sodium hydroxide, improves diet digestibility (and hence voluntary intake) by dissolving hemicellulose and lignin (Jackson, 1977). When calculated from *in vitro* digestibility the energy value of treated straw is overestimated (Wilkinson and Santillana, 1978), but it is possible to base complete diets for dairy cows on ammonia-treated straw as the only source of roughage and maintain high intakes and milk yields (Ørskov *et al*, 1983).

Mixing alkali-treated straw with silage at 25-30% of the DM will neutralize the acidity of the silage and increase DM intake relative to silage or treated straw alone (Terry *et al*, 1975; MAFF, 1982). However the lower feeding value of the treated straw reduces animal production on a mixed diet, compared with silage only (Wilkinson and Santillana, 1978; Terry, *et al*, 1975). Higher inclusion rates of treated straw with silage depress DM intake and production (Owen *et al*, 1980). As a supplement to silage better response has been obtained from straw treated with the Beckman process compared with sodium hydroxide or ammonia (Mason, 1981).

If silage is added to ammonia-treated straw as the basal forage the intake of treated straw declines by 0.8 kg DM kg^{-1} increase in silage DM (Ekern and Vikmo, 1979). As with straw, it is not advisable to feed alkali-treated straw in early lactation due to the restricted appetite at this time.

CHAPTER 3

EXPERIMENT 1 THE EFFECTS OF OFFERING HAY TO DAIRY COWS SET-STOCKED AT A HIGH AND A LOW RATE

3.1 INTRODUCTION

Traditionally grazing land has been understocked, which provides a residue of herbage that is able to buffer the effects of weather and husbandry on herbage availability (Greenhalgh, 1975) but also results in low levels of grassland utilization. In addition, as frequent harvesting is necessary to maintain high quality pastures, the planned use of understocking to buffer variation in herbage availability results in a low quality pasture. Grazed herbage is therefore unsuitable as a buffer as it deteriorates with time.

With the advocation of higher stocking rates for more efficient grassland utilization and increased output ha^{-1}, the need has developed for a storable buffer. Concentrate feed is readily available but is expensive and requires considerable skill in allocation on the part of the farmer as it tends to be eaten in preference to herbage. If concentrates are offered when not required, they will substitute for herbage and depress grassland utilization (Leaver *et al*, 1968).

The use of conserved forage as a buffer that will be eaten when required, but not in preference to pasture, should enable a high level of grassland utilization to be achieved without restricting intake (Greenhalgh, 1975). In addition, whereas the use of low stocking rates can to some extent buffer the effects of weather on herbage availability, it cannot counteract the adverse effects of weather on the animal itself. In inclement weather grazing animals lose "the will to feed" (Duckham, 1967), but offering conserved forage indoors could avert any depression in intake.

This experiment investigated the effects of stocking rate and offering hay as a buffer feed on the performance of set-stocked dairy cows.

3.2 MATERIAL AND METHODS

3.2.1 Design

Forty-eight British Friesian cows (marker cows) with a mean calving date of 19 February were allocated to 4 treatments in a 2 factor factorial experiment - H, high stocking rate; Hh, high stocking rate + hay; L, low stocking rate and Lh, low stocking rate + hay. Treatment groups were balanced for milk yield, live weight, condition score, number of days calved and previous experimental treatment (Appendix 3). The experiment ran for 24 weeks (divided into 3 eight week seasons) from 15 April to 30 September 1981.

Stocking rates were maintained as in table 3.1 using additional autumn and late-winter calving cows. These were allocated to the 4 treatment groups and were balanced in the same way as the 48 marker cows in order to equate DM intakes (Appendix 3).

Table 3.1 Stocking rates

Season	Date	Stocking rate High	Stocking rate Low
Early	15/4- 9/6	6.7	5.9
Mid	10/6- 4/8	4.3	3.7
Late	5/8-29/9	3.7	3.2
Mean		4.9	4.3

At the end of early and mid-season two of the extra cows were removed from each treatment, the balance of milk yield and liveweight in the remaining extra cows being maintained. Treatment effects were determined solely from the 48 marker cows that remained on the experiment throughout the 24 weeks.

3.2.2 Dairy cow management and measurements

Between calving and the start of the experiment cows were offered *ad libitum* self-feed silage and 9-15 kg concentrate day^{-1} in a separate experiment. Previous experimental treatment was taken into account during allocation to treatment groups.

During the experiment cows were milked from approximately 06.30 to 07.30 and 15.00 to 16.00 hours. After morning milking cows on treatments Hh and Lh were offered chopped hay in a feeding passage for approximately 45 minutes. Cows not receiving hay were given access to cubicles during this period and all cows were returned to grazing at approximately 08.30 hours. For a trial period when hay intakes were particularly high (10-24 June) hay was also offered after afternoon milking. This was discontinued after intakes declined to a low level.

Milk yield was measured on one day each week and separate aliquot milk samples taken at morning and evening milking for the analysis of fat, protein and lactose content using a Foss Electric Milkoscan 203 (Biggs, 1979). Live weight and condition score (assessed by the tailhead scoring system of NIRD, 1977) were measured weekly and liveweight change and condition score change determined for early, mid and late season by regression.

Six of the higher yielding marker cows on each treatment were used for the observation of grazing behaviour. Treatment means of these cows were balanced for initial milk yield, live weight and stage of lactation (Appendix 3). Cows were identified by numbers painted on each side in white gloss paint. At monthly intervals records of time spent grazing, standing, standing and ruminating, lying, lying and ruminating, walking and the number of drinks were made by a team of observers over a 24 hour period. For the purposes of these observations grazing was not necessarily an instantaneous assessment but was defined as "the ingestion of herbage within 15 seconds of initial observation". Observation was aided during the day by a pair of binoculars and during the night by the use of a 6 Volt torch. Cows were conditioned to the presence of an observer and torch on nights prior to the first observation. Records were made at 5 minute intervals during the day and 15 minute intervals at night .

Rate of biting at pasture was measured with the same cows on 20 days in late season. The measurements were taken during the first grazing period after morning milking ie between 08.45 and 09.45 hours approximately. The number of grazing bites (assessed by movement of the cow's head) taken in 90 seconds was recorded but if there was an interruption in the biting action of more than 15 seconds a new recording was initiated. The sequence for recording cows was determined daily by allocating the 24 cows to 6 blocks at random, followed by random allocation of the treatments within blocks.

On two occasions each week observations were made of the length of time each cow on treatments Hh and Lh spent ingesting hay. Observations of which cows were feeding were made every three minutes over the entire feeding period, and the results were related to the mean daily hay intake of each group to obtain individual hay DM intakes.

After the experiment all cows were housed throughout the day and were offered self-feed silage and 3 kg concentrate day^{-1}. A 3 week post-experimental period was used for the analysis of carryover effects. Cows were dried off when their milk yield fell below 5 kg day^{-1}.

3.2.3 Fields and feed management

Fields were bisected with electric fencing and the halves randomly allocated to high or low stocking rates. In early season cows grazed 6.1 ha of a perennial ryegrass (Lolium perenne) ley, variety Perma, during the day and 4.7 ha of a perennial ryegrass, and white clover (Trifolium repens) ley at night. Both fields were sown in 1977. In mid and late season 4.2 ha of silage aftermath (perennial ryegrass, variety Perma, sown in 1977) were introduced and a field rota was determined weekly to equate herbage height on the 3 fields. Mean fertilizer application over the entire area was 364 kg ha^{-1} nitrogen, 63 kg ha^{-1} phosphate and 56 kg ha^{-1} potash (Appendix 4).

Herbage height was measured weekly using a rising plate meter produced by the Milk Marketing Board (Baker, 1980). Approximately 10 measurements ha^{-1} were taken in a W pattern across each treatment area and it was also recorded when a measurement occurred in an area of herbage that had been rejected due to faecal contamination. An investigation was also performed which ascertained that herbage height measurement could not be improved by increasing the number of measurements ha^{-1} or by using the disc described by Castle (1976) (Appendix 5).

Hay offered in early and mid season was made in 1980 from a predominantly perennial ryegrass ley, variety Hora. Hay offered in late season was made in 1981 from a permanent pasture with a variety of herbage species. Hay was chopped using a forage harvester and chop length was determined once in early, mid and late season from an accumulated dried sample at the National Institute for Agricultural Engineering (Gale and Knight, 1979). As the distribution of chop length was not normal, mean chop length was determined from the regression of the % distribution by weight with the log of the chop length (Gale and Knight, 1979). Hay was offered in sufficient quantities to ensure that 10% of the original weight was available for weighing daily as a residue.

Concentrates were offered twice daily in the parlour. All cows received concentrates at the same level which varied weekly according to sward height and the milk yield of cows on the low stocking rate (Appendix 6). Essentially they were offered at a rate of 0.45 kg kg^{-1} milk produced over the yield level attributable to the herbage, which was determined by the herbage height and the season. Concentrates were offered at 4 kg day^{-1} in the first week of the experiment to ensure adequate magnesium intake. The concentrate cube contained, for the majority of the experiment, rolled barley with a mineral/vitamin supplement and molasses as a binding agent (ME 13.4 MJ kg^{-1} DM; CP 112 g kg^{-1} DM). During the last 4 weeks of the experiment the concentrate used was similar to that utilized in the winter feeding trials (Appendix 11) (ME 12.6 MJ kg^{-1} DM; CP 185 g kg^{-1} DM). All cows had access to water both in the field and during hay-feeding.

Herbage samples were collected once a week from each treatment area by hand-plucking (Cook, 1964). Hay samples were taken daily and were sub-sampled weekly for determination of chemical composition. An additional oven DM determination of fresh hay and hay refusals was performed weekly for the calculation of DM intake. Concentrates were sampled once a week for determination of chemical composition. *In vitro* digestibilities of the feeds were determined according to Alexander and McGowan (1961, 1966), and the equation used for the prediction of the ME content of the feeds is shown in Appendix 7.

Herbage DM intakes were calculated from individual animal performance in early, mid and late season using the following equation:

$$\text{Herbage DM intake (kg day}^{-1}\text{)} = \frac{\text{ME Maint.} + \text{ME Milk} + \text{ME Lwt.} - (\text{Conc ME} + \text{Hay ME})}{\text{Herbage ME concentration (MJ kg}^{-1}\text{ DM)}}$$

ME Maint, ME milk and ME Lwt are the ME requirements for maintenance, milk production (including adjustment for milk quality) and liveweight change respectively (from MAFF *et al*, 1975). Conc ME and hay ME represent the ME supplied by concentrates and hay (where applicable). Herbage DM intakes were also calculated by the same method for each treatment on a weekly basis to determine the seasonal change. In this case liveweight change for each week was estimated by a regression of liveweights over 2 weeks either side of each date.

Intake and requirement of rumen degradable protein (RDP) and undegradable protein (UDP) were calculated from ARC (1980).

Weather records were taken at a meteorological station approximately 1500 m from the grazing area.

3.2.4 Statistical analysis

Results were analysed by 2 factor factorial analysis with milk yield and milk composition results being adjusted by covariance analysis for differences in initial milk yield and composition (Steel and Torrie, 1960). One cow in treatment Hh developed recurring mastitis and missing plot values for milk yield and milk composition were calculated according to Steel and Torrie (1960).

Herbage height, chemical composition and the substitution rates of herbage for hay were analysed by 2 factor factorial analysis with treatments and periods as the 2 factors and weeks as replicates. Whilst it is recognized that weeks are not strictly replicates in this instance, their use as such enabled an indication of the significance of the differences to be obtained.

To examine the effects of level of milk yield on the response to hay feeding and stocking rate a third factor - high or low initial milk yield - was introduced into the analysis. For this purpose, the balanced group of 6 high yielding cows treatment^{-1} that were utilized for grazing observations were regarded as high yielders and the remaining 6 cows treatment^{-1} as low yielders.

3.3 RESULTS

3.3.1 Weather

Taken over the whole grazing season total rainfall (491 mm), sunshine hours (881) and mean maximum and minimum temperatures (16.1 and 8.4°C respectively) were normal (Appendix 8). However rainfall was particularly high at the end of the early and late seasons (figure 3.1).

3.3.2 Herbage height

Differences in herbage height between treatments were small (table 3.2) but this may have been affected by initial treatment differences (figure 3.2). As the season progressed herbage height declined and herbage intake may have been restricted during mid and late season. Differences in grazed herbage height (herbage height-rejected herbage measurements) were similar to herbage height although the standard errors of grazed herbage height were lower. In early season grazed herbage height was higher on the high stocking rate, again possibly due to initial treatment differences. In mid and late season grazed herbage height was higher on the low stocking rate and became progressively lower than herbage height (figure 3.2), thus reflecting the increased proportion of rejected herbage. Mean height of the rejected herbage was 10.9 cm.

Standard deviation of herbage height increased as the season progressed and tended to be higher on the low stocking rate. This must have been due to the rejected herbage since the standard deviation of grazed herbage height exhibited no treatment differences and actually declined as the season progressed.

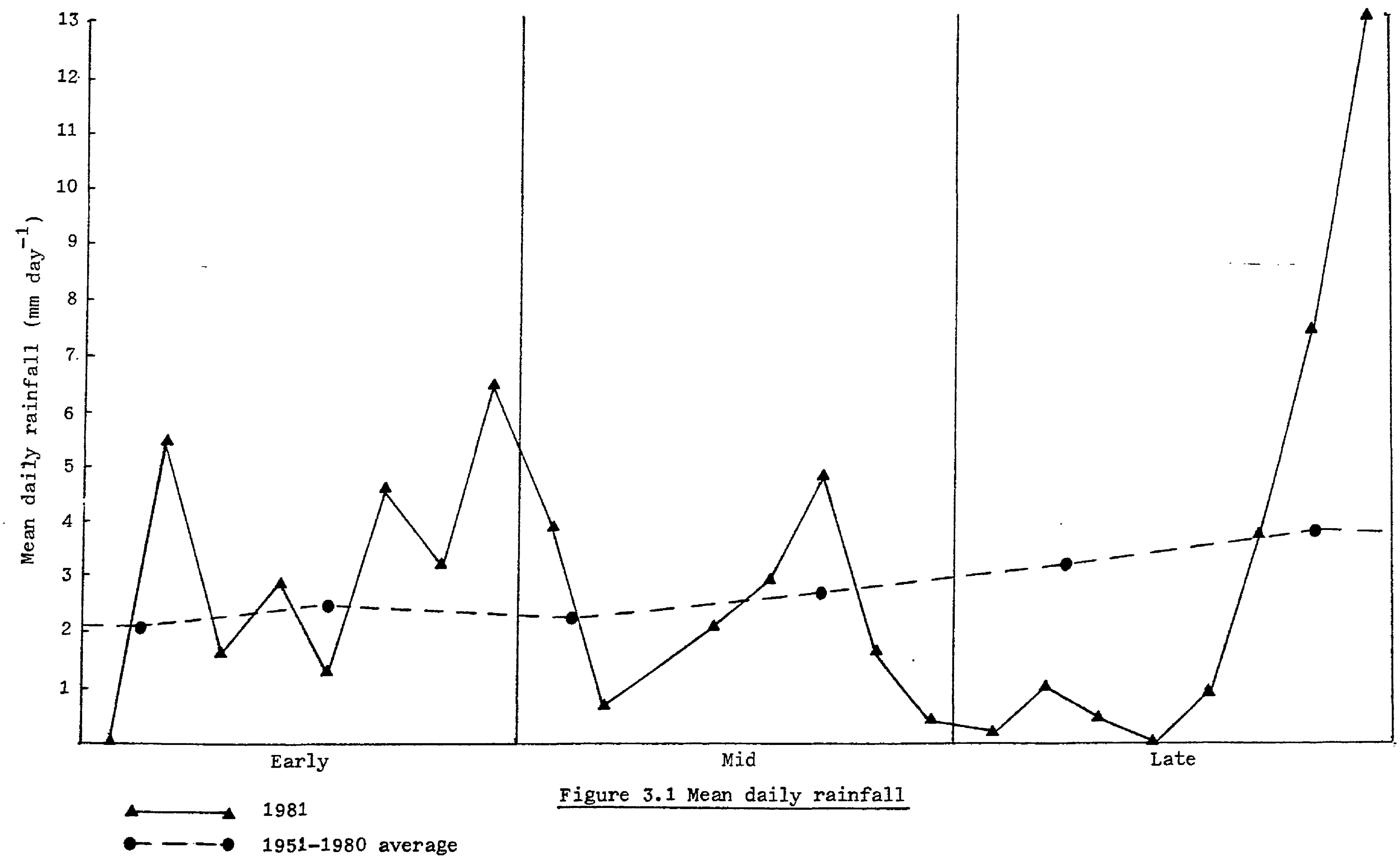


Figure 3.1 Mean daily rainfall

Table 3.2 Mean height and standard deviation of herbage and grazed herbage

Treatment	(1) Herbage height (cm)			(2) Standard deviation of herbage height			(3) Grazed herbage height (cm)			(4) Standard deviation of grazed herbage height			(5) Proportion of herbage rejected		
	H/Hh	L/Lh	SE	H/Hh	L/Lh	SE	H/Hh	L/Lh	SE	H/Hh	L/Lh	SE	H/Hh	L/lh	SE
Season															
Early	7.64	7.48	0.109 NS	2.06	2.12	0.106 NS	7.41	7.21	0.085 *	1.78	1.70	0.070 NS	4.6	4.6	1.21 NS
Mid	5.95	6.18	0.128 NS	2.05	2.22	0.081 NS	5.34	5.66	0.071 **	1.54	1.64	0.131 NS	11.0	12.7	1.05 NS
Late	5.51	5.80	0.122 NS	2.55	2.68	0.124 NS	4.41	4.58	0.106 NS	1.32	1.28	0.072 NS	20.5	22.5	2.10 NS
Mean	6.37	6.49	0.195 NS	2.22	2.33	0.105 NS	5.72	5.81	0.187 NS	1.55	1.54	0.081 NS	12.0	13.3	1.57 NS

Season	(1) Early	Mid	Late		(2) Early	Mid	Late		(3) Early	Mid	Late		(4) Early	Mid	Late		(5) Early	Mid	Late	
	7.56	6.06	5.66	0.239 ***	2.07	2.13	2.61	0.128 ***	7.31	5.50	4.49	0.229 ***	1.74	1.59	1.30	0.100 ***	4.5	11.8	21.5	1.92 **

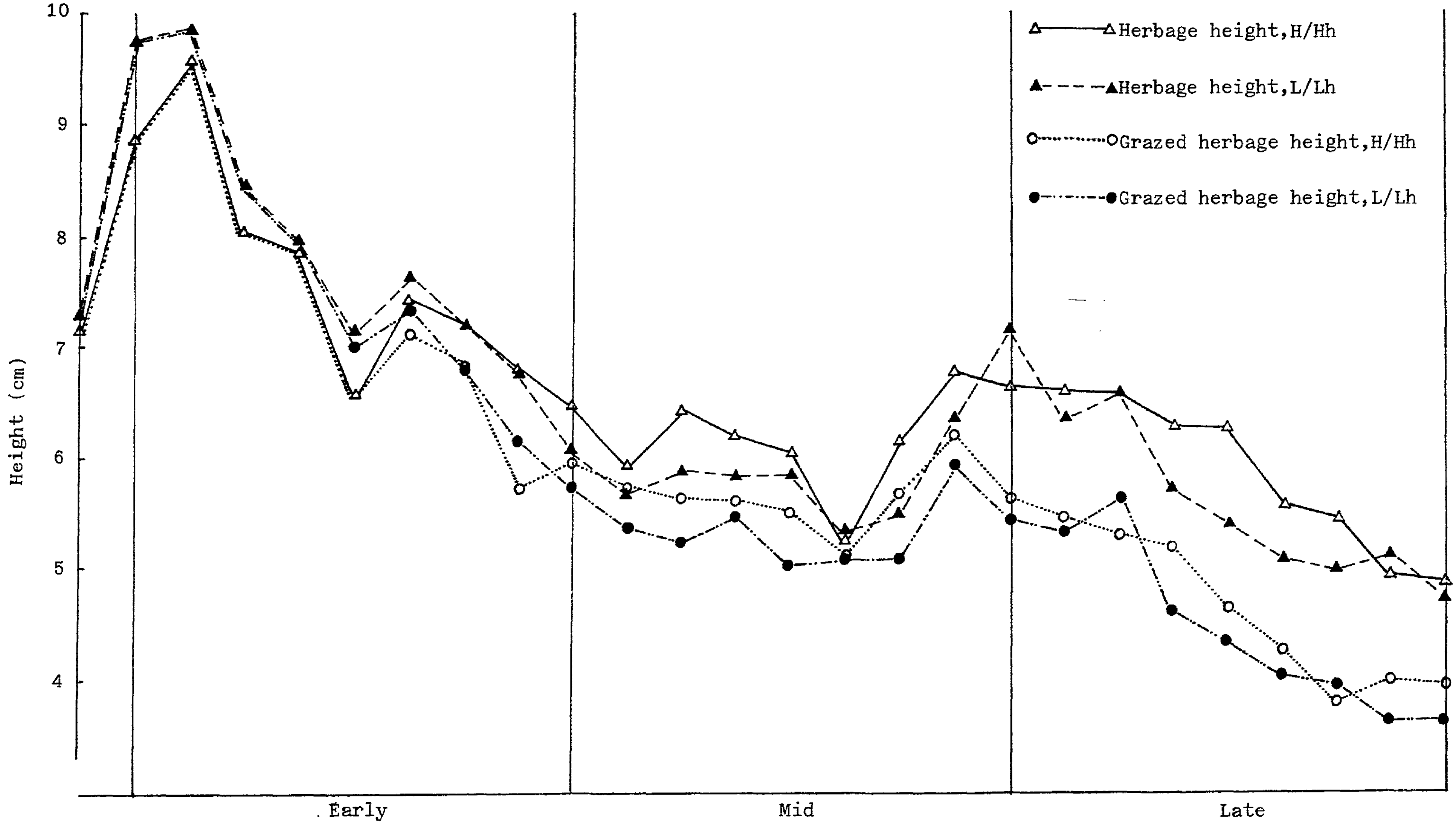


Figure 3.2 Herbage height and grazed herbage height

The proportion of herbage rejected increased linearly over the season and tended to be higher on the low stocking rate in mid and late season. Mean regression equation for the three fields over the grazing season was:

$$y = 0.98x \quad (r = 0.85^{***}) \qquad \text{equation 1}$$

where y = the proportion of herbage rejected (%)

x = week of the grazing season

In other words each week 1% of the area of each field was rejected due to faecal contamination and by the end of the grazing season approximately 25% of the total area had been rejected. Mean proportions of herbage rejected in mid and late season in the silage aftermath, the field used for day grazing in early season and the field used for night grazing in early season were 10, 15 and 26% respectively. The ratio of these three values (19:30:51) corresponds closely to the estimated ratio of faeces deposited ha^{-1} on each field (15:31:54) (calculated from the stocking rates and assuming 1.3 times as much faeces is deposited on the night pasture as on the day pasture (MaClusky, 1959)). There was therefore an accumulation of rejected herbage on the field used for night grazing in early season due to the greater proportion of faeces deposited on this field (plate 1).

3.3.3 Feed composition

Chemical composition of the feeds is shown in table 3.3. Herbage ME content declined in early and late season and was relatively constant in mid season (figure 3.3). There was no apparent difference between the two stocking rates. Herbage crude protein exhibited a series of peaks and troughs, most evident in the early part of the season.

NIGHT GRAZING FIELD

DAY GRAZING FIELD

PLATE 1

Fields used for night and day grazing after six weeks of the grazing season.

Table 3.3 Chemical composition of the feeds (g kg^{-1} DM unless otherwise stated)

Herbage	Treatment Effects H/Hh	L/Lh	SE		Seasonal Effects Early	Mid	Late	SE	
Dry matter (g kg^{-1})	165	166	4.45	NS	159	163	175	5.45	*
ME (MJ kg^{-1} DM)	11.2	11.1	0.177	NS	12.1	11.2	10.3	0.217	***
Organic matter	896	898	2.02	NS	902	894	895	2.47	**
Crude protein	227	226	6.33	NS	219	238	224	7.76	*
In vitro digestibility	667	664	7.52	NS	706	665	626	9.21	***
Calcium	4.88	4.90	0.110	NS	4.76	5.18	4.73	0.134	**
Phosphorus	4.43	4.43	0.088	NS	4.63	4.54	4.11	0.108	***
Magnesium	2.62	2.60	0.056	NS	2.38	2.82	2.64	0.069	***
Potassium	34.3	33.0	0.871	NS	32.8	34.4	33.9	1.07	NS

Season	Hay Early	Mid	Late	Mean	Concentrate
Dry matter (g kg^{-1})	824	835	839	832	867
ME (MJ kg^{-1} DM)	9.6	9.4	8.5	9.2	13.2
Organic matter	913	911	913	912	905
Crude protein	142	130	118	130	124
In vitro digestibility	596	590	550	579	747
Calcium	5.55	5.26	4.18	5.00	9.78
Phosphorus	3.59	3.34	3.50	3.48	5.90
Magnesium	2.38	2.25	1.81	2.15	4.04
Chop length (mm)	17.5	12.5	14.7	14.9	

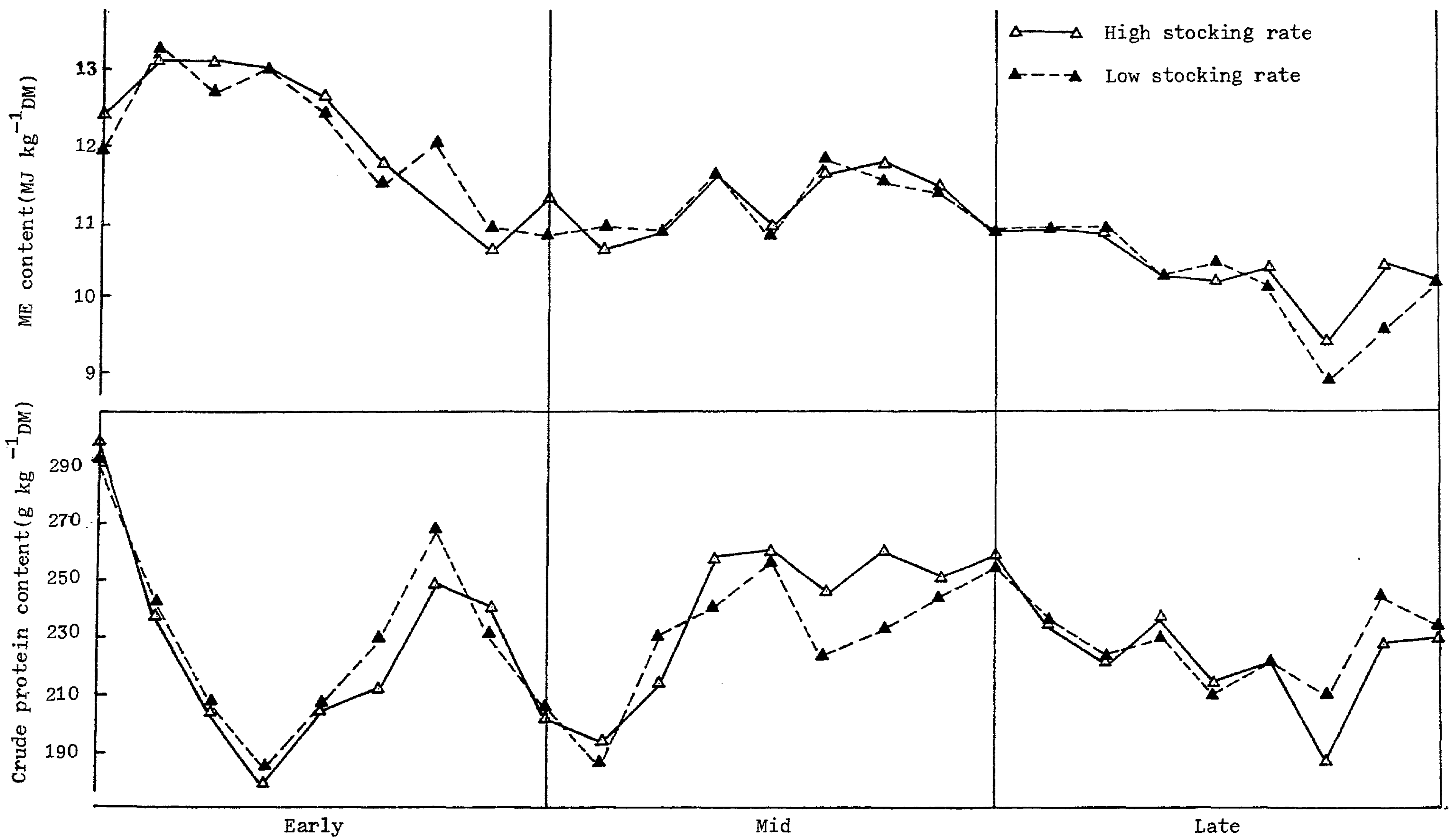


Figure 3.3 Herbage metabolizable energy and crude protein content

Rapid increases in crude protein content seemed to be associated with nitrogen application in periods of rapid growth. Slightly higher crude protein content was observed on the treatment with the lower herbage height - low stocking rate in early season and high stocking rate in mid and late season. Overall however there were no significant treatment effects on herbage composition.

Hay was of reasonable quality - 9.2 MJ kg^{-1} DM ME, 130 g kg^{-1} DM crude protein. The quality of the 1981 hay that was used in late season was lower than the 1980 hay used in early and mid season. Mean hay chop length was 14.9 mm.

3.3.4 Feed and nutrient intake

Intake of hay, concentrate and the derived herbage and total DM intake are shown in table 3.4. Herbage intake tended to be lower for cows fed hay, particularly in mid season and for cows on the high stocking rate in late season, although neither difference was quite significant. Herbage intake declined through the season (figure 3.4) with large depressions in herbage intake occurring during periods of high rainfall (compare figure 3.4 with figure 3.1). Herbage DM intake in each week was significantly correlated with the mean daily rainfall in each week ($P<0.01$):

$$y = 13.2 - 0.48x \qquad (r = -0.58x^{**}) \qquad \text{equation 2}$$

where x = rainfall (mm day^{-1})

y = herbage intake (kg DM day^{-1}).

The variation in herbage DM intake through the season (measured as coefficient of variation %) was lower for cows offered hay and stocked at the lower rate (table 3.5).

Table 3.4 Mean daily feed intakes (kg DM day^{-1})

	Season	H	Hh	L	Lh	SED	Significance Hay	Significance Stocking Rate	Period Effect Mean	Period Effect SED Significance
Herbage	Early	13.4	12.8	14.0	13.8	0.569	NS	NS	13.5)	
	Mid	12.2	10.9	12.2	11.5	0.519	NS	NS	11.7)	0.50***
	Late	9.1	8.7	10.0	10.1	0.623	NS	NS	9.5)	
	Mean	11.6	10.8	12.1	11.8	0.502	NS	NS		
Hay	Early		1.5		1.3	0.149		NS	1.4)	
	Mid		1.7		1.5	0.320		NS	1.6)	0.14 NS
	Late		1.8		1.6	0.334		NS	1.7)	
	Mean		1.7		1.5	0.249		NS		
Concentrate	Early	2.2	2.2	2.2	2.2					
	Mid	2.8	2.8	2.8	2.8					
	Late	3.5	3.5	3.5	3.5					
	Mean	2.8	2.8	2.8	2.8					
Total		15.6	16.6	16.2	17.2	0.559	NS	NS	16.4)	
		15.0	15.3	15.0	15.7	0.476	NS	NS	15.3)	0.49***
		12.6	13.9	13.5	15.3	0.597	*	NS	13.8)	
		14.4	15.3	14.9	16.1	0.473	*	NS		

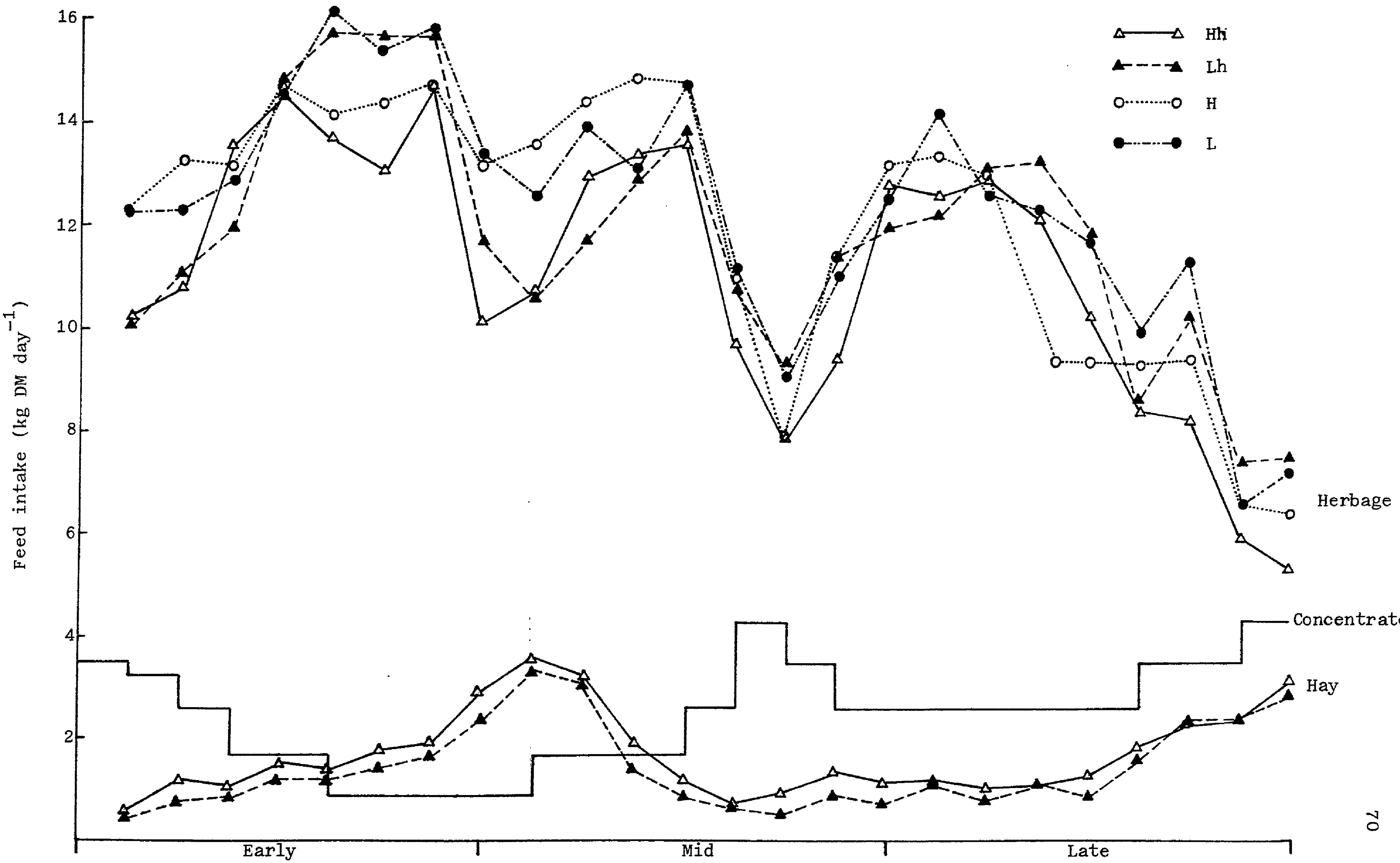


Figure 3.4 Seasonal variation in feed intake

Table 3.5 Coefficient of variation (%) of treatment means over 24 weeks

CV % of	H	Hh	L	Lh
Herbage DM intake	22.0	19.7	19.7	15.5
Hay DM intake	-	49.3	-	57.9
Total DM intake	13.8	11.8	11.9	9.3

Hay intake was slightly higher on the high stocking rate but this difference was not significant. Hay DM intake was also significantly related to rainfall ($P<0.001$):

$$y = 1.3 + 0.054x \qquad (r = 0.38^{***}) \qquad \text{equation 3}$$

where x = rainfall (mm day^{-1})

y = hay intake (kg DM day^{-1})

Maximum hay intake in 45 minutes was approximately 3 kg DM. Variation in hay intake was high over the grazing season and variation between cows was also high (coefficient of variation of 28.4% and 24.3% for Hh and Lh respectively).

Concentrate intake varied between 1 and 5 kg freshweight day^{-1} and tended to be higher in late season. The peak of concentrate allowance in mid season may have contributed, together with high rainfall, to the depression in herbage DM intake at this time.

Total DM intake was increased by offering hay and tended to be higher at the low stocking rate. Offering hay had the greatest effect on total DM intake in late season and the differences in stocking rate at this time also approached significance. Total DM intake declined over the grazing season and exhibited a similar pattern of seasonal variation to that in herbage DM intake (figure 3.5). Both offering hay and stocking at the lower rate decreased the

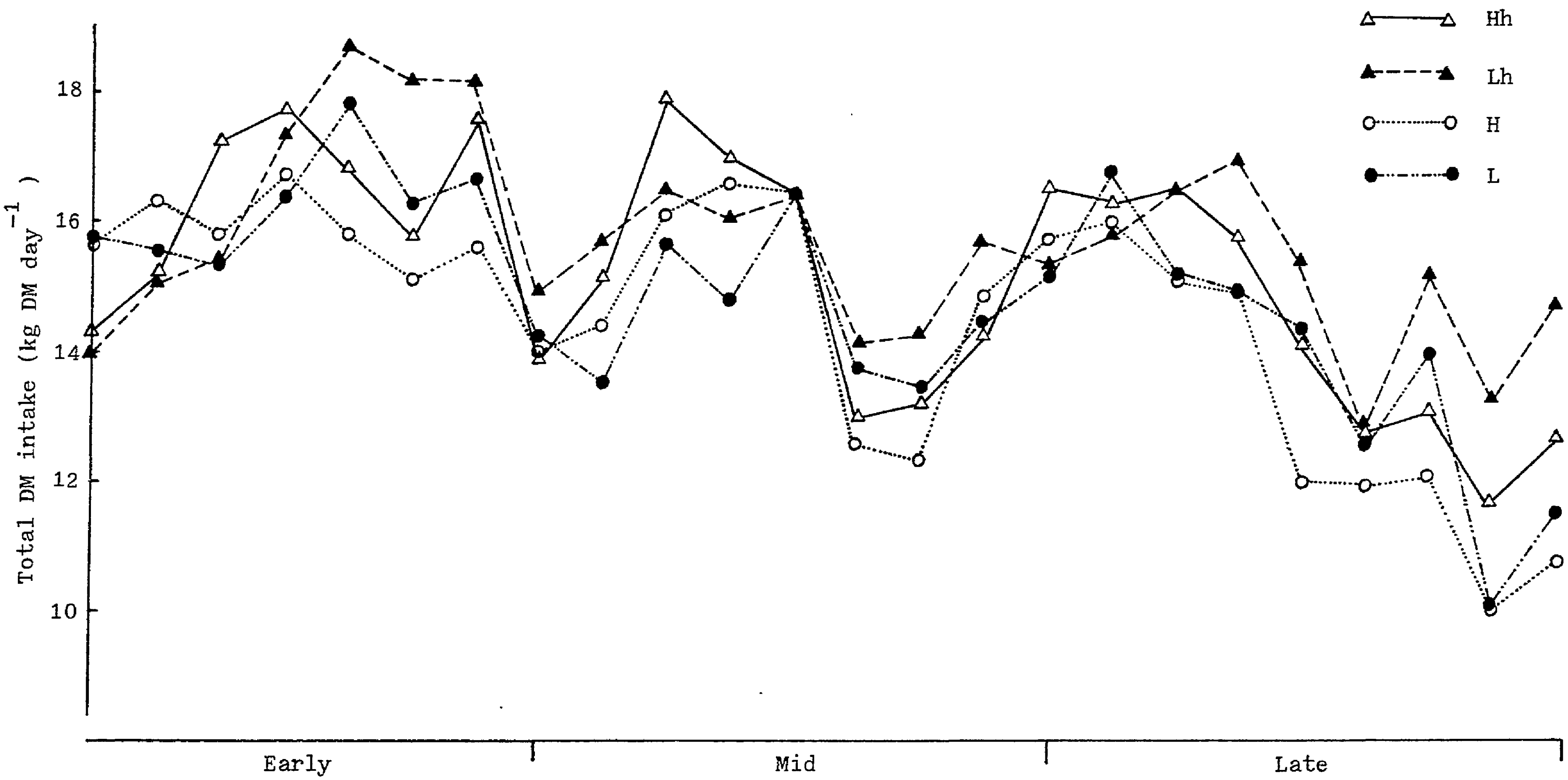


Figure 3.5 Seasonal variation in total DM intake

coefficient of variation over the 24 weeks.

Mean substitution rates (kg herbage DM kg^{-1} hay DM) for early, mid and late season were 0.30, 0.63 and 0.08 respectively and 0.47 and 0.20 for the high and low stocking rates respectively. Neither seasonal nor stocking rate differences were significant ($P>0.05$) when analysed using weeks as replicates. Overall for every kg of hay DM eaten herbage DM intake was reduced by 0.34 kg. Substitution rate tended to be lower when rainfall was high and herbage was in short supply.

Intakes of metabolizable energy were increased by offering hay (table 3.6) but this increase was proportionately less than the increase in total DM intake due to the lower ME content of hay than the herbage. Offering hay had the greatest effect on ME intake in late season. There was also a marked decline in ME intake between early and late season.

Utilized ME from herbage (UME - GJ ha^{-1}) was decreased by stocking at the lower rate and to a lesser extent by offering hay. Most of the difference between treatments occurred in early and mid season. Overall levels of UME were high and were equivalent to 8.6-9.7 tonnes herbage DM ha^{-1}.

The supply and output of rumen-degradable protein (RDP) and undegradable protein (UDP) are shown in table 3.6. Supply was calculated over the range of possible values for degradability as these have not yet been precisely defined (ARC, 1980). Even at

Table 3.6 Metabolizable energy intakes and rumen degradable and undegradable protein supply/output

Metabolizable Energy †

	Season	H	Hh	L	Lh	SED	Significance Hay	Significance Stocking rate	Period effect Mean	Period effect SED	Period effect Significance
Total ME intake ($MJ\ day^{-1}$)	Early	193	200	198	208	6.62	NS	NS	200		
	Mid	174	175	173	179	5.39	NS	NS	175	5.30	***
	Late	139	150	147	163	6.15	*	NS	150		
	Mean	169	175	173	183	5.29	NS	NS			
Utilized ME from herbage ($GJ\ ha^{-1}$)	Early	61	58	56	55				58		
	Mid	33	29	29	27				30		
	Late	20	19	18	19				19		
	Total	114	106	103	101				107		
Herbage yield ($t\ DM\ ha^{-1}$)		9.7	9.2	8.8	8.6						

Rumen Degradable (RDP) and Undegradable (UDP) Protein*

	H	Hh	L	Lh
RDP supply‡	1559-2155	1622-2225	1609-2224	1711-2352
RDP output	1315	1364	1350	1430
UDP supply‡	824-1419	797-1395	853-1469	853-1484
UDP output	445	461	472	506

	Early	Mid	Late
RDP supply‡	1822-2511	1786-2456	1524-2082
RDP output	1559	1367	1168
UDP supply‡	935-1624	891-1561	702-1259
UDP output	910	766	604

† MAFF *et al* (1975) * ARC (1980)

‡ Calculated for the range in degradabilities suggested by ARC (1980) - herbage 0.5-0.7, hay and concentrate 0.7-0.9

the extremes of rumen degradability, RDP and UDP supply exceeded the mean RDP and UDP output both for different treatments and at different stages in the season.

3.3.5 Behaviour

3.3.5.1 Hay feeding

There were no significant treatment differences in the time spent eating hay (table 3.7) and cows on average spent 63% of the allocated time eating the hay. Mean rate of hay intake was almost 50 g DM min^{-1} with no obvious treatment differences.

3.3.5.2 Grazing

Results of the six 24 hour grazing observations are shown in table 3.8. Further results and weather records on the observation days are shown in Appendices 9 and 10 respectively.

Grazing time tended to be depressed by offering hay and was slightly higher on the high stocking rate. It was highest in mid season and may have been depressed in late season by the high level of concentrates offered and adverse weather conditions. The relationship between grazing time and milk yield for the 24 observation cows approached significance in early and mid season (table 3.9) (grazing time was significantly related to milk yield on the second and fourth observation, $P<0.05$). As the season progressed the value of 1 hour of grazing declined from 1.9 kg milk in early season (equation 4) to 1.4 kg milk in late season (equation 6).

Table 3.7 Hay Feeding Behaviour

	Time (min day^{-1})				Rate of intake (g DM min^{-1})	
	Allowed	Spent eating				
		Hh	Lh	SED	Hh	Lh
Early	48	34.1	31.0	3.43 NS	45.7	40.3
Mid	56	35.0	26.0	6.12 NS	50.0	55.8
Late	48	32.1	32.3	6.42 NS	54.2	50.5
Mean	51	33.7	29.8	4.97 NS	50.0	48.9

Table 3.8 Grazing behaviour

		H	Hh	L	Lh	SED	Significance Hay		Significance Stocking rate	Period effect Mean	Period effect SED significance
Grazing time (hours day^{-1})	Early	8.6	8.1	8.0	8.3	0.29	NS		NS	8.6)	
	Mid	9.9	9.0	9.8	9.5	0.41	NS		NS	10.6)	0.29 ***
	Late	8.8	8.5	8.4	7.9	0.31	NS		NS	9.0)	
	Mean	9.1	8.5	8.7	8.6	0.27	NS		NS		
Ruminating time (hours day^{-1})	Early	6.2[b]	7.3[a]	6.5[ab]	6.5[b]	0.27	NS	* Inter-action	NS	6.6)	
	Mid	7.6	7.4	6.8	7.2	0.33	NS		NS	7.2)	0.27 NS
	Late	6.7	7.0	7.1	6.9	0.33	NS		NS	6.9)	
	Mean	6.8	7.2	6.8	6.9	0.22	NS		NS		
Biting rate (bites min^{-1})		67.2	62.3	65.9	65.7	1.87	NS		NS		
Bites day^{-1}		36,635	31,640	34,455	33,848	1473	NS		NS		
Derived bite size (g DM)		0.33	0.37	0.36	0.39	0.024	NS		NS		
Derived herbage intake rate (g DM min^{-1})		21.9	23.5	23.4	25.7	1.43	NS		NS		

Means with different superscripts are significantly different.

Table 3.9 The relationship between grazing time and milk yield

Season			
Early	$y = 11.1 + 1.87x$	$r = 0.35$ NS	equation 4
Mid	$y = 6.1 + 1.54x$	$r = 0.39$ NS	equation 5
Late	$y = 3.8 + 1.38x$	$r = 0.27$ NS	equation 6

where x = grazing time (hours day^{-1})

y = milk yield (kg day^{-1})

Ruminating time was significantly higher in treatment Hh than treatment H or Lh in early season and tended to be higher overall for cows offered hay. Mean ruminating time kg^{-1} herbage DM for treatments H and L (assuming a negligible contribution from concentrates) were 28, 35 and 43 minutes in early, mid and late season respectively.

The ratio of ruminating time to grazing time for those cows not receiving hay varied little over the grazing season, averaging 0.77, 0.73 and 0.80 in early, mid and late season respectively. The distribution of grazing and ruminating during the day in early, mid and late season is shown in figure 3.6. The reduction in daylight hours in late season resulted in a concentration of grazing time between 08.00 and 20.00 hours. Grazing was not however exclusively confined to daylight hours in any part of the season. On average over the whole grazing season 54% of grazing was between the afternoon and morning milking and 46% between the morning and afternoon milking. Ruminating tended to be concentrated in the hours of darkness but was also interspersed between the major grazing bouts in the daytime. As the season progressed more of the ruminating time occurred while the cows were lying down rather than standing (Appendix 9). Time spent walking at pasture was significantly higher on the high stocking

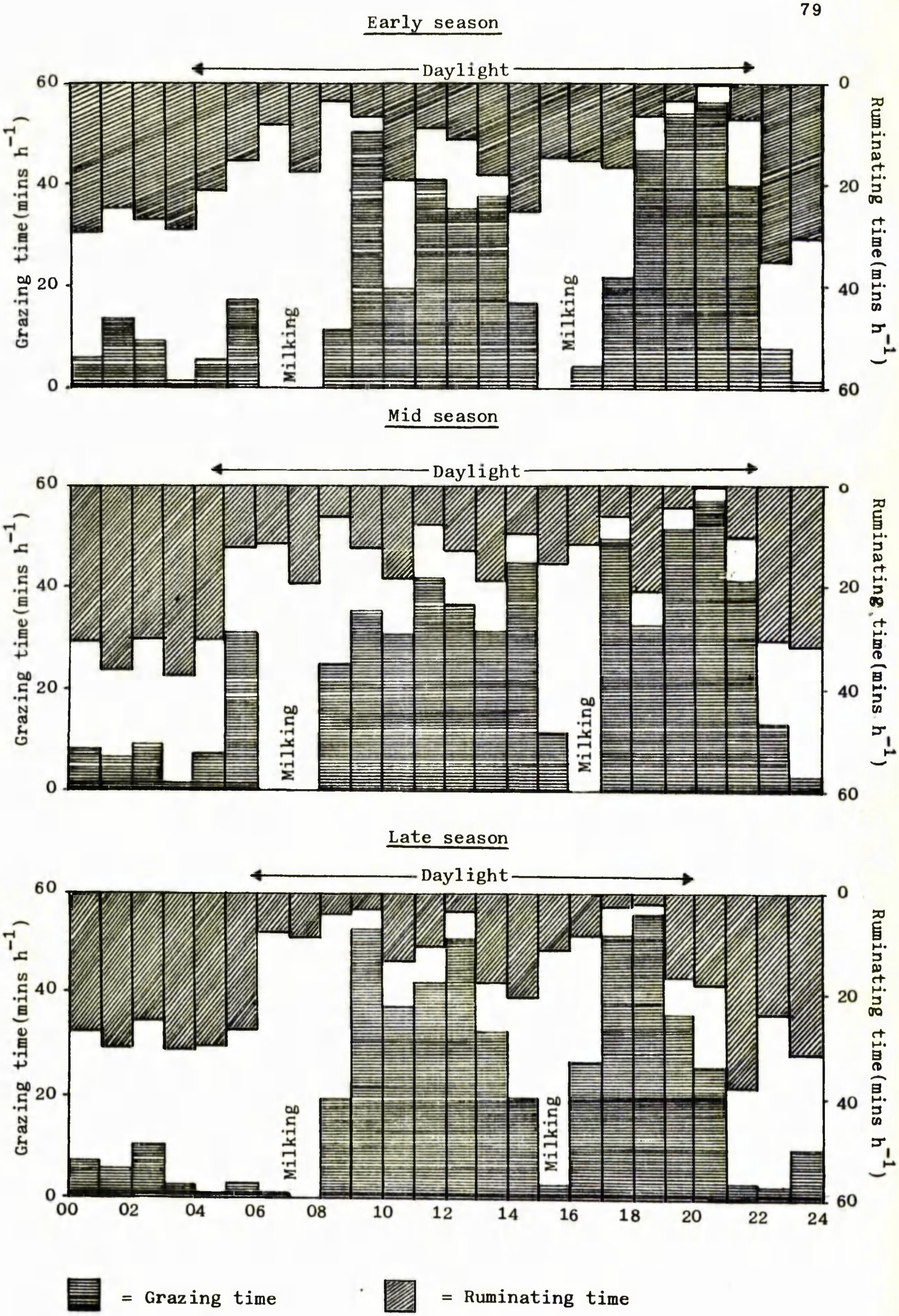


Figure 3.6 Distribution of grazing and ruminating time

rate, thus reflecting the greater search for herbage by these cows. The number of drinks was low but tended to be higher for those cows offered hay (1.5 drinks day^{-1} compared with 1.1 for those not receiving hay). The number of drinks was also greatly reduced when it rained during the observation period.

Biting rate tended to be reduced by offering hay on the high stocking rate but was not affected on the low stocking rate. Offering hay tended to depress the total number of bites day^{-1} especially on the high stocking rate. Bite size (herbage DM intake ÷ number of daily bites) and herbage intake rate (herbage DM intake ÷ grazing time) tended to be higher on the low stocking rate.

3.3.6 Milk yield and composition

Milk yield and milk composition results (adjusted by covariance) are shown in table 3.10. Covariance adjustment, based on initial milk yield and composition, had little effect on mean daily milk yield (adjustment ranged from 0.04 to 0.14 kg day^{-1}) but reduced the standard errors.

Milk yield was significantly increased by offering hay in early season and this difference approached significance in mid season. Overall milk yield was increased by 0.89 and 0.61 kg milk kg^{-1} hay DM on the high and low stocking rates respectively. Stocking rate had no effect on milk yield. Very little of the benefit of offering hay was continued into the post-experimental period and differences between treatments were not significant. Indeed 305 day milk yields reveal that there was a negligible carryover effect of offering hay since

Table 3.10 Milk yield and composition

		H	Hh	L	Lh	SED	Significance Hay	Significance Stocking rate	Period effect Mean	Period effect SED significance
Milk yield ($kg\ day^{-1}$)	E	24.2	25.6	24.4	25.6	0.65	*	NS	25.0)	
	M	19.2	21.1	19.9	20.5	0.72	NS	NS	20.2)	1.00 ***
	L	14.4	15.5	14.9	15.5	0.91	NS	NS	15.1)	
	Mean	19.3	20.8	19.7	20.6	0.69	NS	NS		
	Post-experimental	12.3	12.7	11.8	12.9	1.12	NS	NS		
	305 day (kg)	5368	5611	5333	5483	311	NS	NS		
	Milk yield ha^{-1} (kg)	16,649	17,872	14,936	15,587					
Fat content ($g\ kg^{-1}$)	E	37.5	36.9	36.7	37.2	0.94	NS	NS	37.1)	
	M	37.1	37.5	36.9	36.8	1.09	NS	NS	37.1)	0.93 ***
	L	39.7	41.5	40.0	40.0	1.28	NS	NS	40.3)	
	Mean	38.1	38.6	37.9	38.0	1.01	NS	NS		
	Post-experimental	41.7	44.2	42.5	40.7	1.42	NS	NS		
	Fat yield ($g\ day^{-1}$)	739	794	730	777	28.9	NS	NS		
Protein content ($g\ kg^{-1}$)	E	34.4	33.0	34.1	33.7	0.49	NS	NS	33.8)	
	M	34.8	34.0	34.9	35.0	0.58	NS	NS	34.7)	0.61 ***
	L	37.2	36.8	37.1	37.4	0.82	NS	NS	37.1)	
	Mean	35.5	34.6	35.4	35.4	0.60	NS	NS		
	Post-experimental	37.6	39.0	38.1	38.0	0.94	NS	NS		
	Protein yield ($g\ day^{-1}$)	678	717	692	724	26.9	NS	NS		
Lactose content ($g\ kg^{-1}$)	E	48.5	48.1	48.7	48.8	0.31	NS	NS	48.5)	
	M	46.7	46.5	47.1	47.7	0.41	NS	NS	47.0)	0.42 ***
	L	44.1	44.2	44.5	45.3	0.55	NS	NS	44.5)	
	Mean	46.5	46.3	46.8	47.3	0.40	NS	NS		
	Post-experimental	45.0	44.8	44.6	45.1	0.64	NS	NS		
	Lactose yield ($g\ day^{-1}$)	899	960	922	972	53.6	NS	NS		

the same response is obtained to the provision of hay over 305 days (0.89 and 0.61 kg milk kg^{-1} hay DM on the high and low stocking rates respectively). Milk yield declined at an average of 2.4% $week^{-1}$ with little difference between treatments (figure 3.7). There were particularly rapid declines in all treatments during inclement weather at the end of the early and late season, but hay feeding was not of greater benefit during these times. Milk output ha^{-1} was increased by stocking at the higher rate, particularly when hay was offered.

Milk fat content was not affected by hay feeding or stocking rate. Following turnout it declined by 5-8 g kg^{-1} over two weeks with no apparent treatment differences, followed by a recovery over the next two weeks (figure 3.8). Milk fat content was the most variable of the three major milk constituents and was significantly higher in late season than early or mid season. Fat yield tended to be increased for cows offered hay but this difference was not quite significant.

Milk protein content tended to be reduced in early season by feeding hay, especially with cows on the high stocking rate. It increased through the season but this trend was reversed in the post-experimental period when silage replaced herbage as the basal forage.

Milk lactose content was not affected by offering hay but tended to be increased in mid and late season by stocking at the lower rate. It declined in mid and late season but this trend was reversed in the post-experimental period.

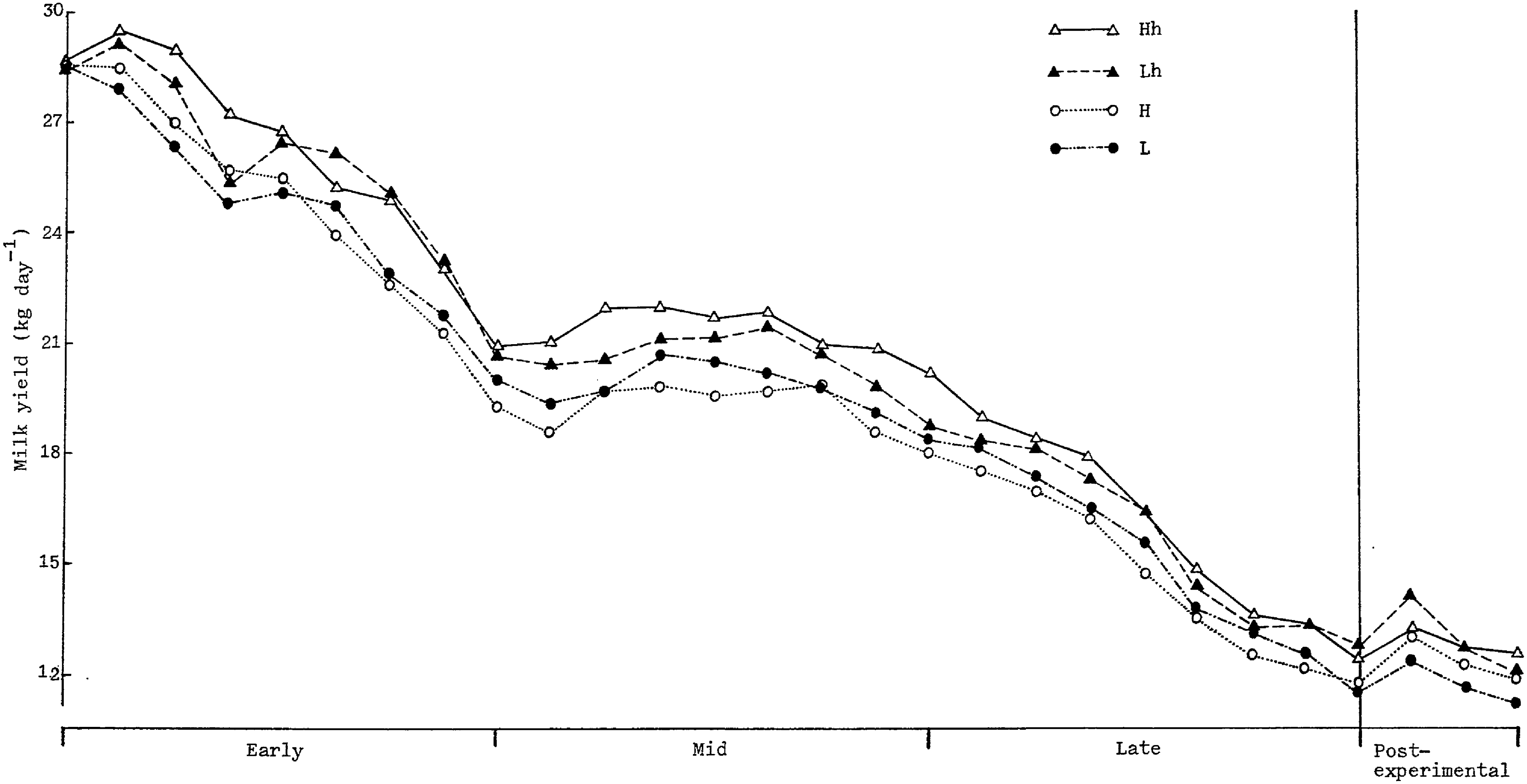


Figure 3.7 Seasonal variation in milk yield

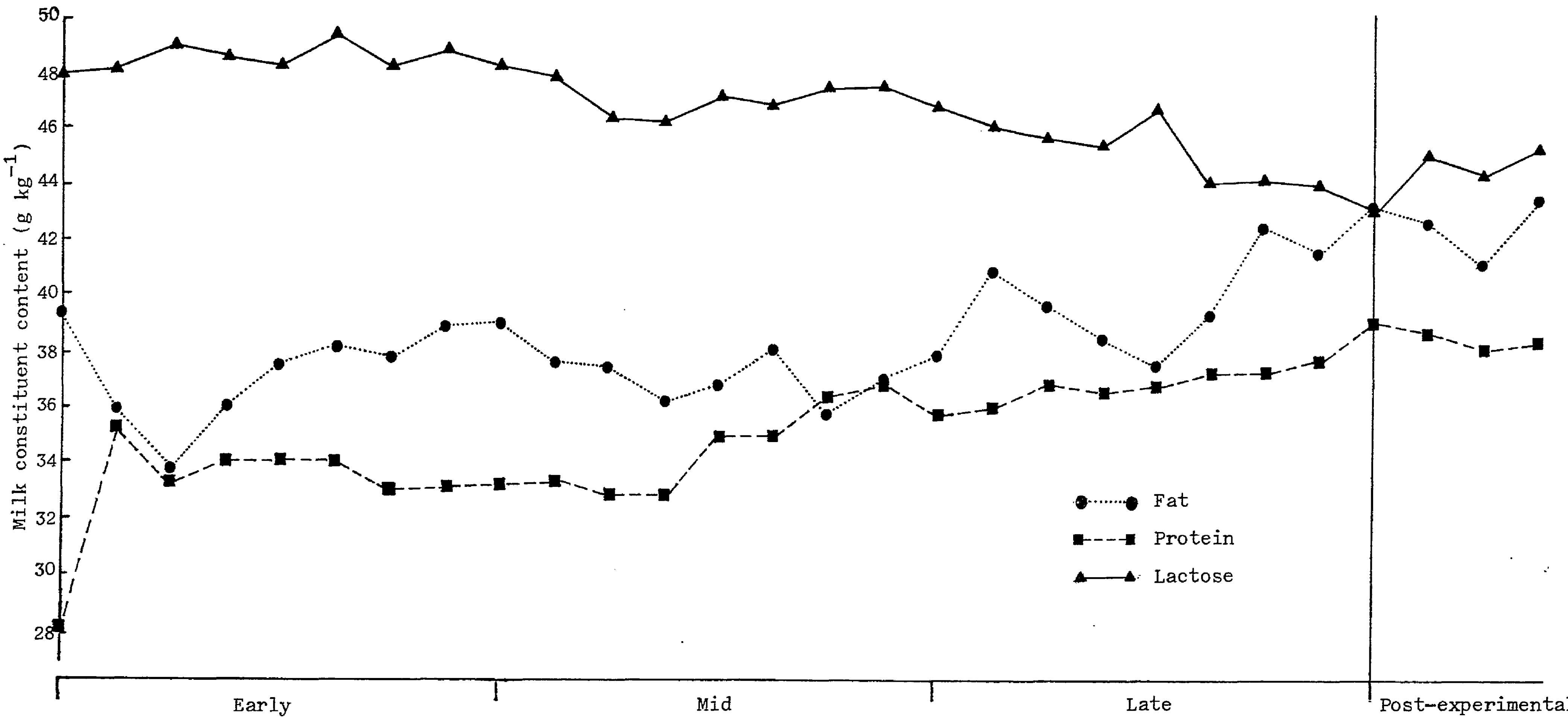


Figure 3.8 Milk fat,protein and lactose content

3.3.7 Liveweight gain and condition score gain

Liveweight gain was increased by stocking at the lower rate, particularly in late season (table 3.11). Offering hay also increased liveweight gain in late season and had some benefit in early season. Cows in treatment H had a disproportionately high liveweight gain in mid season, but this was not reflected in condition score change. There was no significant effect of season on liveweight change although cows tended to gain most weight in early and mid season. During the post-experimental period cows gained weight at a higher rate than in late season and treatment differences were maintained despite equalized feeding.

Condition score was increased by stocking at the lower rate in mid and late season and tended to be increased by offering hay in late season. Gain in condition score was significantly higher in late season than in early or mid season. Differences between treatments in liveweight change and condition score change were similar but differences between periods were not- liveweight change was highest in early and mid season whereas condition score change was highest in late season.

3.3.8 Yield level

The effect of yield level (on average 31 and 26 kg milk day^{-1} at the start of the experiment for the high and low yielders respectively) is shown in table 3.12. The response of high yielders in herbage intake to a supplement of hay was significantly different from that of low yielders - for low yielders herbage intake was depressed on average by 0.86 kg DM for every kg of hay DM eaten,

Table 3.11 Liveweight gain and condition score gain

		H	Hh	L	Lh	SED	Significance Hay	Significance Stocking rate	Period Effect Mean	Period Effect SED	Period Effect Significance
Liveweight change	E	+0.17	+0.23	+0.38	+0.44	0.122	NS	NS	0.31)		
(kg day^{-1})	M	+0.40	+0.13	+0.31	+0.35	0.083	NS	NS	0.30)	0.092	NS
	L	-0.02	+0.08	+0.13	+0.45	0.097	*	**	0.16)		
	Mean	+0.18	+0.15	+0.27	+0.42	0.066	NS	**			
	Post-experimental	+0.20	+0.33	+0.39	+0.63	0.114	NS	*			
Condition score change	E	+0.08	+0.06	+0.07	+0.12	0.099	NS	NS	0.08)		
(units)	M	-0.08	-0.10	+0.10	+0.16	0.086	NS	*	0.04)	0.076	***
	L	+0.22	+0.30	+0.33	+0.51	0.068	NS	*	0.34)		
	Total	+0.29	+0.23	+0.49	+0.80	0.168	NS	*			

Table 3.12 The effect of yield level on the response to hay feeding and stocking rate

	Hay				Stocking rate				Yield level		Interaction
	HY		LY		HY		HY				
	hay	no hay	hay	no hay	High	Low	High	Low	SED	Significance	
Herbage intake (kg DM day^{-1})	12.5	12.1	10.1	11.6	11.8	12.7	10.5	11.2	0.45	**	Hay x yield*
Hay intake (kg DM day^{-1})	1.40	-	1.74	-	1.37	1.41	1.96	1.51	0.16	*	NS
Total intake (kg DM day^{-1})	16.7	14.9	14.6	14.4	15.4	16.2	14.2	14.8	0.43	**	NS
ME intake (MJ day^{-1})	193	172	168	168	179	186	166	170	4.67	**	Hay x yield*
Initial milk yield (kg day^{-1})	30.9	30.9	26.1	25.9	30.0	30.9	26.2	25.8	1.13	***	NS
Milk yield (kg day^{-1})	22.9	20.8	18.5	18.1	21.7	22.0	18.5	18.1	1.01	**	NS
Fat content (g kg^{-1})	38.0	36.7	38.7	39.2	37.8	36.9	38.9	39.0	0.99	NS	NS
Protein content (g kg^{-1})	34.4	34.8	35.4	36.1	34.5	34.8	35.4	36.1	0.65	NS	NS
Lactose content (g kg^{-1})	46.6	46.8	46.8	46.6	46.1	47.3	46.4	47.0	0.45	NS	NS
Liveweight change (kg day^{-1})	0.29	0.11	0.27	0.35	0.11	0.29	0.23	0.39	0.06	NS	Hay x yield*
Condition score change (units)	0.40	0.27	0.63	0.52	0.32	0.35	0.22	0.93	0.16	NS	Stocking rate x yield*

HY = High yielders
LY = Low yielders

with high yielders herbage intake was increased by 0.29 kg DM kg^{-1} hay DM. High yielders had a higher herbage intake but a slightly lower hay intake than low yielders. High yielders responded significantly better to a supplement of hay in terms of ME intake, increasing their intake by 21 MJ day^{-1} compared with no increase for low yielders. Similarly, the milk yield of high yielders was increased by almost 2 kg day^{-1} by offering hay whereas there was no effect with low yielders. The difference in milk yield between high and low yielders declined as the season progressed.

High yielders tended to have a lower milk fat content than low yielders, especially where no hay was offered, and also a lower crude protein content, although neither of these differences was statistically significant.

Whereas high yielders increased liveweight gain and condition score gain when fed hay, low yielders did not. Low yielders, however, responded significantly better in condition score gain to a low stocking rate than high yielders. In addition, the overall level of liveweight gain and condition score gain was higher for low yielders than high yielders.

From these results it can be seen that, whereas hay feeding was of considerable benefit to high yielders and no benefit to low yielders, stocking at a lower rate was of similar benefit to both high and low yielders.

3.4 DISCUSSION

3.4.1 Results

3.4.1.1 Hay feeding

Offering hay increased the total DM intake of the high yielding cows throughout the season but the greatest benefit was obtained in late season. High yielding cows may be restricted at pasture by the time taken to harvest sufficient herbage (Leaver, 1981) and the total number of daily grazing bites rarely exceeds 36,000 (Stobbs, 1974; Hodgson, 1982). In early season grazing times were low and hay intake was also low, suggesting that cows were not limited by herbage availability at this time. In mid season grazing times were high (average 9.6 hours day^{-1}) and the cows were able to some extent to buffer the shortage of herbage by increasing grazing time. However, it is likely that the high yielding cows were still restricted in mid season since total daily number of grazing bites averaged 39,300 for those cows not receiving hay (assuming that the measured biting rate was representative of actual biting rate in mid season). In late season low grazed herbage height restricted the herbage intake of the high yielders still further and inclement weather prevented the cows from increasing grazing time. Thus total DM intake was increased in mid and late season by offering hay that was consumed at 50 g DM $minute^{-1}$ compared with herbage at only 24 g DM $minute^{-1}$. Balch (1971) reported that cows ate hay at 35 g DM $minute^{-1}$ but in this experiment it is likely that chopping the hay and offering it for a short time only increased the rate of intake (Campling and Morgan, 1981).

Le Du and Hutchinson (1982) proposed that herbage DM intake is depressed when the height of a continuously grazed sward falls below 6-8 cm as measured by a ruler, although this value will vary with the level of animal production and sward density. In addition, milk production will suffer if this restriction lasts for longer than 2 weeks. In this experiment grazed herbage height (measured by the MMB grassmeter) declined from 9.7 cm at the start to 3.8 cm at the end of the experiment which corresponds to 12.5 and 5.3 cm respectively on a graduated ruler (Baker, 1980). In addition Baker (1980) found no benefit in terms of milk production of herbage heights (graduated ruler) greater than 6.5 cm in early season.

The anomaly remains as to why milk yield and total DM intake of the high yielders was increased in early season by offering hay. Conceivably the low crude fibre content of the herbage at this time may have resulted in subclinical acidosis which depressed voluntary feed intake. Low herbage DM intakes are common in early season even when adequate herbage is available (Jamieson, 1975; Le Du *et al*, 1981). This does not appear to be due to metabolic intake regulation since ME intakes can be lower than later in the grazing season (Jamieson, 1975). Furthermore, it is unlikely that the DM content of the herbage limits intake at this time through a decreased rate of DM intake since grazing times are generally low in early season (Jamieson, 1975). It is likely therefore that feeding hay increased total DM intake by increasing the crude fibre intake. This response was only seen in high yielders due to their higher milk fat production and greater requirement, relative to total DM intake, for crude fibre to support this.

Castle *et al* (1960) and Walsh (1969) reported low DM intakes of hay after turnout (approximately 1 kg DM day^{-1}) but significant increases in milk fat content (14-24 g kg^{-1}). In this experiment there was no effect on milk fat content but milk yield of the high yielders was increased and milk protein content tended to be decreased. Effectively this had the same result that milk fat yield was increased and milk protein production stayed the same. The change in emphasis from an increase in milk fat content to an increase in milk yield may result from the higher yield level in this experiment (31 kg at turnout) compared with Castle *et al* and Walsh's experiments (13-19 kg) and the genetic trend in recent years towards cows that respond well in terms of milk yield.

Later in the season the benefit of feeding hay to high yielding cows was directed towards liveweight change rather than milk yield. This reflects the changing partition of energy from milk yield in early lactation to liveweight gain in late lactation.

It remains unclear why the low yielders ate more hay than the high yielders and yet derived no benefit from it. Conceivably high yielders are used to eating greater quantities of high energy feeds and may not exhibit the desire for high fibre feeds to the same extent as low yielders. In any event it would be wrong to attribute the synergistic effect (see glossary) exhibited here with herbage and hay by the high yielders to any "nutritional wisdom" on the part of the cow; more likely there was a palatability effect of offering hay which is high in crude fibre and DM content as a complement to herbage which is low in both. Sonneveld (1965) found that herbage

DM intake was directly proportional to the crude fibre content at low dry matter content.

It was surprising that hay was of no greater benefit during the prolonged periods of inclement weather at the end of early and late grazing season. During these periods the milk yield of all four treatments declined at a more rapid rate and the hay intake on treatments Hh and Lh increased. Given that the dairy cow is reluctant to graze in inclement weather, the provision of hay would be expected to act as a supplement to, rather than a substitute for, herbage. Evidently to truly buffer depressions in herbage DM intake during inclement weather much greater quantities of forage must be offered. This is exemplified by the arrest in milk yield decline at the end of the experiment when herbage intakes had declined to approximately 7 kg DM day^{-1} in a period of particularly high rainfall and milk yields declined rapidly despite the provision of up to 5 kg concentrates day^{-1}. Following housing, and the provision of *ad libitum* silage and 2-3 kg concentrates day^{-1} milk yield and milk lactose content increased. Low milk lactose content in autumn has been reported by Waite *et al* (1956) and Le Du *et al* (1981) and probably arises from both under-feeding and the late stage of lactation (Rook, 1961).

After housing, the normal increase in milk protein content in mid-late lactation was reversed, which reflects the low crude protein content of silage compared to late season herbage. Despite increasing the energy status, offering hay also tended to slightly depress milk protein content. This also may have been an effect on the non-protein nitrogen content of the milk (Thomas, 1980) since offering hay, which had approximately half the crude protein content of the herbage, reduced the ratio of crude protein to energy in the diet.

Offering hay depressed the grazing time of the high yielders by 21 minutes on average (15 minutes kg^{-1} hay DM). Seath and Miller (1947) found that offering hay at pasture depressed grazing time by 40 minutes (16 minutes kg^{-1} hay freshweight). In this experiment hay increased ruminating time by 9 minutes kg hay DM^{-1} which is considerably less than the 65 minutes kg^{-1} hay DM reported by Campling (1966) for a hay based diet. Although chopping the hay may have reduced the required ruminating time, and there was a small substitution effect of herbage for hay, it is unclear why offering hay did not increase ruminating time to a greater extent .

3.4.1.2 Stocking rate

The absence of any effect of stocking rate on milk yield, fat or protein content can be largely attributed to the high herbage availability in early season and also the small differences in herbage height between the two stocking rates in early and mid season. The latter may have been partly due to initial treatment differences - Baker (1980) found that similar stocking rates in early season produced a sward 1 cm higher on the low stocking rate.

In late season when herbage height was on average 0.3 cm higher on the low stocking rate cows responded by increasing liveweight and condition score gain rather than milk yield because they were in late lactation (King *et al*, 1977). Cows stocked at a higher rate were therefore able to use liveweight as a buffer to variation in herbage intake and milk yield was therefore maintained. The increase in milk lactose content with cows stocked at a lower rate has also been reported by Gordon (1973) and Le Du *et al* (1979, 1981) and was not accompanied by any increase in milk protein content.

Whereas the effects of hay-feeding on milk yield disappeared in the post-experimental period, treatment effects on liveweight gain were maintained into the post-experimental period. In contrast to the effects of hay feeding the benefit of stocking at a lower rate was as great, if not greater, with low yielders as high yielders. This may be because low yielders tend to respond more in liveweight change than milk yield.

Milk output ha^{-1} was increased by 15% by stocking at the higher rate when hay was provided as a buffer feed but only 11% with no hay. In a review by Journet and Demarquilly (1979) milk output ha^{-1} was increased by 20% for an increase in stocking rate of 1 cow ha^{-1} (ie 12% increase for a 0.6 cows ha^{-1} increase in this experiment). Thus offering hay can increase the benefit of a high stocking rate.

Increases in UME ha^{-1} from stocking at the higher rate were 4, 3 and 1 GJ in early, mid and late season respectively. Baker (1980) obtained the same total increase in UME as in this experiment with a similar difference in stocking rate except that it was only applied in early season. Since the only detrimental effect of stocking at the higher rate in this experiment was the low liveweight gain in late season it would appear that stocking rates in early season could be increased and in late season decreased with advantages. Liveweight gain in late lactation in the late grazing season will be more efficient than in the dry period (Moe *et al*, 1971) and cheaper if the energy is provided from herbage rather than silage.

3.4.2 Experimental techniques

3.4.2.1 Herbage intake

The technique employed for the measurement of herbage intake from animal production data is dependant upon the adequacy of energy standards and the accurate measurement of animal output (Baker, 1982). Close agreement between ME input and output of individually-fed cows on a winter-feeding regime (section 6.3.4) promotes confidence in the use of the ME system (MAFF *et al*, 1975) to predict energy requirements. No allowance has been added for the additional maintenance requirement of grazing because estimates of this vary with pasture type and distance walked, and it is probable that any extra ME required would be the same for all treatments. Grazing dairy cattle also spend more time lying compared with housed cattle (section 4.3.5) which will slightly reduce the overall maintenance requirement (Clark *et al*, 1972; ARC, 1980).

A further possible source of error is the estimation of liveweight change being confounded by variation in gut contents. In an extreme situation an abrupt change in diet from winter feeding to grazing can cause a reduction in live weight of 30 kg in the first 3 days after turnout (Balch and Line, 1957). However, no reduction in liveweight after turnout was experienced in this experiment, possibly because of the relatively high level of concentrates offered before turnout (figure 3.9). In addition there was little effect on the liveweight of the cows when they were housed at the end of the experiment (figure 3.9). There was a large weekly variation in the liveweight of the grazing cows, probably due to the effect of seasonal and environmental changes (eg inclement weather, relative herbage height on different fields) on the periodicity of grazing during the day (Taylor, 1954). Close inspection of liveweights revealed that weekly variation did not contribute to the large depressions in herbage DM intake that occurred during inclement weather.

An anomaly exists between the liveweight change (which was highest in early and mid season) and condition score change (which was highest in late season). This effect has also been observed by Leaver (1982) and may represent the reparation of internal lipid deposits in early and mid grazing season followed by subcutaneous lipid deposits in late grazing season. In addition the level of gut contents may have increased over the grazing season as herbage digestibility declined. Over the entire grazing season treatment differences were similar for liveweight change and condition change and represent an average of 79 kg liveweight gain $unitary^{-1}$ increase in condition score.

Further errors may have occurred from the estimation of ME content of the herbage since this was obtained from samples plucked from grazed areas rather than the herbage ingested by the cow. Although several studies have shown that the digestibility of herbage selected by the cow is up to 100 g kg^{-1} higher than that of the whole sward

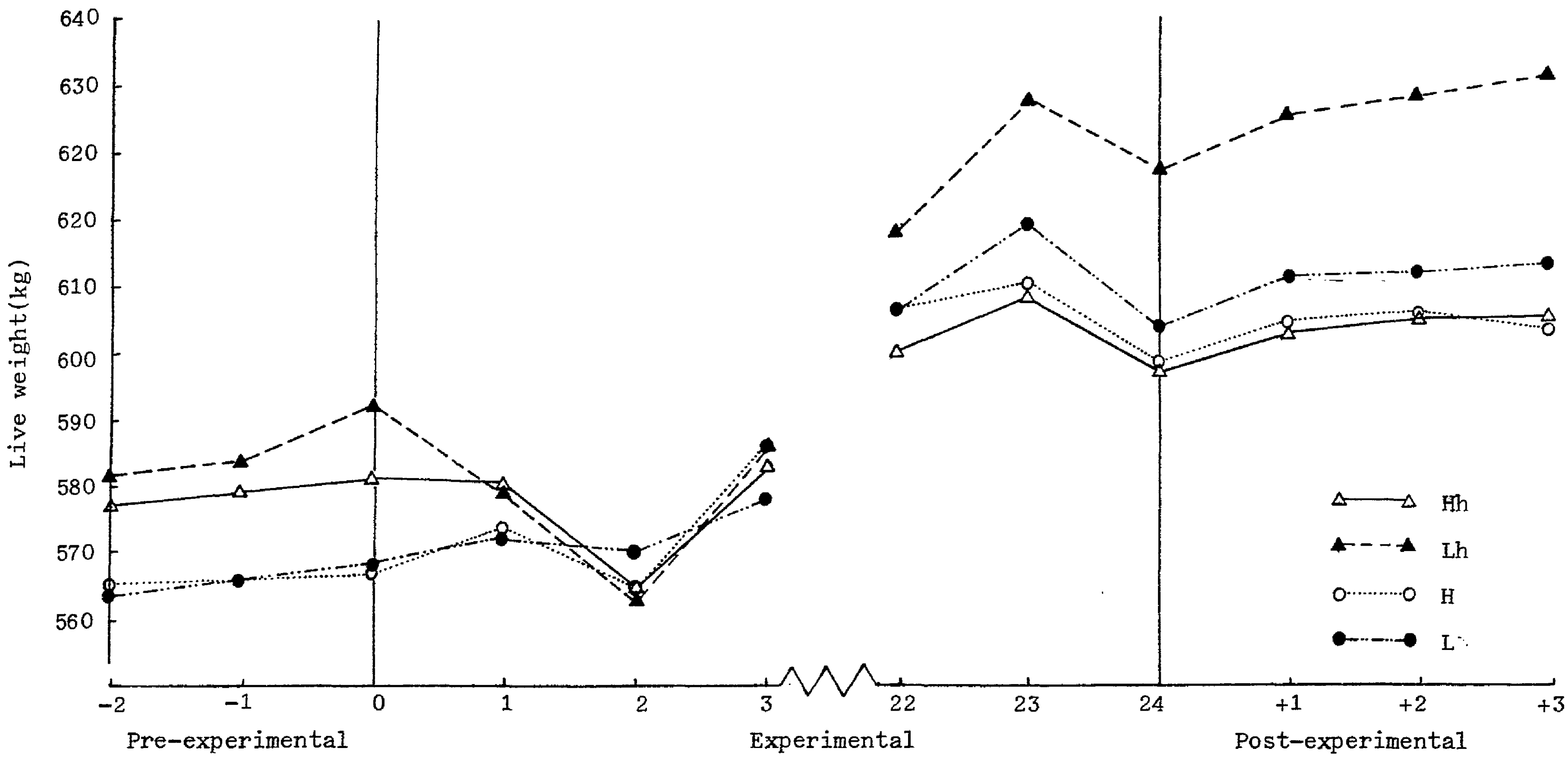


Figure 3.9 The effect of turnout and housing on live weight

(see 1.1.2) the hand-plucked samples vary little with that selected by the cow (Zoby and Holmes, 1983).

In conclusion there may be errors involved in estimating herbage DM intakes by this method, but these are unlikely to be greater than errors incurred by other techniques and are systematic errors that occur to a similar degree on all treatments.

3.4.2.2 Grazing behaviour

Observation of grazing behaviour was limited by the number of cows that can be observed at night by one person. It was not possible to record all the marker cows (48) at night within the recommended maximum time interval of 15 minutes (Hull *et al*, 1960; Hodgson, 1982) and it was therefore decided to record the higher yielding cows on the basis that these were more likely to exhibit treatment differences. In retrospect the effect of hay feeding on grazing time is likely to have been greater for the lower yielding cows due to the greater depression in herbage intake when these cows were offered hay. It may have been more appropriate therefore to select a representative sample of cows from each treatment for the behaviour studies.

The possibility also exists that the grazing time of cows offered hay was artificially increased because they were grazed with cows that did not receive hay (social facilitation; Bailey *et al*, 1974; Tribe, 1950). However it is unlikely that social facilitation occurred to any great extent since the herbage intake of high and low yielders was not affected equally.

It has been shown that biting rate is more accurately measured by recording the number of bites in two minutes rather than the time taken for 20 bites (Jamieson, 1975) due to the interruptions that normally occur as the animal grazes. In this experiment, to enable all the recordings to be taken in the same grazing bout, measurements were taken of the number of bites in 90 seconds, with no interruption of more than 15 seconds. There was no clear evidence of variation in biting rate within the first grazing bout although it tended to be lower at the beginning and end of the bout. Hancock (1952) also found low biting rates at the end of grazing bouts.

Between-cow variation of the ingestive behaviour measurements (expressed as the coefficient of variation, %) was within the range quoted by Jamieson (1975) (table 3.13).

Table 3.13 Coefficient of variation (CV%) between cows and the range of CV% quoted by Jamieson (1975)

Variable	CV%	Range of CV% Jamieson (1975)
Grazing time	7.6	5-7
Biting rate	4.7	4-12
Total daily bites	10.6	6-12
Bite size	15.9†	7-30‡
Rate of intake	14.8†	7-18†

† Predicted from herbage intake and ingestive behaviour measurements

‡ Measured with oesophageally-fistulated animals

Both in this experiment and the study of Jamieson (1975) bite size was the most variable component with relatively little variation in grazing time and biting rate.

Some error in estimating individual hay DM intakes may arise from variation in rate of eating both between cows and within the hay feeding period. Variation in rate of biting hay is low and there is little change in biting rate over the length of a meal (Campling and Morgan, 1981). As with grazing behaviour the greatest variation is likely to occur in bite size.

3.4.2.3 Herbage height measurement

The importance of accurate herbage height measurement is emphasized by the relatively large effect on liveweight change of small differences in herbage height in late season. This suggests the existence of a grazed horizon in the upper layers of the sward. It has been demonstrated with sheep that such a horizon exists and is confined to the layer which contains only green leaf material ie above the layer containing sheath and dead leaf (Barthram, 1981).

The accuracy of herbage height measurement in this experiment was examined by increasing the number of measurements ha^{-1} and by using a meter with a lighter plate that would be less likely to depress the herbage (Baker, 1980). No improvement could be found with either modification. However improvement was obtained by measuring the rejected herbage and from this it was possible to determine the height of the herbage that was actually grazed by the cows and to reduce the standard deviation of herbage height measurements. As the proportion and the height of the rejected herbage increased through the season,the decline in herbage availability in mid to late season would not have been apparent if herbage height alone had been measured.

3.5 SUMMARY

For three 8 week periods of the grazing season 48 spring-calving cows were set-stocked at a high and a low rate, which declined through the season (average 4.9 and 4.3 cows ha^{-1} respectively). Within each stocking rate group half the cows were allowed access to hay for 45 minutes daily after morning milking, the other half received no hay.

Hay intakes tended to be increased by stocking at the higher rate and during prolonged periods of inclement weather. Offering hay reduced the variation in total DM intake and increased total DM intake overall. However, there were times when, because of inclement weather and low herbage height, herbage DM intake declined to very low levels and offering hay was unable to prevent a decline in total DM intake.

Grazing time tended to be reduced, and ruminating time increased by offering hay. Rate of biting at pasture was not affected.

Offering hay increased milk yield in the early grazing season and liveweight gain in late grazing season. There were no significant effects on milk composition. High yielding cows benefitted considerably more from hay feeding than low yielding cows.

Stocking rate had only small effects on herbage height. Stocking at the higher rate reduced liveweight gain in late grazing season and tended to reduce herbage DM intake.

Overall levels of Utilized Metabolizable Energy from herbage were high but were reduced by feeding hay and stocking at the lower rate.

CHAPTER 4

EXPERIMENT 2 THE EFFECT OF OFFERING SILAGE TO SET-STOCKED DAIRY COWS IN THE EARLY PART OF THE GRAZING SEASON

4.1 INTRODUCTION

Previous results (experiment 1) demonstrated that the provision of a buffer feed in the grazing season can reduce the variation in herbage DM intake and increase milk production of dairy cows. However at certain times eg inclement weather, herbage DM intake declined to a very low level and offering additional forage for 45 minutes was insufficient to compensate for this. Offering forage overnight could increase total DM intakes in such circumstances even though this will in itself restrict herbage DM intake (Vík , 1956).

Silage is more suitable for feeding overnight than hay, firstly because it is made in larger quantities, particularly in high output dairy farms (Murdoch, 1980); secondly because it is of higher quality and is therefore less likely to depress animal production when fed in large quantities; thirdly because it is more easily handled for feeding in large quantities.

It was not known whether silage would be preferred to grazed herbage due to its ease of prehension and the restriction on grazing time by housing the cows overnight. In addition due to the higher cost of conserved forage compared with grazed herbage it is undesirable to feed more silage than is necessary to act as a buffer feed. An alternative to offering silage *ad libitum* overnight was to offer a fixed level of silage which could act as a buffer feed but would prevent excessive silage consumption.

This experiment examined the effects on dairy cow production and behaviour of offering silage for 45 minutes after morning milking, at a restricted level overnight or *ad libitum* overnight with adequate herbage available at all other times. These three treatments which included a buffer feed were compared with a grazing only treatment with no buffer feed.

4.2 MATERIAL AND METHODS

4.2.1 Design

Thirty-two British Friesian cows were allocated to four treatment groups in a balanced changeover (Latin Square) design (appendix 12) with four treatments: G - grazing only; GMS - grazing + *ad libitum* silage for 45 minutes after morning milking; GRS - grazing + restricted silage overnight; GAS - grazing + *ad libitum* silage overnight.

The cows comprised 12 autumn-calving cows, 4 autumn-calving heifers, 4 spring-calving cows and 12 spring-calving heifers. These were allocated to 8 blocks of the Latin Square design so that the cows within each block were as similar as possible in terms of milk yield and live weight (appendix 13). Within blocks cows were allocated to the four treatments at random.

The experiment ran for 12 weeks (four 3-week periods) from 22 April to 14 July 1982.

4.2.2 Dairy cow management and measurements

Between calving and the start of the experiment cows were offered *ad libitum* self-feed silage and 9 kg concentrates day^{-1}.

During the experiment cows were milked at 07.15 and 16.10 h. Cows in treatments GRS and GAS were at pasture on average for 7 hours 10 minutes and received silage for 14 hours 25 minutes daily.

After the morning milking cows in treatments G, GRS and GAS were taken to pasture and cows in treatments GMS were offered silage *ad libitum* in a feeding passage for 45 minutes. After the afternoon milking cows in treatments GRS and GAS were offered silage in the feeding passage of a timber kennel building until morning milking. These cows also had access to cubicles bedded with sawdust.

In the last six days of each period milk yield and silage intake were recorded daily and separate aliquot samples of milk were taken on two days for fat, protein and lactose analysis (section 3.2.2). Liveweight was recorded on alternate days in the last 16 days of each period (5 days were allowed for change in gut contents), and liveweight change was determined for each cow by regression.

Records of time spent grazing, lying, lying and ruminating, standing, standing and ruminating, walking and eating silage were made in two 24 hour observations in the last week of each period. Records were taken for each cow at 5 minute intervals between morning and afternoon milking and at 10 minute intervals between afternoon and morning milking.

Rate of biting at pasture was measured in the last six days of each period with the aid of a stop-watch (section 3.2.2). Measurements were taken at four times in the day (06.00, 09.00, 14.00 and 19.00) for treatments G and GMS and at two times in the day (09.00 and 14.00) for treatments GRS and GAS. Two measurements were taken at each time for treatments G and GMS and four measurements at each time for GRS and GAS, giving eight measurements cow^{-1} period^{-1} for all treatments. Bite size and herbage intake rate were derived as in Experiment 1 (3.3.5).

4.2.3 Fields and feeds management

Cows were set-stocked in treatment groups with the same available herbage height for all treatments. This avoided the effects of differing herbage availability and composition and also social facilitation (see glossary). It was achieved by rotating the treatment groups daily around four set-stocked areas in a Latin Square design (appendix 12). The four areas used were separated by electric fencing and were 1.2 ha each of a perennial ryegrass (Lolium perenne) and white clover (Trifolium repens) ley sown in 1977. Stocking rate on the grazed area for the four treatments was 6.8 cows ha^{-1}. Fertilizer application is shown in appendix 4.

Herbage height was recorded weekly using an MMB rising plate meter (Baker, 1980). Approximately 17 measurements ha^{-1} were taken in a V pattern across each area, and a record was taken when a measurement occurred in an area of herbage that had been rejected due to faecal contamination. Herbage DM intakes were calculated from animal production as in section 3.2.3 with the inclusion of an allowance for the ME requirements of pregnancy (MAFF *et al*, 1975).

Silage offered in the first three periods was made in 1981 from a regrowth of a perennial ryegrass (Lolium perenne) ley. In the fourth period silage made in 1982 from a primary growth of the same ley was used. Silage was wilted and precision chopped and received 2-3 l $tonne^{-1}$ of an additive containing formic acid ('Add-F', BP Nutrition Ltd).

Silage restriction in treatment GRS was set at 4 kg DM day^{-1}, with the fresh-weight of silage offered being adjusted twice weekly for the DM content of the silage. Silage was offered to treatments GMS and GAS so that 10% of the original weight was available for weighing daily as a residue.

Silage feeding times were used to predict individual silage DM intakes. For this purpose further observations of the silage feeding times of cows in treatments GMS were carried out on three occasions in each period with recordings at three minute intervals. All silage feeding times were adjusted by $liveweight^{1.27}$ to account for differences in rate of intake between animals of different liveweight. This adjustment value was obtained by relating the difference in rate of intake of herbage and silage (calculated as in section 3.2.3) between cows and heifers to the difference in liveweight. Adjusted silage feeding times were then related to mean silage DM intakes to obtain individual silage DM intakes.

Concentrates were offered twice daily in the parlour at 2 kg fresh-weight day^{-1}. Ingredients are listed in appendix 11. Water was available in each grazed area and in the overnight housing.

A herbage sample was collected once each week from the grazed area by handplucking (Cook, 1964). Silage samples were taken daily and were subsampled weekly for determination of chemical composition, and concentrates were sampled weekly. *In vitro* digestibilities of the herbage and concentrates were determined according to Alexander and McGowan (1961, 1966) and the silage according to Alexander and McGowan (1969). Metabolizable energy contents of the feeds were predicted by the equation shown in appendix 7. The intake and requirement of RDP and UDP were calculated from ARC (1980).

Weather records were taken at a meteorological station 1500 m from the grazing area.

4.2.4 Statistical analysis

The significance of the treatment and period differences was examined using the statistical package Genstat 5 Mark 4.03 (Lawes Agricultural Trust, 1980). This programme also statistically analysed differences between the types of animal used in this experiment (autumn-calving cow, autumn-calving heifer, spring-calving cow or spring-calving heifer) and the interaction between treatment and animal type effects.

In addition the effect of treatment in the previous experimental period on treatment effects was examined by the method of Patterson and Lucas (1962) (appendix 14). This method, although indicating the significance of these residual effects, was not sufficiently accurate to adjust the treatment means (Reid, D A, personal communication).

Differences between individual treatment, period and animal type means were tested by Student's "t" test and significant differences ($P<0.05$) are indicated by different superscripts.

One cow had to be removed from the trial after seven weeks due to ligament damage in the udder, and all results for periods 3 and 4 for this cow were estimated by the missing plot technique of Steel and Torrie (1960). Missing plot values for milk yield were calculated for a lame cow in period 1 and a cow that suffered ligament damage in periods 3 and 4. Missing plot values were also calculated in period 4 for the grazing behaviour of a lame cow and the liveweight change of a cow that refused to be weighed.

4.3 RESULTS

4.3.1 Weather

Although the total rainfall in the experimental period (1.8 mm day^{-1}) was not much less than the mean for the same period in 1951-80 (2.2 mm day^{-1}), it was concentrated into a few heavy showers. Altogether only 14 days had more than 2 mm of rain. Mean daily sunshine was 6.2 hours compared with a 1951-80 average of 5.7 hours (appendix 8). It was therefore a relatively dry, sunny season.

4.3.2 Herbage height

Mean herbage height and grazed herbage height over the 12 weeks were 9.6 cm (SD 0.30) and 9.0 cm (SD 0.24) respectively (figure 4.1). The proportion of herbage area that was rejected increased steadily to 19% by the end of the experiment:

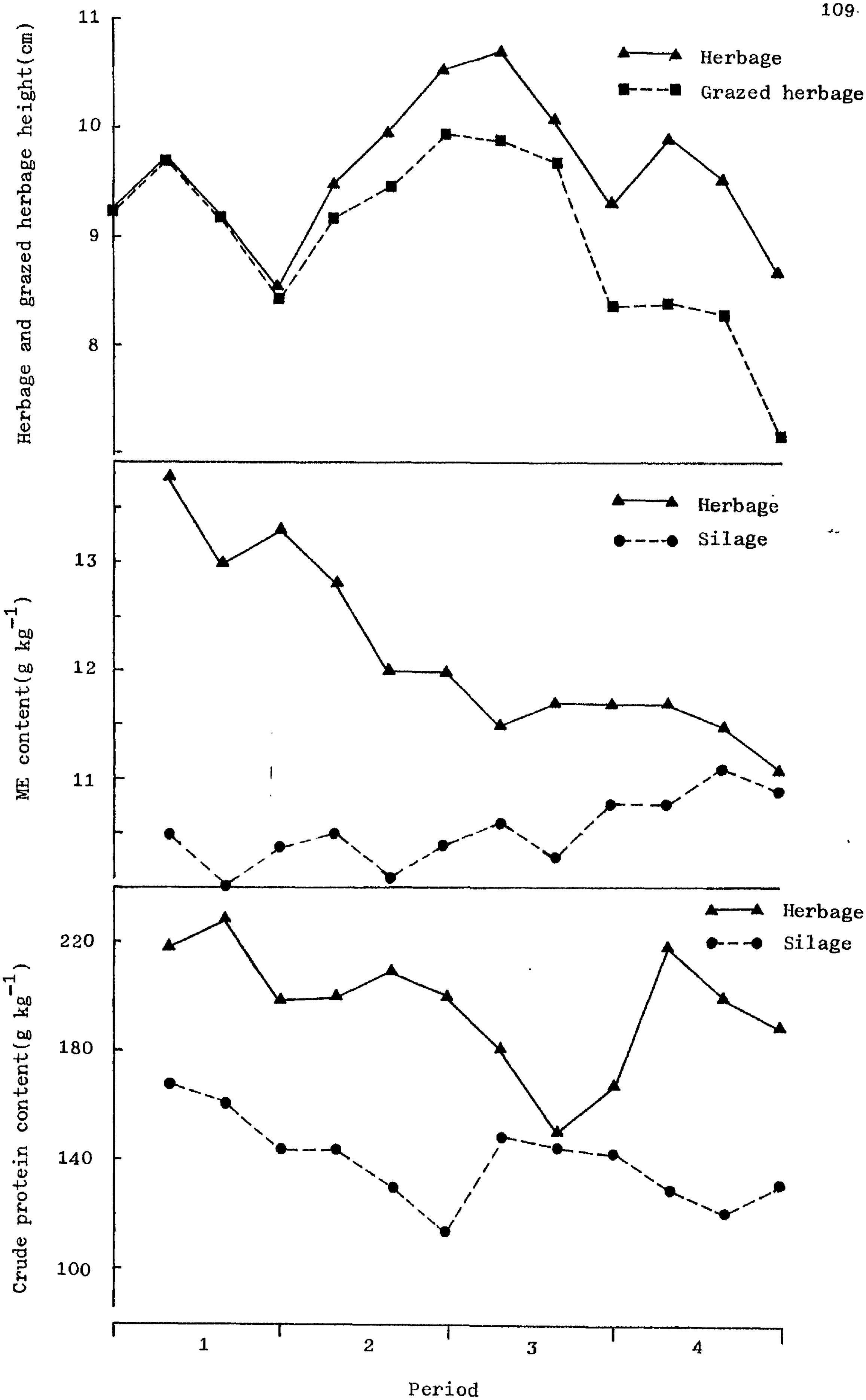


Figure 4.1 Herbage height and chemical composition of the feeds

$y = 1.57x \quad (r = 0.93^{***})$ equation 7

where x = week of experiment

y = proportion rejected (%)

4.3.3 Feed composition

Herbage was of higher ME content and crude protein than silage (table 4.1). Herbage ME content declined over the 12 weeks of the experiment and crude protein content exhibited a wide variation that appeared to be related to stage of growth and fertilizer application (figure 4.1). Silage ME content was higher in the last period when the first cut of 1982 silage was offered.

4.3.4 Feed intake

Herbage DM intakes were depressed by offering silage (table 4.2) especially when silage was offered overnight and in the final period when silage DM intakes were highest (figure 4.2).

Silage DM intakes were highest when silage was offered *ad libitum* overnight,but cows that were offered the restricted silage overnight compensated by increasing herbage DM intake. Offering silage for 45 minutes day^{-1} limited DM intake to approximately 3 kg day^{-1}. In treatments GMS and GAS silage DM intakes were highest in period 4 when herbage was of lower quality and silage was of higher quality.

There were no significant differences in total DM intakes although these tended to be increased by offering silage in the first period (ie just after turnout) and when the higher quality silage was used in period 4. Total DM intakes were significantly higher in the first six weeks after turnout compared with the second six weeks.

Table 4.1 Chemical composition of the feeds (g kg^{-1} DM unless otherwise stated)

	Herbage	Silage	Concentrates
Dry matter (g kg^{-1})	184	214	873
ME (MJ kg^{-1} DM)	12.2	10.5	12.8
Organic matter	916	884	899
Crude protein	198	141	188
In vitro digestibility	705	661	748
Calcium	5.0	6.1	10.7
Phosphorus	4.1	3.9	7.3
Magnesium	2.0	2.2	5.2
Potassium	29.4	-	-
Ammonia nitrogen (g kg^{-1} total N)	-	127	-
pH (units)	-	4.1	-

Table 4.2 Feed intake

	Treatment					Period				
	G	GMS	GRS	GAS	SED Sig.	1	2	3	4	SED Sig.
Herbage DM intake (kg day^{-1})	12.5^{a}	10.3^{b}	9.1^{c}	7.2^{d}	0.49 ***	11.2^{a}	10.8^{a}	9.1^{b}	7.9^{c}	0.47 ***
Silage DM intake (kg day^{-1})	-	1.7^{c}	4.0^{b}	5.8^{a}	0.24 ***	2.2^{c}	2.7^{b}	2.6^{bc}	3.9^{a}	0.23 ***
Concentrates DM intake (kg day^{-1})	1.7	1.7	1.7	1.7		1.7	1.7	1.7	1.7	
Total DM intake (kg day^{-1})	14.1	13.8	14.7	14.7	0.45 NS	15.1^{a}	15.4^{a}	13.5^{b}	13.5^{b}	0.43 ***
Metabolizable energy † (MJ day^{-1})	174	166	178	174	5.23 NS	195^{a}	182^{a}	156^{a}	158^{b}	4.99 ***
Crude protein (g day^{-1})	2803	2607	2694	2572						
RDP intake ‡ (g day^{-1})	1471-2028	1423-1938	1529-2064	1519-2029						
RDP output (g day^{-1})	1357	1295	1388	1357						
UDP intake ‡ (g day^{-1})	776-1336	669-1125	630-1168	543-1056						
UDP output (g day^{-1})	479	456	414	410						

† MAFF *et al*, 1975

‡ Calculated for the range in degradabilities suggested by ARC (1980) - herbage 0.5-0.7, silage and concentrate 0.7-0.9

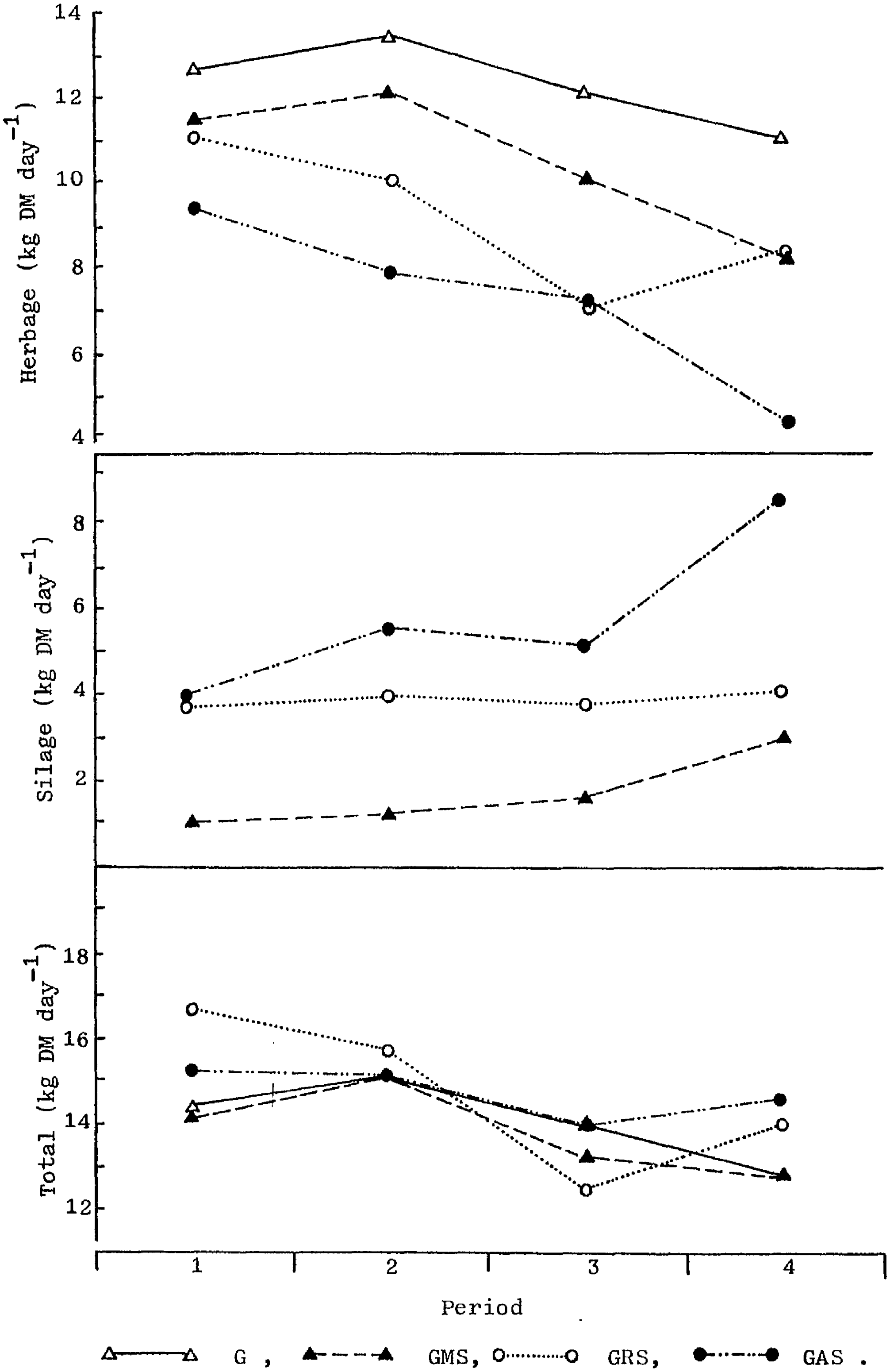


Figure 4.2 Variation in feed intake over the four periods

Mean substitution rates (kg herbage DM kg^{-1} silage DM) for treatments GMS, GRS and GAS were 1.39, 0.87 and 0.91 respectively. There were no significant treatment differences in metabolizable energy intakes but these were significantly higher in the first six weeks compared with the second six weeks.

The intake of crude protein declined at higher levels of silage DM intake due to the low crude protein content of the silage compared with the herbage. In all treatments the intake of RDP and UDP exceeded output even at the most extreme assumed degradabilities.

4.3.5 Cow behaviour

Grazing time was depressed by offering silage - on average by 27, 45 and 38 minutes kg^{-1} silage DM for treatments GMS, GRS and GAS respectively (table 4.3). Cows in treatment G, and to a lesser extent treatment GMS, increased grazing time over the course of the experiment. In period 4 the grazing time of cows in treatment GAS declined as herbage DM intake declined and silage DM intake increased, but the grazing time of cows in treatment GRS increased so that 93% of their time at pasture was spent grazing.

Ruminating time was increased by offering silage, in proportion to the amount fed. It also increased over the season, particularly for those cows offered silage. Cows housed overnight tended to increase standing and ruminating time whereas those at pasture overnight increased their lying and ruminating time (figure 4.3). As the season progressed both lying time and standing time declined as grazing and ruminating times increased.

Table 4.3 Cow behaviour

Time (h day^{-1}) spent:	Treatment G	GMS	GRS	GAS	SED	Significance	Period 1	2	3	4	SED	Significance
Grazing	8.1^{a}	7.4^{b}	5.1^{c}	4.4^{d}	0.13	***	5.5^{c}	6.3^{b}	6.6^{a}	6.8^{a}	0.12	***
Eating silage	-	0.4^{c}	1.3^{b}	2.1^{a}	0.11	***	0.7^{b}	1.1^{a}	0.9^{ab}	1.1^{a}	0.11	**
Standing	2.5^{d}	2.9^{c}	3.9^{a}	3.7^{b}	0.13	***	3.8^{a}	3.2^{b}	3.2^{b}	2.8^{c}	0.12	***
Standing and ruminating	0.3^{b}	0.7^{b}	2.9^{a}	2.9^{a}	0.25	***	0.9^{c}	1.7^{ab}	2.1^{a}	2.1^{a}	0.25	***
Lying	5.4^{a}	4.5^{a}	4.8^{b}	4.5^{b}	0.21	***	6.1^{a}	5.0^{b}	4.2^{c}	3.9^{c}	0.20	***
Lying and ruminating	7.2^{a}	7.4^{a}	5.6^{b}	6.1^{b}	0.29	***	6.4	6.3	6.7	6.9	0.28	NS
Ruminating	7.5^{d}	8.1^{c}	8.5^{b}	9.0^{a}	0.16	***	7.3^{c}	8.0^{b}	8.8^{a}	9.0^{a}	0.15	***
Walking †	0.6^{a}	0.6^{a}	0.3^{b}	0.3^{b}	0.01	***						

† On average 93% of time spent walking was to and from pasture

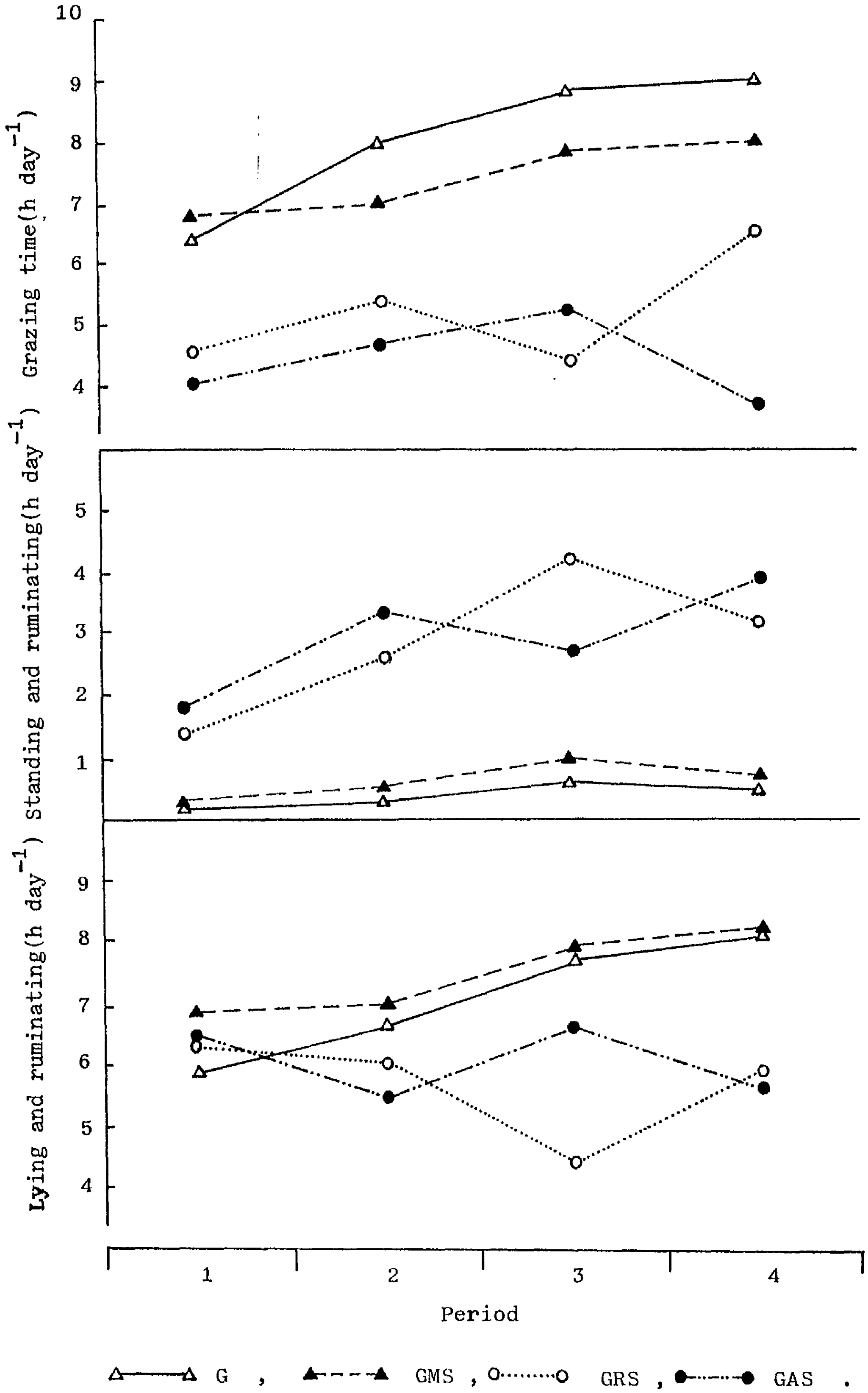


Figure 4.3 Variation in cow behaviour over the four periods

Cows housed overnight spent more time standing/standing and ruminating and less time lying/lying and ruminating than those cows at pasture overnight (table 4.4). To some extent this was due to the reduced total eating time (grazing + eating silage) of cows housed overnight. These cows also spent more time between morning and afternoon milking grazing and less time in other activities and did correspondingly more of their ruminating between afternoon and morning milking.

The diurnal variation in the time spent grazing, eating silage and ruminating is shown in figure 4.4. In treatments G and GMS the longest period of continuous grazing occurred after the afternoon milking. In all treatments there were three major peaks of grazing activity between morning and afternoon milking, interspersed with two periods of rumination. In treatment G the periods of grazing were shorter than for cows housed overnight and the periods of rumination longer. In treatment GMS the period of silage feeding largely replaced the first grazing period after morning milking and was followed by a long period of rumination. Cows in treatment GRS spent on average two thirds of their time at pasture grazing and delayed rumination until the night. The silage offered was not all consumed immediately despite the fact that there was sufficient space for all cows to feed at one time. In the final period, however, silage was cleared up by 19.30 hours. In treatments GRS and GAS there was a peak of silage feeding between 17.00 and 20.00 hours.

Table 4.4 The effects of housing overnight on cow behaviour

	Time (h)	At pasture overnight (G + GMS)	Housed overnight (GRS + GAS)
Lying/lying and ruminating ($h\ day^{-1}$)	07.00-16.00	3.8	2.8
	16.00-07.00	8.4	7.7
Standing/standing and ruminating ($h\ day^{-1}$)	07.00-16.00	1.5	1.1
	16.00-07.00	1.7	5.6
Ruminating ($h\ day^{-1}$)	07.00-16.00	2.5	1.6
	16.00-07.00	5.3	7.1
Total eating time ($h\ day^{-1}$)	07.00-16.00	3.0	4.8
	16.00-07.00	4.6	1.7

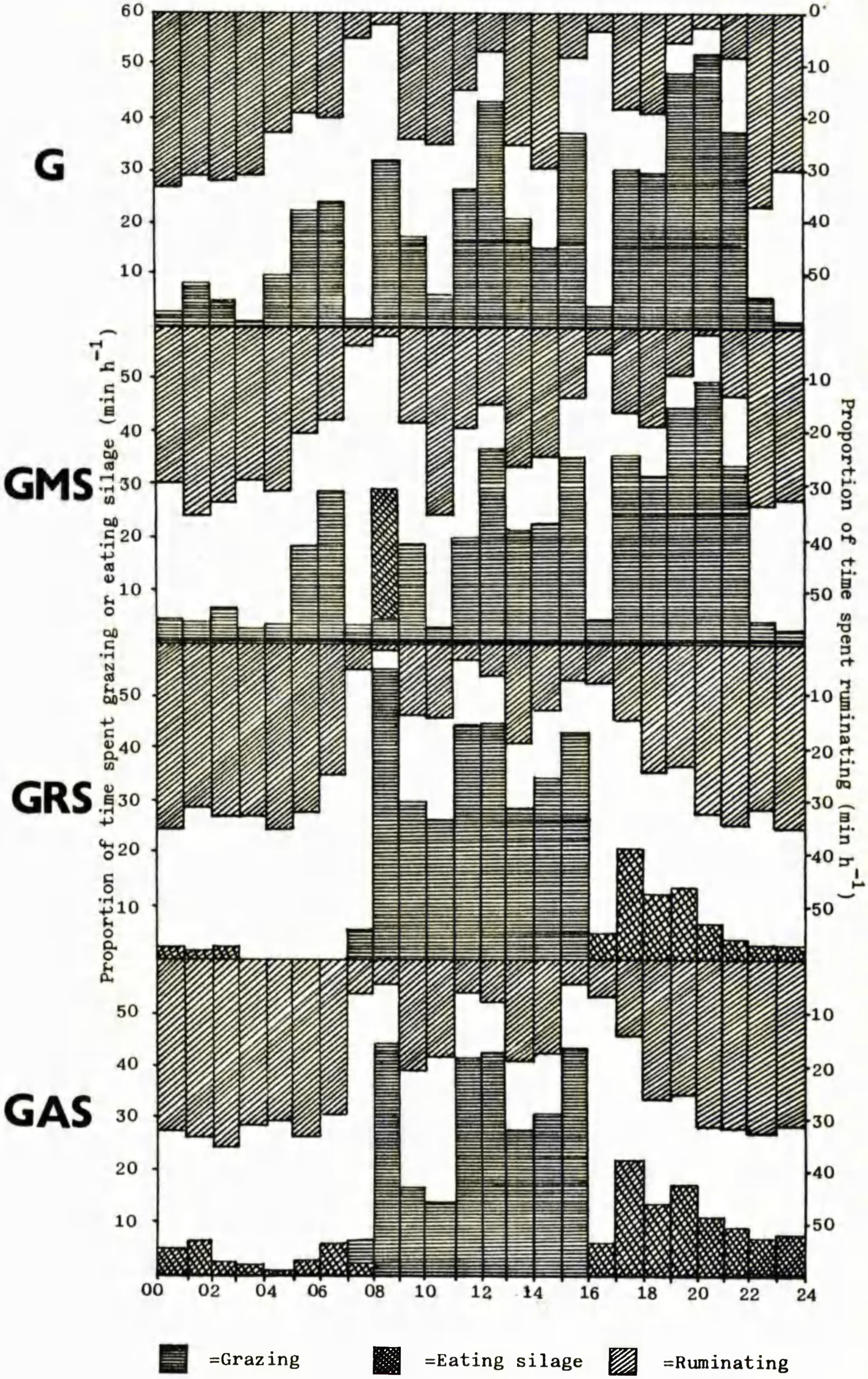


Figure 4.4 Diurnal variation in ingestive behaviour

There were no significant treatment effects on biting rate (table 4.5). For cows at pasture all the time biting rate increased from approximately 56 bites min^{-1} at 06.00 h to 63 bites min^{-1} at 19.00 h. Biting rate increased over the four periods.

Restricting the cows to grazing between morning and afternoon milking increased bite size and herbage DM intake rate, particularly where the amount of silage offered overnight was restricted. Both bite size and herbage DM intake rate declined over the length of the experiment.

Silage DM intake rate was highest in treatment GMS and was slightly increased by restricting the level of silage offered overnight.

4.3.6 Animal production

Offering silage overnight depressed milk yield, but milk fat content was increased compared with treatment G (table 4.6). Offering silage for 45 minutes also increased milk fat content but not as much as offering silage overnight. Fat yield was increased by feeding silage - on average by 8.4, 6.9 and 6.3 g fat kg^{-1} silage DM for treatments GMS, GRS and GAS respectively. There were no significant treatment differences in milk protein content, although it tended to be lower for cows fed silage overnight. Protein yield was depressed by feeding silage overnight.

Before turnout cows yielded on average 22 kg milk day^{-1} at 40.0 g kg^{-1} fat content and 33.7 g kg^{-1} protein content. Following

Table 4.5 Ingestive behaviour

		Treatment						Period					
		G	GMS	GRS	GAS	SED	Sig	1	2	3	4	SED	Sig
HERBAGE													
Biting rate (bites min^{-1})	06.00h	56.5	55.8	-	-								
	09.00	58.8	57.0	59.6	59.8								
	14.00	59.7	60.1	59.8	61.0								
	19.00	62.8	63.1	-	-					–			
	Mean	59.7	59.2	59.6	60.3	0.77	NS	57.1^{c}	58.6^{b}	61.3^{a}	61.8^{a}	0.73	***
Bites day^{-1}		$29,273^{a}$	$27,076^{b}$	$18,449^{c}$	$15,953^{d}$	771	***	$18,833^{c}$	$21,992^{b}$	$24,116^{a}$	$25,165^{a}$	735	***
Derived bite size (g DM)		0.45^{ab}	0.40^{b}	0.52^{a}	0.48^{a}	0.035	**	0.63^{a}	0.50^{b}	0.39^{c}	0.34^{c}	0.033	***
Derived herbage intake rate (g DM min^{-1})		26.4^{bc}	23.7^{c}	30.4^{a}	28.6^{ab}	1.80	**	35.9^{a}	29.2^{b}	23.8^{c}	20.4^{c}	1.72	***
SILAGE													
Silage intake rate (g DM min^{-1})		-	63.0	50.9	48.5			51.3†	47.5†	55.8†	64.6†		

† Mean of treatments GMS, GRS and GAS

Table 4.6 Animal production

	Treatment					Period				
	G	GMS	GRS	GAS	SED Sig	1	2	3	4	SED Sig
Milk yield (kg day^{-1})	19.9^{a}	19.6^{a}	18.9^{b}	18.9^{b}	0.28 **	22.0^{a}	20.9^{b}	18.6^{c}	15.7^{d}	0.27 ***
Fat content (g kg^{-1})	35.6^{c}	36.9^{b}	38.8^{a}	39.4^{a}	0.44 ***	37.5^{b}	36.1^{c}	37.6^{b}	39.5^{a}	0.42 ***
Protein content (g kg^{-1})	35.1	35.3	34.6	34.8	0.36 NS	35.5^{a}	34.5^{b}	35.1^{a}	34.7^{b}	0.35 *
Lactose content (g kg^{-1})	48.5	48.5	48.6	48.5	0.17 NS	49.9^{a}	48.8^{b}	48.4^{c}	47.0^{d}	0.16 ***
Fat yield (g day^{-1})	704^{b}	718^{ab}	731^{a}	741^{a}	12.2 *	825^{a}	749^{b}	700^{c}	620^{d}	11.6 ***
Protein yield (g day^{-1})	698^{a}	690^{a}	655^{b}	663^{b}	12.1 **	781^{a}	719^{b}	652^{c}	553^{d}	11.5 ***
Lactose yield (g day^{-1})	966^{a}	952^{a}	921^{b}	921^{b}	14.4 **	1098^{a}	1019^{b}	902^{c}	741^{d}	13.7 ***
Liveweight gain (kg day^{-1})	0.29	0.06	0.44	0.31	0.16 NS	0.54^{a}	0.42^{a}	-0.18^{b}	0.33^{a}	0.15 ***

turnout in treatments G and GMS milk fat content decreased by 4.3 g kg^{-1}, milk protein content increased by 2.6 g kg^{-1} and there was a slight increase in milk yield (figure 4.5). In treatment GRS and GAS there was little change in these parameters after turnout. Milk fat content in treatments G and GMS gradually recovered after the first two periods, but feeding silage increased fat content in all periods. Higher protein contents in treatments G and GMS, however, were limited to the first two periods. In the first week of the final period the rapid increase in the crude protein content of the herbage after fertilizer application (figure 4.1) caused a temporary increase in milk protein content of 4 g kg^{-1} in all treatments.

Liveweight gain was not significantly affected by treatment or season but tended to be reduced for treatment GMS and earlier in the season.

4.3.7 Animal type

There were no significant interactions between the type of animal (spring-calving cow , spring-calving heifer, autumn-calving cow or autumn-calving heifer) and treatment. Means for the four animal types are shown in table 4.7.

Cows ate more herbage and silage than heifers although the feeding times were similar. Consequently, herbage bite size of the heifers was less than that of the cows (in particular the spring-calving heifers which were 70 kg lighter than the autumn-calving heifers). To compensate for low bite size the spring-calving heifers increased biting rate.

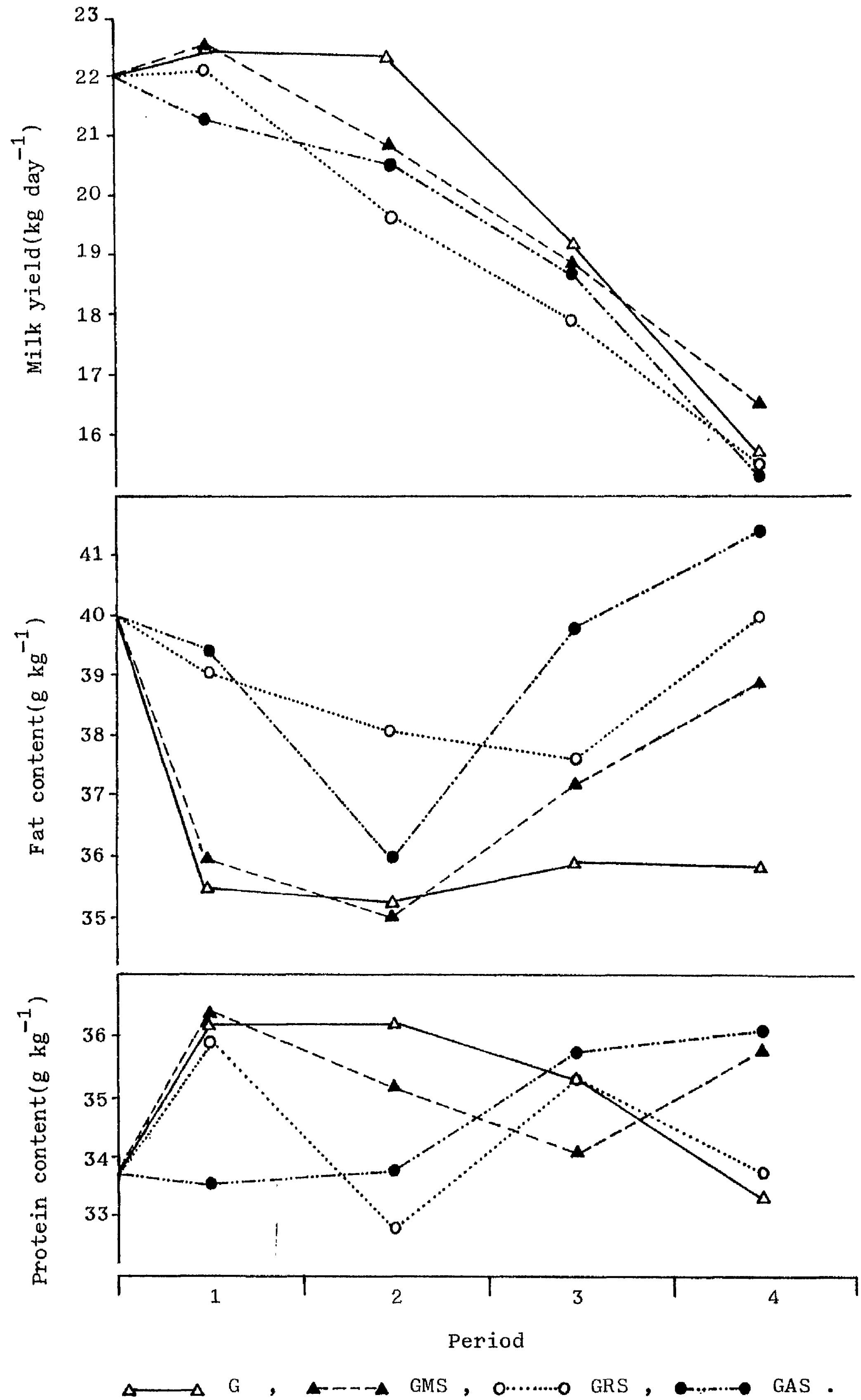


Figure 4.5 Variation in milk yield and composition over the four periods

Table 4.7 The effect of animal type on intake, production and behaviour

	S/C Cows	A/C Cows	S/C Heifers	A/C Heifers	SED	Significance
Herbage DM intake (kg day^{-1})	12.6^{a}	10.3^{b}	8.4^{c}	9.4^{bc}	0.66	***
Silage DM intake (kg day^{-1})	3.4^{a}	3.2^{a}	2.5^{b}	2.4^{b}	0.32	***
Total DM intake (kg day^{-1})	17.9^{a}	15.2^{b}	12.6^{c}	13.7^{c}	0.61	***
Grazing time (h day^{-1})	6.6^{a}	6.0^{c}	6.5^{ab}	6.2^{bc}	0.17	***
Silage feeding time (h day^{-1})	0.93	0.89	1.04	0.80	0.15	NS
Ruminating time (h day^{-1})	8.3^{a}	8.5^{a}	8.1^{a}	8.4^{a}	0.22	*
Herbage biting rate (bites min^{-1})	58.9^{b}	58.1^{b}	62.3^{a}	57.4^{b}	1.03	***
Herbage bite size (g DM min^{-1})	0.55^{a}	0.52^{a}	0.36^{b}	0.50^{a}	0.054	**
Milk yield (kg day^{-1})	26.3^{a}	19.3^{b}	17.8^{c}	16.9^{d}	0.38	***
Fat content (g kg^{-1})	38.2^{a}	39.1^{a}	35.6^{b}	39.3^{a}	0.59	***
Protein content (g kg^{-1})	34.1^{b}	36.3^{a}	33.4^{b}	36.5^{a}	0.49	***
Lactose content (g kg^{-1})	49.0^{b}	47.4^{c}	49.1^{b}	49.7^{a}	0.23	***
Liveweight gain (kg day^{-1})	0.25	0.29	0.27	0.29	0.22	NS

S/C - Spring-calving
A/C - Autumn-calving

Spring-calvers ate more herbage and grazed for longer than autumn-calvers but there was no difference in the intake of silage DM or time spent eating silage.

Milk yield and milk protein content reflect stage of lactation differences. Milk fat content of the spring-calving heifers was significantly lower than the other three types, particularly in treatment GRS (this type:treatment interaction approached significance). The lactose content of the milk was significantly lower for autumn-calving cows than spring-calving cows. The high lactose content of the autumn-calving heifers is probably a vagary of the experimental data as there were only four animals of this type.

4.3.8 Coefficients of variation

The coefficient of variation of individual cow milk yields over the last six days of each period tended to be reduced by offering silage, although this difference was not statistically significant (table 4.8). The coefficient of variation of silage DM intakes over the last 6 days of each period was particularly high in treatment GMS.

Table 4.8 Coefficient of variation (%) over the last six days of each period

	G	GMS	GRS	GAS	SED	Significance
Milk yield	4.8	4.6	4.2	4.1	0.50	NS
Silage DM intake	-	17.8	6.1	9.3		

4.3.9 Residual effects

Significant residual effects are listed in appendix 15. These were primarily in milk composition although there was some indication that, had the experiment been one of continuous design, the silage DM intakes for cows offered silage overnight would have been higher. This is not however supported by the mean change in silage DM intake over the 21 days of each period (figure 4.6) - there was little change for cows housed overnight but DM intakes increased in treatment GMS.

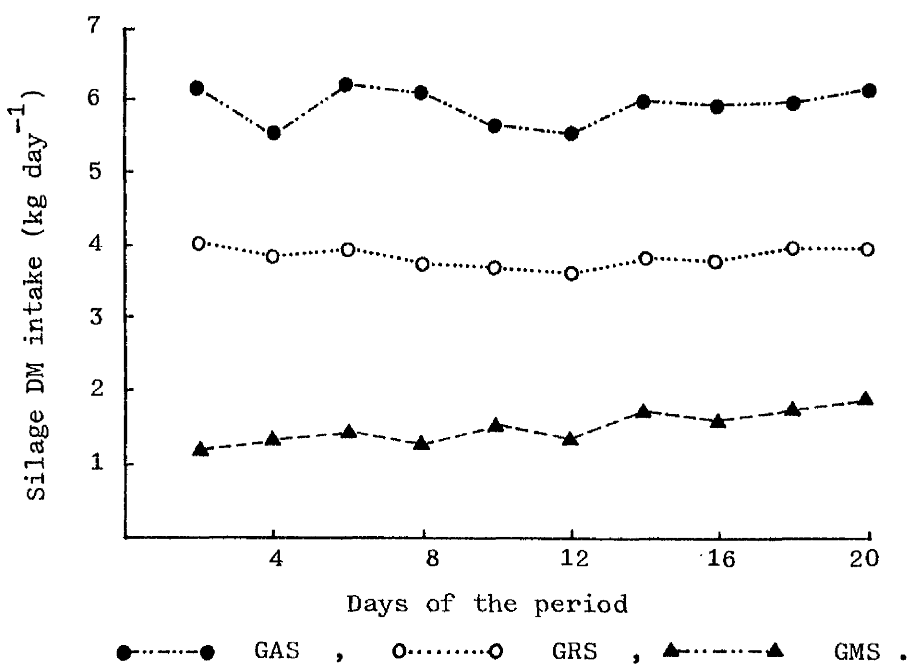


Figure 4.6 Change in silage DM intake in each period

Few of the grazing behaviour parameters had significant residual effects. However, housing overnight did significantly depress the grazing time and number of grazing bites day^{-1} of those cows at pasture overnight in the following period.

The significant residual effects on milk fat content and fat yield suggest that even greater increases in both parameters by offering silage might occur over longer experimental periods. The residual effects on milk protein content, although significant, were relatively small.

4.4 DISCUSSION

4.4.1 Animal production

The decline in milk yield when silage was offered with *ad libitum* herbage is in accordance with the literature (section 1.2.1.1.2). This is due to the lower ME content of the silage compared with the herbage and possibly the increased crude fibre contents of the diets in treatments GRS and GAS (Gordon and Forbes, 1971).

In contrast to this experiment most reports in the literature show little increase in milk fat content when silage is included in a predominantly herbage diet. This is probably due to the high crude fibre content of the herbage in reported experiments (mainly in Australia and New Zealand) compared with the spring herbage in this experiment. If the crude fibre content of the herbage, silage and concentrate in this experiment are estimated at 150, 300 and 50 g kg^{-1} DM respectively (MAFF *et al*, 1975), then the dietary crude fibre contents in treatment G, GMS, GRS and GAS were 140, 155, 179 and 200 g kg^{-1} DM respectively. The critical crude fibre content, below which milk fat content is depressed, has been variously reported as 200 g kg^{-1} DM (Kaufmann, 1976), 150 g kg^{-1} DM (Ronning and Laben, 1966) and 140 g kg^{-1} DM (Kessler and Spahr, 1967).

The results of this experiment suggest that milk fat content is depressed at dietary crude fibre contents below 200 g kg^{-1} DM and the depression was similar to that reported by Hildebrandt (1958) (figure 4.7).

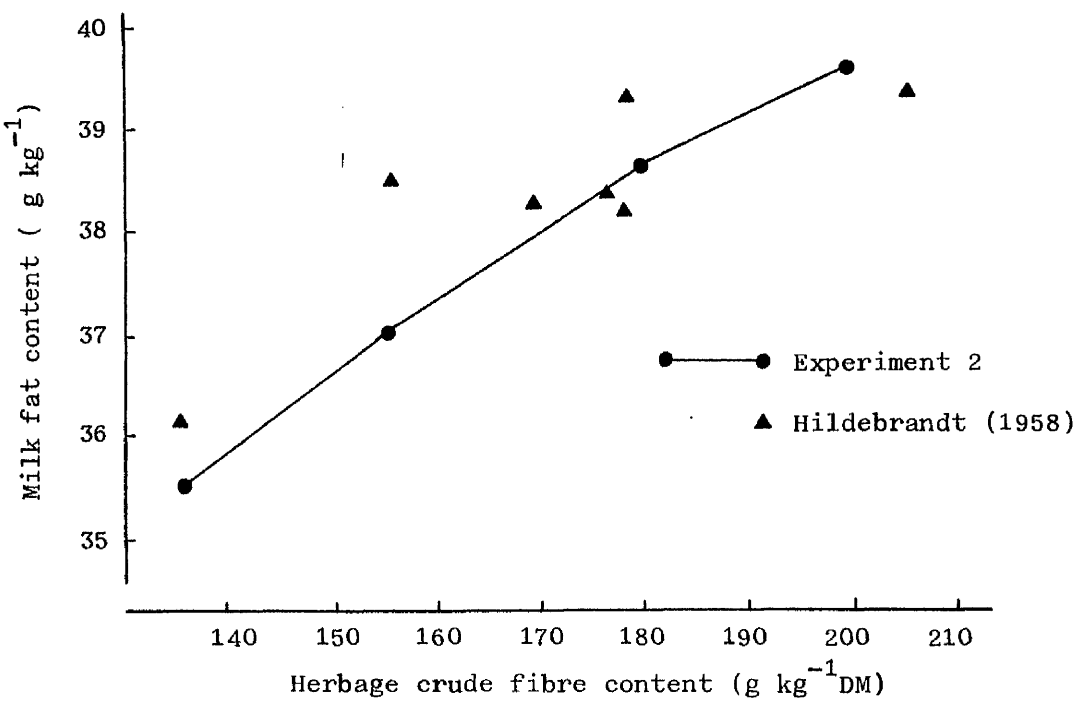


Figure 4.7 Effect of crude fibre content of the diet on milk fat content

The depression in milk protein content when silage was fed overnight, although not significant, confirms the results in the literature (section 1.2.1.1.2) . This was probably due to the low crude protein content of the silage compared with the herbage which reduced the non-protein-nitrogen content of the milk (Thomas, 1980). Both the protein and lactose content of the milk can also be depressed by a high dietary crude fibre content (Gordon and Forbes, 1971).

The dominant influence of weather conditions on the grazing animal were exemplified in this experiment when the milk fat content of cows in treatments G and GMS temporarily declined by 5 g kg^{-1} on the day following a heavy storm. A similar effect has been reported by Sjollema (1950).

The low liveweight gain in treatment GMS, although non-significant, may have unrealistically reduced the herbage DM intake in this treatment. The allowance of five days for adjustment of gut contents is considered to be valid as the decline in live weight when housed cattle are turned out to pasture is accomplished within three days (Balch and Line, 1957). In addition Annison *et al* (1959) found that when sheep were transferred from a hay-based diet to lush spring herbage changes in rumen VFA were accomplished within five days. No comparable data is available for the transition from herbage to silage, but in experiment 1 there was little effect of housing at the end of the experiment on liveweight (figure 3.9). In addition Storry and Sutton (1969) found that on changing from a low roughage to a high roughage diet ruminal changes were completed within a week.

4.4.2 Feed intake

The absence of any effect of offering silage on ME intake suggests that there was no need for a buffer feed in this experiment, with adequate herbage available, very few wet days and low milk yields. Under these conditions even the spring-calving cows (mean milk yield 26 kg) did not appear to require a buffer feed and their mean number of grazing bites day^{-1} on treatment G (31,735) suggests that they were not limited by grazing time (Stobbs, 1973). In experiment 1 cows in early season had a similar milk yield (25 kg day^{-1}) and benefited from a buffer feed of hay. Conceivably the good weather conditions and higher herbage heights in this experiment (9.6 compared with 7.5 cm) may have enabled the spring calvers to harvest sufficient herbage. It is also possible that hay complemented the low DM content of the herbage better than silage, although this would appear unlikely as neither group of spring-calving cows was limited by grazing time at this stage in the season.

The calculation of herbage DM intakes from animal production assumes the same efficiency of utilization of metabolizable energy in all treatments. As maximum efficiency of ME utilization probably occurs at approximately the critical dietary crude fibre content (Van Soest, 1963), it is possible that the herbage DM intake in treatment G was actually higher but was utilized less efficiently.

From herbage DM intakes the effective stocking rates for treatments G, GMS, GRS and GAS were 5.3, 6.5, 7.3 and 9.2 cows ha^{-1} respectively. Total UME from herbage over 12 weeks was 68 GJ ha^{-1}, giving a DM yield of 5.6 t ha^{-1}. Overall grazing pressure was low, resulting in high herbage availability and a greater accumulation of rejected herbage than in experiment 1.

Higher silage DM intakes when silage was offered *ad libitum* overnight compared with for 45 minutes resulted from restriction of herbage DM intake by housing overnight rather than the inability to consume sufficient silage in 45 minutes. Maximum silage DM intake in treatment GMS was the same as the maximum hay DM intake in 45 minutes in experiment 1 (3 kg DM). However in this experiment the additional silage merely substituted for herbage.

Silage quality was found to be an important determinant of DM intake as the change in period 4 brought about a marked increase in silage DM intake (figure 4.2).

Over the whole experiment 0.34 t silage DM cow^{-1} was fed in treatment GRS and 0.50 t DM to treatment GAS. In poorer weather and with less adequate herbage more silage would be required. Housing cows overnight restricted herbage DM intake in this experiment to 11 kg DM day^{-1} in period 1 and 8 kg DM day^{-1} in period 4. For cows grazing throughout the day there is more opportunity to compensate for low herbage availabilities by increasing grazing time than cows housed overnight which have a maximum grazing time of less than eight hours. Thus although a restricted overnight silage allowance might appear to offer savings in feed costs it is likely to make even more demands of good grassland management than treatment G. In addition the pasture-sparing effect of higher levels of silage DM intake may be utilized by increasing stocking rates.

The greatest response to silage in milk fat kg^{-1} silage DM was in treatment GMS. However due to the large diurnal variation in DM intake it was necessary to feed to a high level of refusal to ensure *ad libitum* intake. In practice it could be expensive to offer these small amounts of silage with a high level of wastage.

4.4.3 Cow behaviour

Grazing times for cows in treatments G and GMS were low after turnout and offering silage increased total DM intakes at this time. Low grazing times after turnout have also been reported by Jamieson (1975) and probably result from the high herbage ME content and high bite size rather than a failure of the cows to adjust to a predominantly herbage diet.

As the season progressed the herbage ME content decreased and grazed herbage height declined from 9.1 cm in period 1 to 7.9 cm in period 4. In addition herbage dead matter content increases over this period (Le Du *et al*, 1981). These factors resulted in an increased grazing time and biting rate through the season and a decline in bite size from 0.63 g DM in period 1 to 0.34 g DM in period 4. As in experiment 1 this suggests that small changes in herbage height within a grazed horizon can have large effects on grazing behaviour. More severe reductions in grazed herbage height would have reduced herbage DM intake as well as resulting in behavioural changes. Stobbs (1973) has estimated that the herbage DM intake of 400 kg cows is depressed when bite size is less than 0.3 g DM.

Biting rate increased through the day as the intensity of grazing (the proportion of each hour spent grazing) increased (figure 4.4). Jamieson and Hodgson (1979) found that the biting rate of strip-grazed calves was highest in the afternoon but this was confounded by the introduction of new pasture at 16.00 h. Rate of intake of conserved forage has been found to be higher in the afternoon than the morning (Burt, 1957). Rate of silage DM intakes were higher than where silage is the sole forage (Campling and Morgan, 1981) and were highest when silage was just offered for 45 minutes.

Increase in ruminating time over the course of the experiment was similar in all four treatments but for different reasons - the crude fibre content of herbage increased with advancing maturity and silage DM intakes increased. The results suggest that spring herbage is critically short of fibre and that this depresses milk fat content in the same way as a concentrate:forage imbalance in a winter feeding regime causes a "low fat milk syndrome". Ruminating times in this experiment were 36 minutes kg^{-1} herbage DM (from treatment G and assuming a negligible contribution from concentrates) and 53 minutes kg^{-1} silage DM (from treatments GMS, GRS and GAS by difference). This is similar to the value of 32 min kg^{-1} herbage DM from the same time period in experiment 1 but less than the value of 60-83 minutes kg^{-1} silage DM reported by Balch (1971).

Time spent lying/lying and ruminating was reduced for cows housed overnight. As silage feeding time was also less than grazing time between afternoon and morning milking these cows spent much more of their time between afternoon and morning milking standing/standing and ruminating than those at pasture at this time. Castle *et al* (1950) found that cows spent less time lying/lying and ruminating in a cow-stall with yolks than at pasture, but Burt (1957) found that the pattern of lying/lying ruminating in a straw yard was similar to that at pasture. Clearly the total time spent lying down is reduced for cows in a cubicle house or cow-stall compared with cows at pasture or in a straw yard. Lying time in cubicles may be reduced by either injury to hocks and knees caused by standing up and lying down or by the restriction of movement in the cubicle. Probably the latter is the major factor involved since all cows housed overnight in this experiment lay down for some of the time in the cubicles, and cows at pasture were often observed to remain lying for most of the night.

4.4.4 Animal type

Whereas in experiment 1 it was found that high yielding cows benefitted from a buffer feed throughout the 1981 grazing season, there was no need for a buffer feed in either autumn- or spring-calving cows or heifers in this experiment. However, the analysis of animal type did elucidate differences in grazing behaviour, in particular between cows and heifers.

The smaller bite size of heifers compared with cows is attributable to their smaller size (Burt, 1957) and the relationship between bite size and liveweight was utilized in this experiment to adjust silage feeding times for differences in rate of intake. There was little difference in grazing or silage feeding times between types, although the biting rate of the spring-calving heifers was increased. This suggests that the intake of grazing animals could be modified by social habits ie feeding gregariously, although biting rate may be adjusted to compensate for this habit.

Differences in ruminating time between animal types were also small, despite considerably higher total DM intakes for the cows than the heifers. The relationship between total DM intake and ruminating time is therefore probably confounded by animal size, a factor which could limit the usefulness of the Chewing Index proposed by Balch (1971).

4.4.5 Residual effects

The existence of significant residual effects in some of the results suggests that the cows did not fully adjust to dietary changes within the 15 days in each period before measurements were taken. Although there were no significant residual effects in herbage DM intake or most of the behaviour variables it would appear that the effects on milk composition were not complete. However, the residual effects on milk composition were not large and it was not considered necessary or sufficiently accurate to adjust the results accordingly.

In general short-term changeover experiments with grazing dairy cows have given very similar results to long-term experiments (see Greenhalgh *et al*, 1966, 1967). For example the only major difference in the changeover and continuous experiments of Greenhalgh *et al* (1966, 1967) that examined herbage availability for dairy cows was that the short-term trial overestimated liveweight change. No adjustment period was allowed in the changeover experiment for changes in gut contents. However underfeeding dairy cows causes mobilization of body reserves initially, followed by reduced milk production after reserves have fallen to a basal level (Neilson *et al*, 1983). Thus some overestimation of liveweight losses when cows are underfed for short periods of time is likely.

4.3 SUMMARY

The effects of offering silage as a buffer feed on the performance and behaviour of set-stocked dairy cows was examined in the early part of the grazing season. Silage was offered either overnight, at a restricted level or *ad libitum*, or for 45 minutes after morning milking. Adequate pasture was available at all other times. These systems including silage as a buffer feed were compared with a grazing only treatment with no buffer feed.

Silage intakes were highest when silage was offered *ad libitum* overnight but this was accompanied by a reduction in herbage DM intake. Total ME intakes were not affected by offering silage.

Offering silage overnight depressed milk yield but overall milk fat content was increased in proportion to the amount of silage fed. At the higher levels of silage intake fat yields were increased and protein yields decreased relative to the grazing only treatment. There were no significant effects on liveweight gain.

Offering silage depressed grazing times and increased ruminating times but there were no significant effects on biting rate at pasture.

The good grazing conditions and relatively low milk yields in this experiment appeared to obviate the need to buffer variation in herbage DM intake. Inclusion of silage into a herbage-based diet, however, had beneficial effects in terms of increased milk fat yield and reduced grazing requirements.

CHAPTER 5

EXPERIMENT 3 THE EFFECT OF OFFERING SILAGE TO SET-STOCKED DAIRY COWS IN THE LATE PART OF THE GRAZING SEASON

5.1 INTRODUCTION

Experiment 2 demonstrated that under the conditions of that experiment there was little need for a buffer to variation in herbage DM intake in the early part of the grazing season. However in the later part of the grazing season herbage DM intake can be reduced by inclement weather, a high degree of faecal contamination of the pasture and a high dead matter content of the sward.

As variation in herbage DM intake is likely to be greater in the late grazing season, it was important in planning this experiment for mid-late season that silage offered overnight was available *ad libitum*. In addition it was envisaged that offering silage after morning milking might have limited effectiveness as a buffer if restricted to a 45 minute period. A second treatment, therefore examined the provision of silage after morning milking until the cows had finished eating.

This experiment examined the effect of three feeding systems on dairy cow production and behaviour; grazing throughout the day; grazing with silage offered *ad libitum* after morning milking and grazing during the day with silage offered *ad libitum* overnight.

5.2 MATERIAL AND METHODS

5.2.1 Design

Eight British Friesian cows and ten British Friesian heifers were allocated to the three treatment groups in a balanced changeover design (appendix 12), similar to that used in experiment 2 (4.2.1): G - grazing only; GMS - grazing + *ad libitum* silage after morning milking; GAS - grazing + *ad libitum* silage overnight. Cows were allocated to the six blocks of the Latin Square design so that the cows within each block were as similar as possible in terms of milk yield and live weight (appendix 13). Within blocks cows were allocated to the three treatments at random.

The experiment ran for nine weeks (three 3 week periods) from 4 August to 6 October 1982.

5.2.2 Dairy cow management and measurements

For three weeks prior to the commencement of the experiment cows grazed unrestricted pasture with 4 kg concentrates day^{-1}. Before this the majority of the cows had received varying proportions of herbage and silage in experiment 2.

During the experiment cows were milked at 07.30 and 16.10. Cows in treatment GAS were at pasture on average for 7 hours 25 minutes and received silage for 14 hours 40 minutes.

After morning milking cows in treatment G and GAS were taken to pasture. Cows in treatment GMS were offered silage *ad libitum* in a feeding passage and were returned to pasture when two thirds of the cows had finished eating silage. After the afternoon milking cows in treatment GAS were offered silage in the feeding passage of a kennel building in periods 1 and 2 and a cubicle house in period 3 until morning milking (plate 2). All cubicles were bedded with sawdust.

Records of milk yield and composition, liveweight, silage DM intake, herbage height and grazing behaviour were taken as in experiment 2 (4.2.2). Rate of biting at pasture was recorded as in section 4.2.2, except that measurement for treatments G and GMS were taken on three days $period^{-1}$ at 09.15, 13.20 and 17.40 hours (plate 2), giving 9 measurements cow^{-1} $period^{-1}$. As cows in these treatments did very little grazing before morning milking it was not possible to record biting rate at that time.

5.2.3 Fields and feeds management

Cows were stocked in a continuous grazing system with the same available herbage height for each treatment group. This was achieved as in experiment 2 by rotating treatment groups around three of the areas of 1.2 ha each that were used in experiment 2. These areas were topped two weeks before the start of the trial to remove rejected herbage. Overall stocking rate for the three treatment groups was 5.1 cows ha^{-1}. Fertilizer application is shown in appendix 4.

Silage offered was from a primary growth of a perennial ryegrass (Lolium perenne) and white clover (Trifolium repens) ley made as in section 4.2.3. Individual silage DM intakes were calculated from the time spent eating silage adjusted for individual rates of eating energy from silage and herbage.

PLATE 2

TOP - The grazing area. Division of the grazing area by electric fencing resulted in the cows in each treatment group behaving as a separate herd.

MIDDLE - Recording grazing behaviour.

BOTTOM - Silage feeding in the cubicle house.

Concentrates were offered twice daily in the parlour at 3 kg freshweight day^{-1}. Ingredients are listed in appendix 11. Water was available in each grazed area and in the overnight housing. Feed sampling and chemical analyses were performed as in experiment 2 (4.2.3).

5.2.4 Statistical analysis

Treatment, period and residual effects were analysed according to Patterson and Lucas (1962) (appendix 14). Differences between individual treatment means were tested by Student's "t" test and significant differences ($P<0.05$) are indicated by different superscripts. As in experiment 2 treatment means were not adjusted for residual effects.

All animals were in good health throughout the experiment and there were no missing plots.

5.3 RESULTS

5.3.1 Weather

Mean daily rainfall in the experimental period (4.4 mm day^{-1}) was higher than the average for 1951-80 over this period (3.3 mm day^{-1}) and considerably higher than earlier in the season (1.8 mm day^{-1} - section 4.3.1) (appendix 8). Mean daily sunshine hours (3.8 h day^{-1}) were less than earlier in the season (6.2 h day^{-1}) and the average for 1951-80 over this period (4.2 h day^{-1}).

5.3.2 Herbage height

Mean herbage height and grazed herbage height over the 12 weeks were 7.2 cm (SD 0.39) and 6.1 cm (SD 0.31) respectively. Grazed herbage height and, to a lesser extent, herbage height declined over the course of the experiment (figure 5.1).

The proportion of the herbage area that was rejected increased through the experiment, but the rate of increase was less than earlier in the season (4.3.2):

$$y = 18.5 + 1.27x \qquad \text{equation 8}$$

where x = week of experiment

y = proportion of herbage area rejected (%).

5.3.3 Feed composition

Herbage was of similar ME content to silage but had twice the crude protein content (table 5.1). There was little change in the ME content of herbage or silage over the course of the experiment although there was an increase in herbage crude protein content (figure 5.1).

5.3.4 Feed intake

Herbage DM intakes were depressed by offering silage, particularly in treatment GAS (table 5.2), and declined through the experiment (figure 5.2).

Silage DM intakes were considerably higher when cows were offered silage overnight compared with after morning milking. The mean

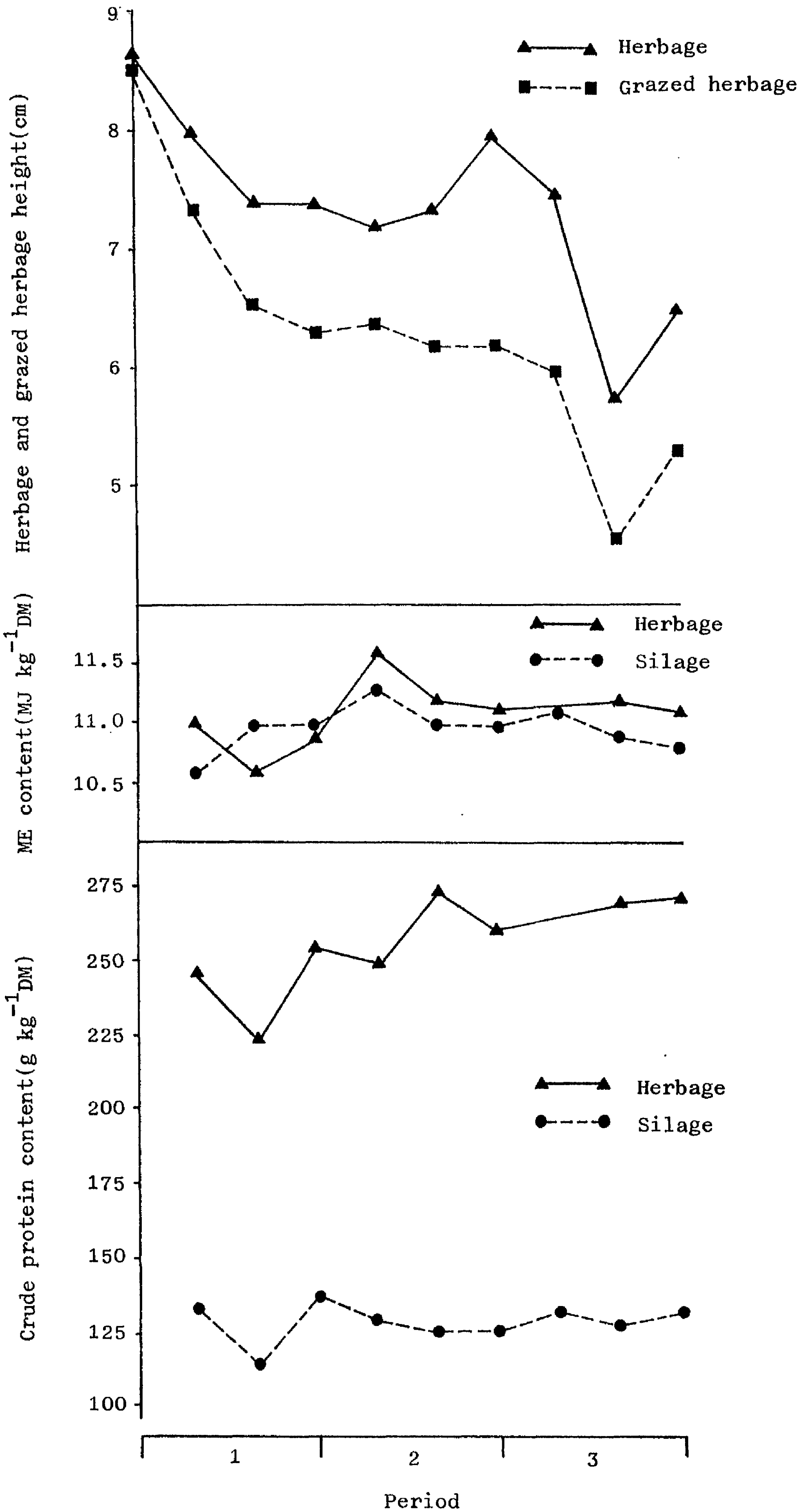


Figure 5.1 Herbage height and chemical composition of the feeds

Table 5.1 Chemical composition of the feeds (g kg^{-1} DM unless otherwise stated)

	Herbage	Silage	Concentrates
Dry matter (g kg^{-1})	161	261	874
ME (MJ kg^{-1} DM)	11.2	10.9	13.0
Organic matter	898	904	902
Crude protein	258	129	193
In vitro digestibility	650	697	748
Calcium	4.4	5.3	11.5
Phosphorus	5.0	3.4	8.1
Magnesium	2.1	2.2	5.2
Potassium	36.2	-	-
Ammonia nitrogen (g kg^{-1} total N)	-	98	-
pH (units)	-	4.0	-

Table 5.2 Feed intake

	Treatment					Period			
	G	GMS	GAS	SED	Significance	1	2	3	Significance
Herbage DM intake (kg day^{-1})	10.2^{a}	7.4^{b}	2.6^{c}	0.58	***	7.6	6.9	5.8	**
Silage DM intake (kg day^{-1})	-	4.1^{b}	10.4^{a}	0.37	***	4.4	4.7	5.0	NS
Concentrate DM intake (kg day^{-1})	2.6	2.6	2.6			2.6	2.6	2.6	
Total DM intake (kg day^{-1})	12.6^{b}	13.8^{b}	15.6^{a}	0.64	***	14.6	14.2	13.4	**
Metabolizable energy intake † (MJ day^{-1})	147^{b}	162^{a}	176^{a}	6.88	**	171	165	148	**
Crude protein intake (g day^{-1})	3144	2953	2503						
RDP intake (g day^{-1})‡	1675-2304	1685-2276	1623-2124						
RDP output (g day^{-1})	1144	1261	1369						
UDP intake (g day^{-1})‡	844-1473	680-1272	383-884						
UDP output (g day^{-1})	684	760	796						

† MAFF *et al*, 1975

‡ Calculated for the range in degradabilities suggested by ARC (1980) - herbage 0.5-0.7, silage and concentrates 0.7-0.9

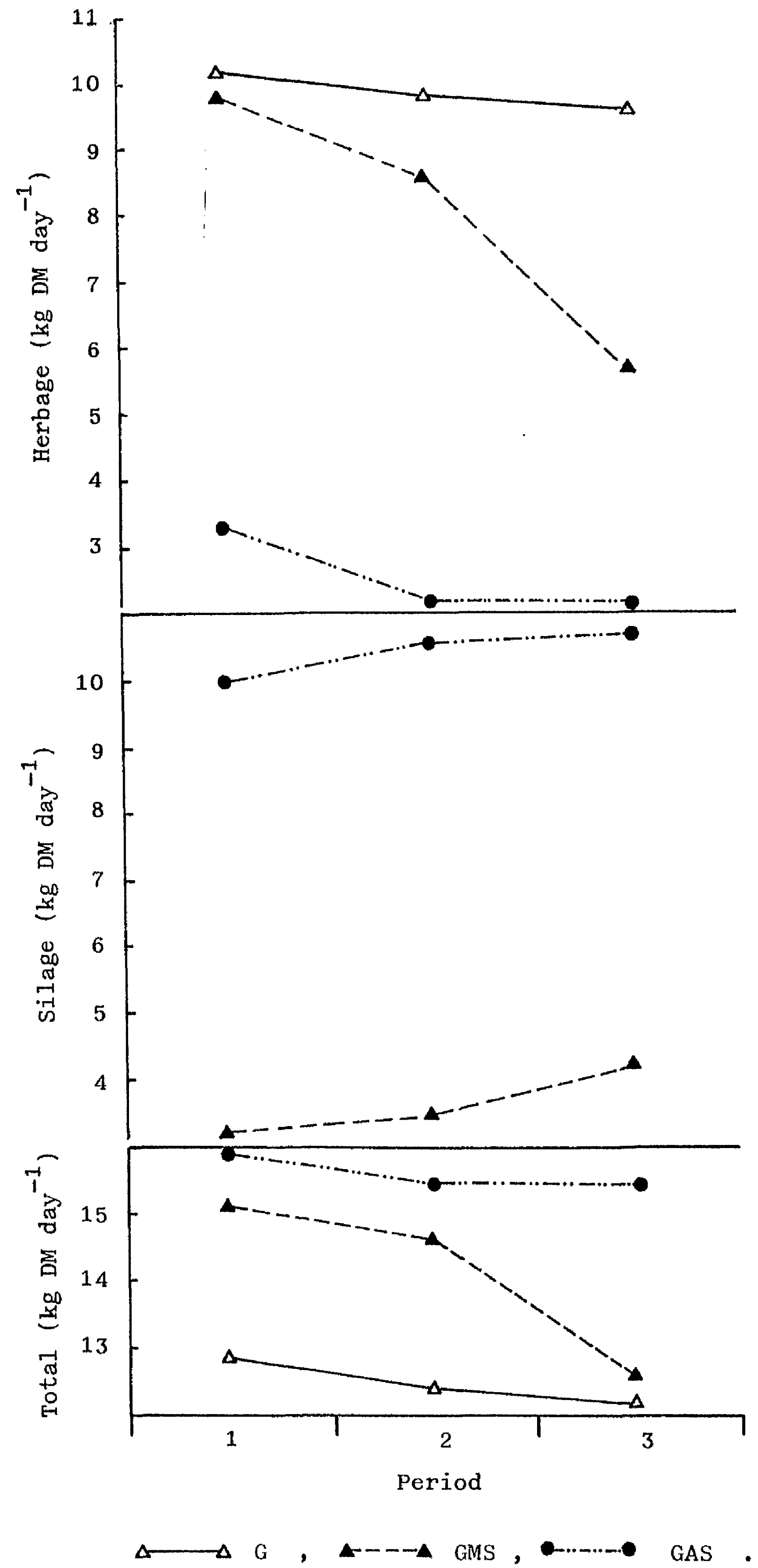


Figure 5.2 Variation in feed intake over the three periods

length of time for which cows in treatment GMS were offered silage was 67 minutes, with little difference between periods. Silage DM intakes tended to increase over the season as herbage DM intakes declined, although this difference was not significant. In treatment GMS silage DM intake was significantly related to mean daily rainfall:

$$y = 3.2 + 0.033x; \quad (r = 0.26^{*}) \qquad \text{equation 9}$$

where x = rainfall (mm day^{-1})

y = silage DM intake (kg day^{-1})

Total DM intakes were increased by offering silage, especially in treatment GAS. Mean substitution rates (kg herbage DM kg^{-1} silage DM) for treatments GMS and GAS were 0.68 and 0.74 respectively. Total DM intakes declined over the course of the experiment. ME intakes were similarly increased by offering silage and declined through the season.

Intake of crude protein was decreased by offering silage, despite higher total DM intakes, because of the low crude protein content of the silage compared with herbage. Supply of RDP was adequate in all treatments, but UDP was probably limiting in treatment GAS and possibly treatment GMS, depending upon the actual degradabilities of the feeds.

5.3.5 Cow behaviour

Grazing time was depressed by offering silage (table 5.3), on average by 27 and 33 minutes kg^{-1} silage DM for treatments GMS and GAS respectively. Grazing time in treatment G was higher than for similar cows earlier in the season (4.3.5) but was similar in

Table 5.3 Cow behaviour

	Treatment					Period			
Time (h day^{-1}) spent:	G	GMS	GAS	SED	Significance	1	2	3	Significance
Grazing	9.4^{a}	7.6^{b}	3.8^{c}	0.18	***	7.1	6.5	7.2	***
Eating silage	-	0.8^{b}	3.3^{a}	0.13	***	1.2	1.5	1.4	*
Standing	2.5^{c}	3.1^{b}	3.8^{a}	0.21	***	3.2	3.2	3.0	NS
Standing and ruminating	0.8^{b}	1.2^{b}	3.4^{a}	0.41	***	2.6	1.9	1.0	**
Lying	5.1^{a}	4.3^{b}	3.0^{c}	0.23	***	3.7	4.3	4.4	**
Lying and ruminating	5.6	6.4	6.3	0.43	NS	5.8	6.1	6.6	NS
Ruminating	6.4^{c}	7.7^{b}	9.8^{a}	0.27	***	8.3	7.3	7.6	*
Walking †	0.6^{a}	0.6^{a}	0.3^{b}	0.02	***	0.5	0.6	0.4	***

† On average 95% of time spent walking was to and from pasture.

treatments GMS and GAS. It was significantly lower in treatment GAS in period 2 but there was little change over the season in treatments G and GMS (figure 5.3). This and other period differences may have been confounded by varying weather conditions and cow groups in the three periods. Cows offered silage after morning milking ate for 43 minutes on average.

Offering silage increased ruminating time, particularly in treatment GAS. Ruminating time was highest in period 1, probably due to higher feed intakes at this time (table 5.2).

As was found earlier in the season cows housed overnight (treatment GAS) spent more of their time between afternoon and morning milking standing/standing and ruminating and less time lying/lying and ruminating than those cows at pasture overnight (table 5.4). Between morning and afternoon milking this situation was reversed, with cows receiving silage overnight spending more time lying/lying and ruminating than those cows at pasture overnight. As the season progressed cows in treatment GAS tended to spend more time lying and ruminating and less time standing and ruminating (figure 5.3). These cows also spent less time eating either during the day (grazing) or at night.

The diurnal variation in time spent grazing, eating silage and ruminating is shown in figure 5.4. In treatment G there were three major grazing bouts - two between morning and afternoon milking and one in the evening. There was also a smaller peak of grazing activity at midnight. The pattern was similar in treatment GMS except that the first grazing bout after morning

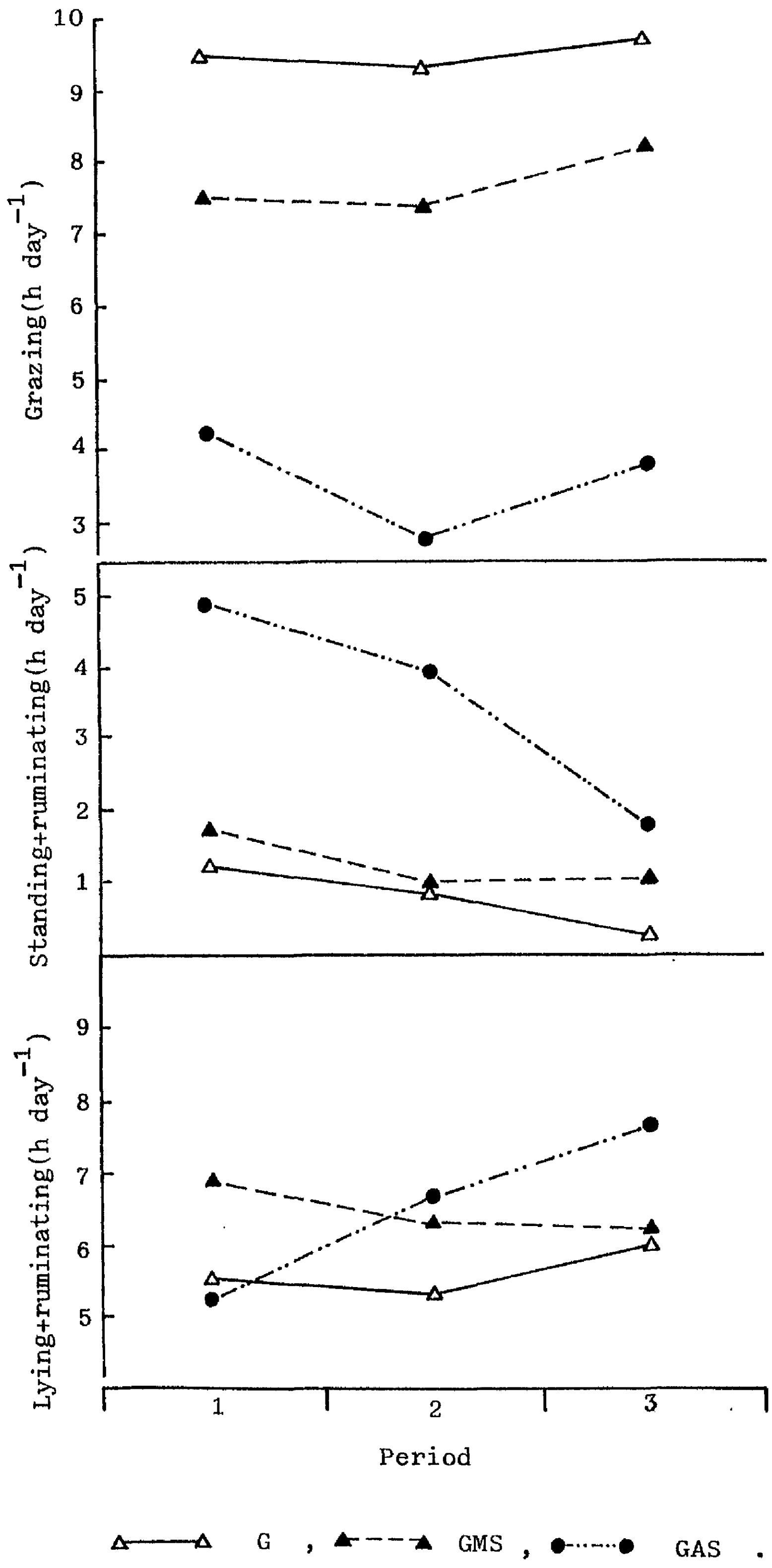


Figure 5.3 Variation cow behaviour over the three periods

Table 5.4 The effect of housing overnight on cow behaviour

	Time (h)	Cows at pasture (G and GMS)	Cows housed overnight (GAS)
Lying/lying and ruminating	07.00-16.00	1.1	3.2
	16.00-07.00	8.9	6.1
Standing/standing and ruminating	07.00-16.00	2.1	1.8
	16.00-07.00	1.6	5.5
Ruminating	07.00-16.00	1.9	2.7
	16.00-07.00	5.2	6.9
Total eating time (grazing + eating silage)	07.00-16.00	4.1	3.7
	16.00-07.00	4.4	3.2

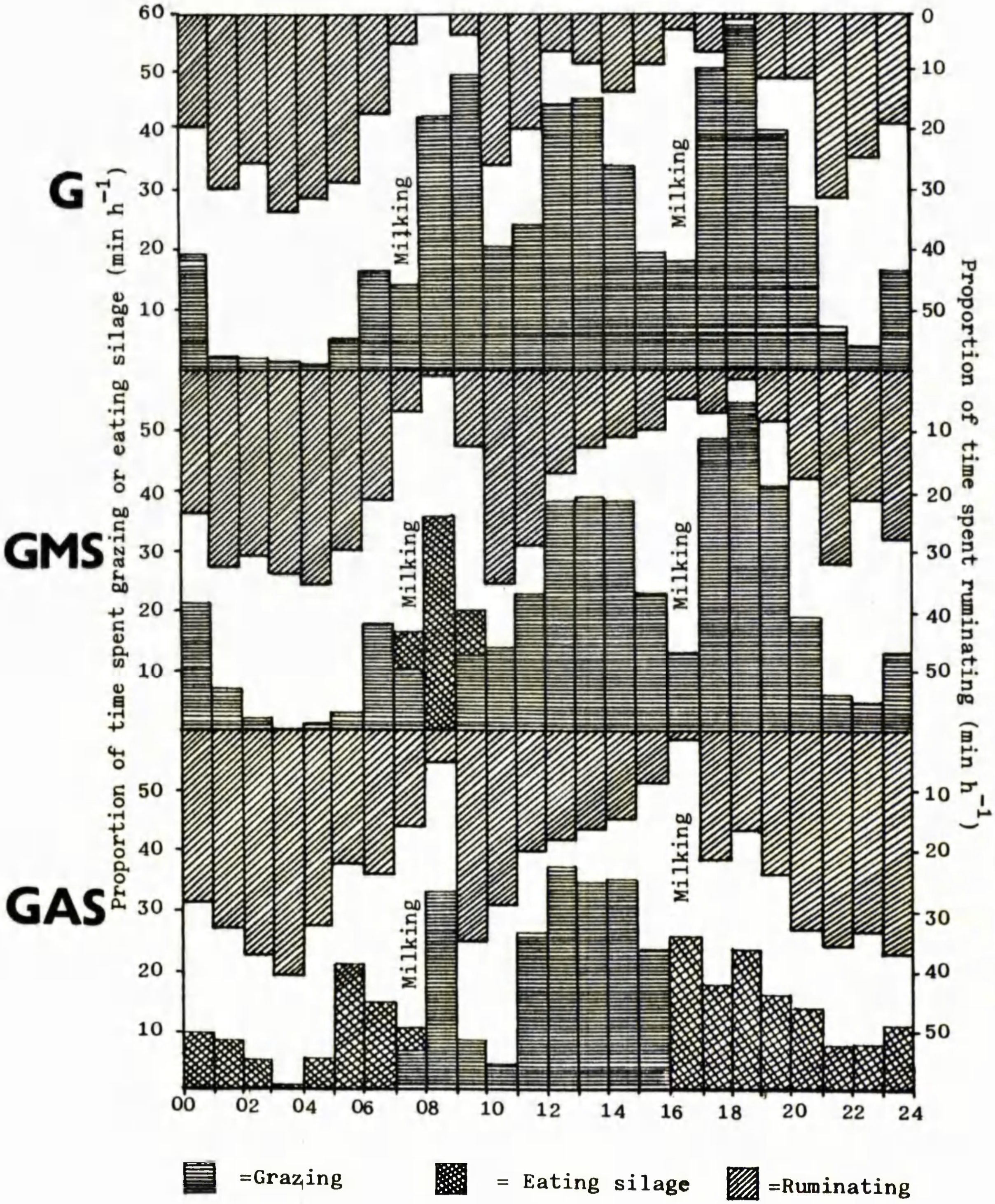


Figure 5.4 Diurnal variation in ingestive behaviour

milking was largely replaced by silage feeding. In treatment GAS most of the grazing activity was concentrated into the afternoon and silage feeding was predominantly in the evening, except for a peak around 06.00 hours.

Ruminating activity was mainly at night in treatment G but feeding silage after morning milking (GMS) increased the time spent ruminating between morning and afternoon milking.

Biting rate tended to be decreased by offering silage, particularly in treatment GAS, and this difference approached significance (table 5.5).It also tended to increase through the day and offering silage after morning milking decreased biting rate in the morning. Despite declining herbage height there was only a small increase in biting rate over the course of the experiment.

The number of daily grazing bites was high in treatment G and was reduced by offering silage - a reflection of lower grazing times and biting rates. Derived bite size and herbage intake rate were low and were also reduced by offering silage. Bite size and herbage intake rate were reduced in period 3 when grazed herbage height was lowest.

Silage intake rates were higher than recorded earlier in the season and were highest when silage was offered after morning milking. Silage intake rates declined over the course of the experiment.

Table 5.5 Ingestive behaviour

		Treatment					Period			
		G	GMS	GAS	SED	Significance	1	2	3	Significance
HERBAGE										
Biting rate (bites min^{-1})	09.15 h	65.7	60.5	61.9						
	13.20 h	65.2	64.3	64.0						
	17.40 h	66.8	68.1	-						
		66.1	64.7	63.0	1.25	NS	63.4	65.2	65.2	NS
Bites day^{-1}		$37,252^{a}$	$29,338^{b}$	$14,010^{c}$	958	***	27,050	25,319	28,231	**
Derived bite size (g DM)		0.29^{a}	0.26^{a}	0.20^{b}	0.026	**	0.27	0.28	0.19	**
Derived herbage intake rate (g DM min^{-1})		18.3^{a}	16.2^{ab}	12.6^{b}	1.83	*	16.8	17.6	12.6	*
SILAGE										
Silage intake rate (g DM min^{-1})		-	69.7	55.6			68.7†	63.4†	55.8†	

† mean of treatments GMS and GAS

5.3.6 Animal production

Milk yield was not significantly affected by treatment (table 5.6), although it tended to be increased by offering silage in period 3 when rainfall was high (figure 5.5).

Milk fat content and milk fat yield were significantly increased by offering silage overnight, and milk fat yield also tended to be increased in treatment GMS. The rapid decline in milk yield in treatment G in period 3 was accompanied by a marked increase in milk fat and protein contents.

Milk protein content was not significantly affected by treatment, although it tended to be depressed when silage was fed overnight. Over the course of the experiment milk yield declined and milk fat and protein content increased, reflecting stage of lactation differences.

Milk lactose content was significantly increased by offering silage overnight, this difference mainly occurring in the final period.

Liveweight gain was significantly increased by offering silage, in particular in treatment GAS. Although not significant, liveweight gain tended to be reduced in period 3.

5.3.7 Coefficients of variation

The coefficient of variation of individual cow milk yields over the last six days of each period tended to be reduced by offering

Table 5.6 Animal production

	Treatment					Period			
	G	GMS	GAS	SED	Significance	1	2	3	Significance
Milk yield (kg day^{-1})	13.7	14.3	14.1	0.32	NS	15.6	14.4	12.1	***
Fat content (g kg^{-1})	41.3^{b}	41.4^{b}	44.1^{a}	0.94	*	40.4	41.3	45.0	***
Protein content (g kg^{-1})	38.7	38.7	37.9	0.63	NS	37.9	39.2	41.1	***
Lactose content (g kg^{-1})	46.1^{b}	46.8^{a}	47.2^{a}	0.32	*	47.0	46.6	46.4	NS
Fat yield (g day^{-1})	553^{b}	587^{ab}	617^{a}	18.5	**	629	591	538	***
Protein yield (g day^{-1})	522	547	531	10.5	NS	567	541	492	***
Lactose yield (g day^{-1})	633	668	661	16.9	NS	731	672	559	***
Liveweight gain (kg day^{-1})	0.31^{b}	0.65^{ab}	1.02^{a}	0.20	**	0.71	0.75	0.48	NS

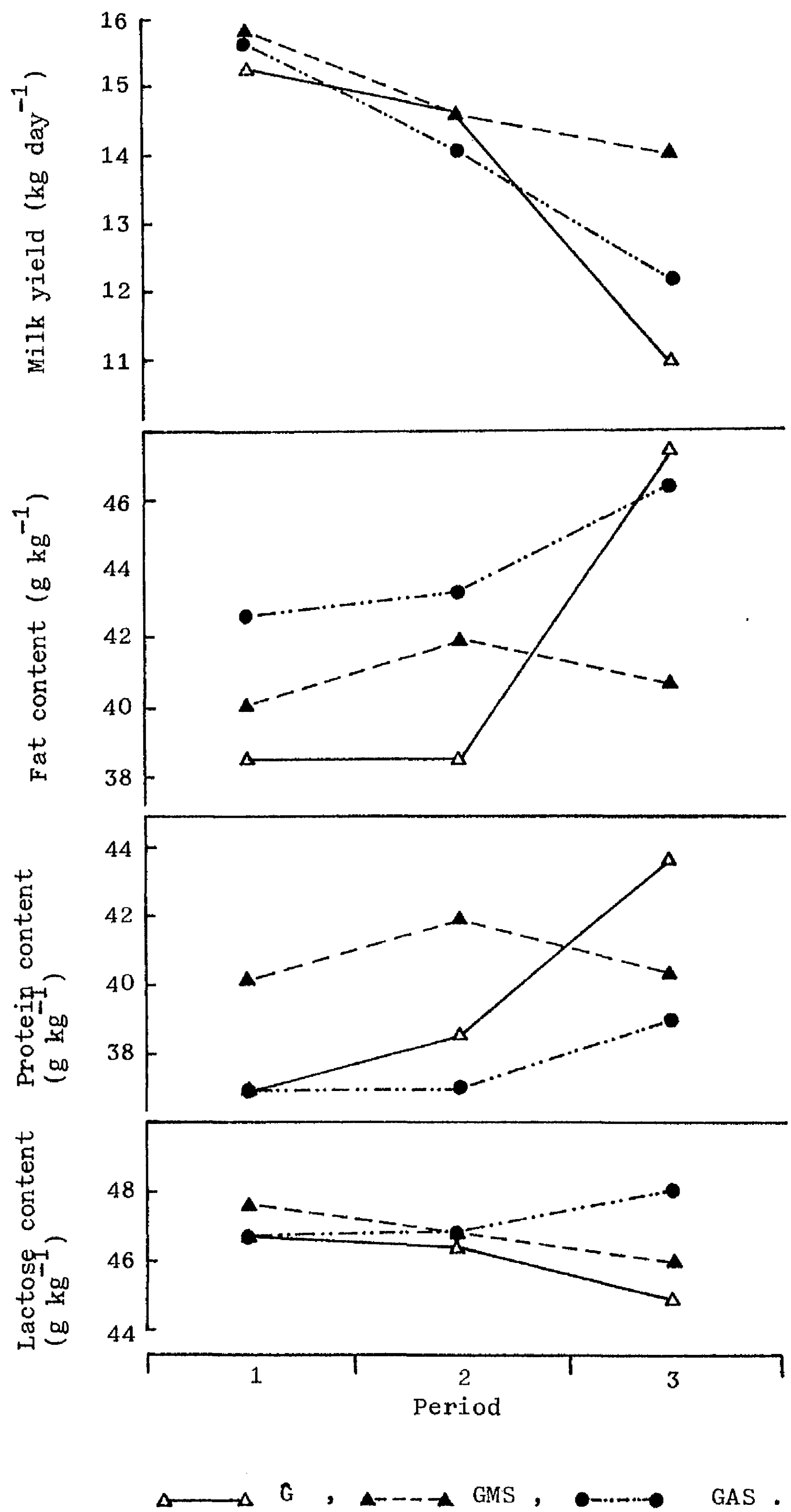


Figure 5.5 Variation in milk yield and composition over the three periods.

silage overnight (table 5.7). There was little difference in the coefficient of variation of silage DM intake between treatments GMS and GAS.

Table 5.7 Coefficient of variation (%) of milk yield and silage DM intake over the last six days of each period

	G	GMS	GAS	SED	Significance
Milk yield	7.6	7.4	5.8	1.19	NS
Silage DM intake	-	12.1	10.8		

5.3.8 Residual effects

Significant residual effects are listed in appendix 15. These were mainly in ingestive behaviour. Grazing time and herbage DM intake of cows in treatment GMS may have been increased by experimental treatment in the previous period and this was reflected in significant residual effects in milk protein yield. It is also possible that the grazing time of cows in treatment GAS was lower than it would have been in a continuous trial.

There were no significant residual effects on silage DM intake, although the change in intake over the 21 days of each period suggests that the cows may not have reached maximum intake by day 15 when measurements commenced (figure 5.6).

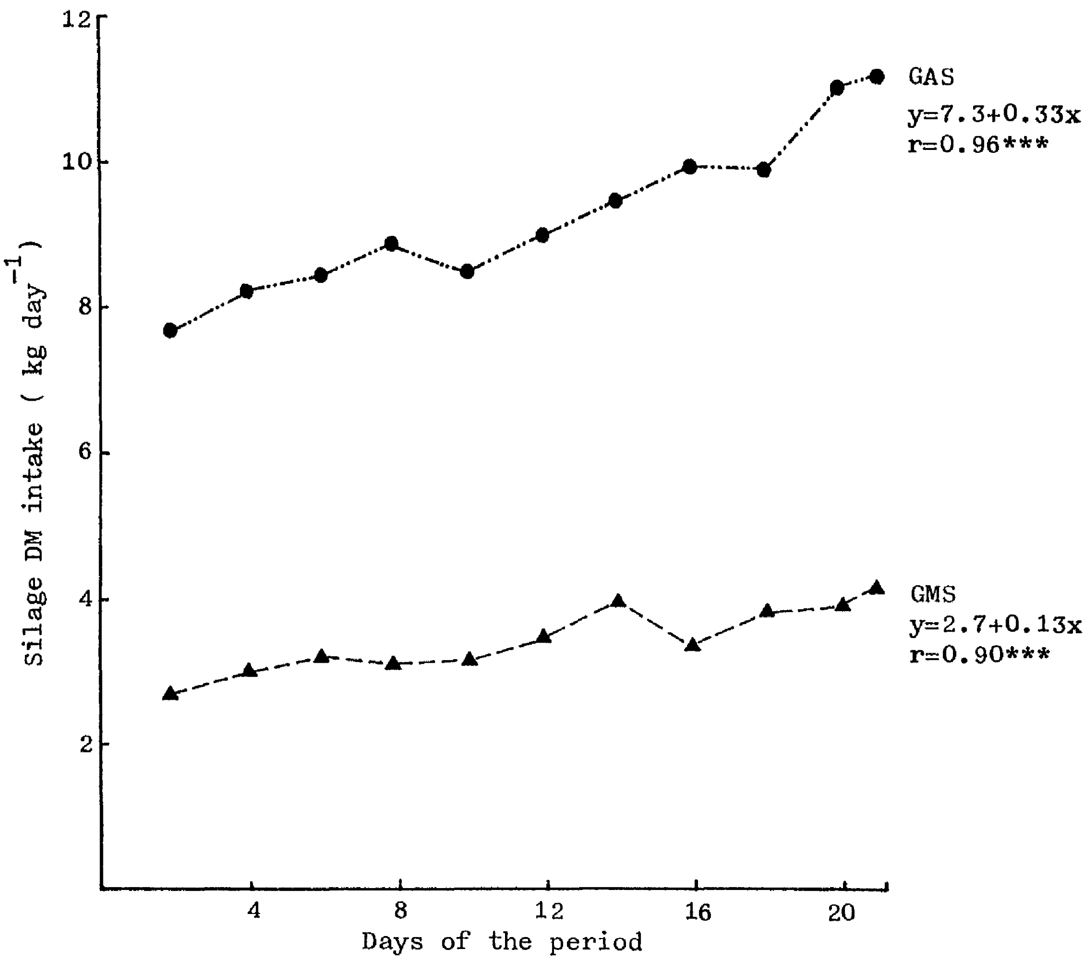


Figure 5.6 Change in silage DM intake in each period

5.4 DISCUSSION

5.4.1 Animal production

Offering silage increased ME intake, particularly when offered overnight, and most of this extra output was directed towards liveweight gain. This is not surprising since the cows were on average in their sixth month of lactation at the start of the experiment and were therefore likely to respond to extra energy intake by increasing live weight rather than milk production (Broster, 1972). In addition most of the animals were heifers which partition relatively more energy to liveweight change and less to milk production compared with cows (Broster, 1972).

For spring-calving cows it is more efficient to replenish in late lactation the fat depots that were utilized in early lactation, rather than in the dry period (Moe *et al*, 1971). To this end a liveweight gain of at least 0.5 kg day^{-1} is required at this time (ADAS, 1978). For heifers a higher liveweight gain is required in order to ultimately achieve mature live weight. In this experiment the heifers were on average only 500 kg at the start of the experiment compared with a mature live weight of cows in this herd of 630 kg, and a high liveweight gain at this time could increase subsequent milk production.

The errors in measurement of liveweight change under similar circumstances have been discussed in section 4.4.1 and the same considerations apply in this experiment.

The increased ME intake is in contrast to results from earlier in the grazing season (experiment 2). Grazed herbage height at its minimum - 5 cm by MMB rising plate meter, equivalent to 6.6 cm on a graduated ruler (Baker, 1980) - probably did not greatly restrict herbage DM intake (Le Du and Hutchinson, 1982). However, the high rainfall in period 3 (mean herbage DM content of 120 g kg^{-1} at this time) probably did restrict herbage DM intake. A possible mechanism is reduced bite size of herbage DM - mean herbage bite size in periods 1, 2 and 3 was 1.54, 1.55 and 1.58 g freshweight but 0.27, 0.28 and 0.19 g DM respectively. High grazing times and biting rates in treatment G suggest that grazing behaviour was modified in an attempt to minimize any restriction on herbage DM intake. In addition high dead matter content of the herbage and the high degree of faecal contamination of the pasture may have intrinsically depressed herbage DM intake.

Under these circumstances offering silage that was consumed at 70 g DM min^{-1} when offered for one hour and 56 g DM min^{-1} when offered overnight, compared with only 18 g DM min^{-1} for fresh herbage, resulted in a substantial increase in DM intake.

The importance of weather conditions as a factor affecting herbage DM intake has been demonstrated by Slade (C R, personal communication), who offered September calving cows either unrestricted herbage or *ad libitum* silage as the basal forage after calving. This was examined for three years and the results show that in a wet autumn milk production was highest from cows offered silage, whereas in dry weather the reverse was true. Other workers have found that prolonged periods of inclement weather result in a rapid decline in the milk yield of grazing cows even when herbage is unrestricted (ADAS, 1981).

The increase in milk fat content when silage was offered overnight could have been due either to the increase in crude fibre content of the diet compared with treatment G or the increase in energy intake.

If the crude fibre contents of the feeds are estimated as 200, 300 and 50 g kg^{-1} DM for herbage, silage and concentrates respectively (MAFF *et al*, 1975) then dietary crude fibre concentrations were 172, 206 and 242 g kg^{-1} DM for treatments G, GMS and GAS respectively. Reports in the literature suggest that there is no increase in milk fat production above crude fibre contents of 200 g kg^{-1} DM (section 4.4.1).

The increase in fat yield in this experiment when silage was offered overnight was 2.2 g MJ^{-1} of additional ME intake. This is similar to the value of 2.2 g MJ^{-1} of additional digestible energy from Sutton *et al* (1978), where the concentrate;forage ratio was constant at both levels of energy intake. The increase in milk fat yield in the latter experiment was manifested by an increase in milk yield and fat content, but the absence of a significant increase in milk yield in this experiment may be attributable to the low level of milk yield. In other experiments the effect of increasing energy intake on milk fat content has been obscured by an increasing concentrate:forage ratio. It is likely in this experiment that increased energy intake and possibly crude fibre intake caused the increase in milk fat content.

The depression in milk protein content when silage was fed overnight is similar to that found in experiment 1 and probably represents a decrease in the non-protein-nitrogen content of the milk. With isonitrogenous diets an increase in energy intake results in an increase in milk protein content, but in this case, the large difference in crude protein contents of the diets (249, 213 and 161 g kg^{-1} DM for treatments G, GMS and GAS respectively) had an over-riding effect on milk protein content.

Despite the conventional view among dairy scientists that the lactose content of the milk is immutable (eg Schmidt and Van Vleck, 1974), several experiments have shown that improved feeding can increase milk lactose content (Rook and Storry, 1964), albeit to a lesser extent than milk fat and protein content. In addition high stocking rates and correspondingly low feeding levels were found to depress milk lactose content in experiment 1 (3.3.6). The increase in milk lactose content when silage was fed overnight in this experiment is therefore indicative of a higher plane of nutrition and to some extent dispels any doubts about the accuracy of herbage DM intake measurements.

5.4.2 Feed intake

An important difference between this experiment and experiment 2 is that silage and herbage were of similar energy content in this experiment, whereas herbage was of 1.7 MJ kg^{-1} DM higher ME content in experiment 1. Cows that received silage overnight may have preferred silage to herbage due to its ease of prehension. Evidence for this comes from the period of silage feeding before being taken to pasture and the low grazing times of these cows. In addition biting rate and bite size tended to be reduced, suggesting less intensive grazing compared with cows in treatment G. However, even if silage was preferred to herbage, cows in treatment GAS still ate some herbage, and this made a useful contribution to the intake of UDP, which could have been limiting.

It was not determined in this experiment whether feeding high quality silage overnight at this stage in the grazing season would result in poor herbage utilization, even if stocking rates at pasture were high. From herbage DM intakes the effective stocking rates at pasture were 3.4, 4.6 and 13.5 cows ha^{-1} for G, GMS & GAS, but even if cows offered silage overnight were stocked at 13 cows ha^{-1} it is unlikely that herbage utilization would be high because of the low intensity of grazing. In such circumstances it is likely that the area of herbage rejected around each faecal deposit would be high and problems could arise with excessive poaching at the gateways. It should be remembered, however, that the cows are only passing through the gateways twice a day and only 35-40% of the faeces is deposited on the day pasture (MaClusky, 1959).

Although cows in treatment GMS were allowed access to silage until they had stopped eating, intakes of ME were still less than when silage was offered overnight. Maximum silage DM intake after morning milking was 5 kg cow^{-1}. Meal time of silage is low compared with hay, particularly for very acidic silages (Campling and Morgan, 1981), and this property of silage may have limited the intake of cows in treatment GMS. Intake could have been limited by gut fill, but this is unlikely since there was usually a period of grazing after these cows were returned to the field. Offering silage after morning and afternoon milking could increase the buffering effect of silage without restricting herbage DM intake by housing the cows overnight.

The total output of UME in this experiment was 24.0 GJ ha^{-1}, which is equivalent to 2.1 tonnes herbage DM. In experiment 1 outputs of 19 GJ ha^{-1} were achieved over a similar time period.

5.4.3 Grazing behaviour

The high grazing times and biting rates in treatment G suggest that grazing behaviour was adapted to compensate for low bite size (g DM). The number of bites day^{-1} for the heifers in treatment G (38,223) was considerably higher than the maximum proposed by Stobbs (1973); that of the cows was lower than the heifers (36,247) because of a lower biting rate (as was found in experiment 2) rather than a lower grazing time. Mean bite size of the cows and heifers (0.29 g DM) was similar to the limiting bite size of 0.30 g DM proposed by Stobbs (1973).

Ruminating times in this experiment were 38 minutes kg^{-1} herbage DM and 45 minutes kg^{-1} silage DM (calculated as in experiment 2). These values are similar to those obtained in experiment 2 although higher ruminating times kg^{-1} DM for heifers compared with cows (experiment 2) prevents detailed comparison.

As in experiment 2 cows housed overnight spent more time standing/standing and ruminating and less time lying/lying and ruminating than cows at pasture overnight. This difference was observed in both buildings used for overnight housing and is unlikely to have been caused by unsuitable cubicles.

5.5 SUMMARY

The effects on the performance and behaviour of set-stocked dairy cows of offering silage as a buffer to variation in herbage DM intake was examined in the late part of the grazing season. Silage was offered *ad libitum* either after morning milking or indoors overnight with adequate pasture available at all other times. These systems including silage as a buffer feed were compared with a grazing only treatment with no buffer feed.

Silage DM intakes were highest when silage was offered overnight and in this treatment herbage comprised only 20% of the total forage DM intake. However total DM intakes were increased both in this treatment and, to a lesser extent, when silage was offered after morning milking. Mean substitution rate was 0.7 kg herbage DM kg^{-1} silage DM.

Offering silage tended to increase milk yield and milk fat content, but most of the extra energy intake was utilized for liveweight gain, because of the late stage of lactation and high proportion of heifers. Milk lactose content was increased and milk protein content tended to be decreased by offering silage overnight.

Cows fed silage overnight had a lower intensity of grazing during the day, with lower grazing times, biting rates and bite size. Ruminating times were increased by offering silage.

In this period of relatively high rainfall and a high degree of faecal contamination of the pasture, with a correspondingly low herbage DM intake, the need for a buffer feed was evident. Offering silage after morning milking did not result in as great an increase in production as when silage was offered overnight.

CHAPTER 6

EXPERIMENT 4. THE EFFECT OF RESTRICTION OF SILAGE DM INTAKE AND THE PROVISION OF HAY AS A BUFFER FEED ON DAIRY COW PRODUCTION

6.1 INTRODUCTION

The silage DM intake of dairy cows may be restricted for several reasons in a winter feeding regime. Firstly, the conservation of silage may be insufficient to maintain *ad libitum* intakes throughout the winter, and a restriction is implemented by reducing the amount of silage offered to the cows in a passageway feeding system or by restricting the movement of a barrier or access to the silage face in a self-feeding system. Secondly, silage DM intake may be restricted by making the cows clear up all the silage offered in a passageway or by a restricted width of feeding space per cow in a passageway or self-feeding system. Thirdly, low silage quality may restrict both silage DM intake and the nutrients obtainable from the silage. Finally, by restricting silage DM intake farm stocking rates can be increased as it is possible to carry more cows on the same area of land.

In these situations provision of an alternative forage to buffer the reduced silage DM intake could increase forage DM intake and improve milk production. A suitable forage for this purpose is hay since it is of similar nutritional value to silage and is readily purchased. However, if the hay is preferred to the silage, it may be necessary to restrict hay DM intakes so that the hay will not substitute for the restricted ration of silage. In this experiment, therefore, hay was offered *ad libitum* for 90 minutes after morning milking.

This experiment examined the effects of offering silage either *ad libitum* or at a restricted level and of offering hay as a buffer feed at both silage levels.

6.2 MATERIAL AND METHODS

6.2.1 Design

Twelve British Friesian cows and four British Friesian heifers were allocated to four treatment groups of a balanced changeover (Latin Square) design (appendix 12): A - *ad libitum* silage; Ah - *ad libitum* silage + hay; R - restricted silage and Rh - restricted silage + hay. In addition all cows received 9 kg concentrate day^{-1}. The experiment comprised four 3 week periods and ran from 8 January to 1 April 1981.

Cows were allocated to the four blocks of the Latin Square design so that the cows within each block were as similar as possible in milk yield, live weight, parity, calving date and condition score. At the start of the experiment average milk yield (kg day^{-1}), liveweight (kg) and condition score for the 16 cows were 24.2 (range 16.5-30.2), 583 (range 450-660) and 2.4 (range 2.0-3.0) respectively. Mean calving date was 16 November (range 16 October - 27 November).

6.2.2 Dairy cow and feed management

Cows were group housed with access to 16 cubicles. Feed was offered in individual boxes fitted with Calan gates (American Calan Inc.,Northwood, USA), activated by transponders suspended from the cows' necks (Broadbent *et al*, 1970). Boxes were sited either side of a central passage adjacent to the cubicle area.

After training the cows to open the Calan gates, cows were offered silage *ad libitum* and 9 kg concentrates daily for two weeks prior to the start of the experiment. The restricted silage ration for each cow was then calculated as 80% of the average daily silage DM intake of that cow eaten in the final week of the pre-experimental period.

During the experiment silage refusals on treatments A and Ah were weighed daily immediately before hay was offered *ad libitum* for one and a half hours at 08.30 h.to cows on treatments Ah and Rh. Hay refusals were then weighed and fresh silage rations placed in the boxes. Both forages were offered in sufficient quantities to ensure that 10-15% of the original weight was available as a residue when offered *ad libitum*. Hay was chopped using a precision-chop forage harvester to prevent it being pulled out of the feeding boxes. Silage was from a predominantly perennial ryegrass (Lolium perenne) and white clover (Trifolium repens) sward that was harvested as described in section 4.2.3.

Concentrates were offered at the same level - 9 kg freshweight day^{-1} - to all cows throughout the experiment. Of this 1 kg was fed in the parlour at each milking, and 3.5 kg was fed in the boxes after the afternoon milking. The remaining 3.5 kg was fed at the start of the hay feeding, those cows not receiving hay being removed to the cubicle area when they had consumed their concentrate ration. The composition of the concentrate cube is given in appendix 11.

Water was freely available to all cows in the feeding area. Cows were milked twice daily at 07.00 and 17.00 h.

6.2.3 Dairy cow and feed measurements

Milk yields were recorded at each milking during the last six days of each period and in the first six days of periods 2, 3 and 4. Rate of change of milk yield was calculated by regression of these milk yield recordings.

Aliquot samples of milk were taken at each milking in the last two days of each period and in the fifth and sixth days of periods 2, 3 and 4. Samples were analysed for fat, protein and lactose content using a 1st Electric Milkoscan 203 (Biggs, 1979).

Live weight was recorded on days 7, 14 and 21 of each period and liveweight change was calculated for each cow by linear regression.

Hay, silage and concentrates were sampled once a week for the determination of chemical composition. An additional oven DM determination of silage and hay samples was performed daily for the calculation of DM intake. *In vitro* digestibilities of the feeds were determined according to Alexander and McGowan (1966, 1969) and the equation used for the prediction of the metabolizable energy (ME) content of the feeds is shown in appendix 7. The output of ME was calculated from MAFF *et al* (1975), and the intake and requirement of rumen-degradable protein (RDP) and undegradable protein (UDP) were calculated from ARC (1980).

6.2.4 Statistical analysis

The significance of the treatment differences was examined by the method of Patterson and Lucas (1962). This method also examined the effect of treatment in the previous experimental period on treatment effects (residual effects). Differences between individual treatment means were tested by Student's "t" test, and significant differences ($P<0.05$) are indicated by different superscripts.

The health of all animals on the experiment was satisfactory and there were no missing plots.

6.3 RESULTS

6.3.1 Feed composition

Silage was relatively mature and had a low energy content (table 6.1). In addition it had a high ammonia-nitrogen content and pH, and a substantial proportion had undergone a butyric fermentation. Hay was of good quality with a high energy and crude protein content.

6.3.2 Feed intake

Restricting the silage ration reduced intake to 62% of *ad libitum* intake (treatment R compared with treatment A, table 6.2). This was lower than expected due to higher *ad libitum* silage DM intakes during the experiment compared with in the pre-experimental period, as a result of low silage quality in the latter (7.0 MJ kg^{-1} DM; 262 g ammonia N kg^{-1} total N; pH 5.0).

When silage was offered *ad libitum*, offering hay depressed silage DM intake, on average by 0.67 kg silage DM kg^{-1} hay DM. When silage was offered at a restricted level there was no

Table 6.1 Chemical composition of the feeds (g kg^{-1} DM unless otherwise stated)

	Silage	Hay	Concentrates
Dry matter (g kg^{-1})	205	810	861
ME (MJ kg^{-1} DM)	8.2	10.0	13.2
Organic matter	890	898	894
Crude protein	151	164	197
In vitro digestibility	560	678	748
Calcium	5.1	4.6	11.1
Phosphorus	3.5	4.4	6.8
Magnesium	2.3	1.9	7.1
Ammonia nitrogen (g kg^{-1} total N)	139	-	-
pH (units)	4.4	-	-

Table 6.2 Feed intake (kg day^{-1})

	A	Ah	R	Rh	SED	Significance
Silage DM	7.8^{a}	6.0^{b}	4.8^{c}	4.7^{c}	0.22	***
Hay DM	–	2.7^{b}	–	3.1^{a}	0.16	***
Forage DM	7.8^{b}	8.7^{a}	4.8^{c}	7.8^{b}	0.21	***
Concentrate DM	7.7	7.7	7.7	7.7		
Total DM	15.6^{b}	16.5^{a}	12.6^{c}	15.5^{b}	0.21	***

substitution of silage for hay. Hay DM intakes were lower when silage was offered *ad libitum*.

Total DM intake was increased by offering hay, both when silage was offered *ad libitum* and at a restricted level. As a result total DM intake was highest when hay was offered with *ad libitum* silage. Cows offered hay with restricted silage (treatment Rh) had a similar total DM intake to cows offered silage *ad libitum* (treatment A).

6.3.3 Animal production

Milk yield was significantly increased by offering hay but was not affected by restricting the silage ration (table 6.3). There were no significant effects on the fat or lactose content of the milk but milk protein content was significantly reduced in treatment R.

Milk protein and lactose yield were significantly increased by offering hay. Restricting the silage ration reduced the yield of milk protein and tended to reduce the yield of milk fat.

In all treatments cows on average lost weight over the course of the experiment. In treatment R loss of live weight was particularly high.

The average rate of decline of milk yield over the first and last six days and the entire period is shown in table 6.4. In the first six days restricting the silage ration (treatments R and Rh) increased the rate of milk yield decline, but in the third week the

Table 6.3 Animal production

	A	Ah	R	Rh	SED	Significance
Milk yield (kg day^{-1})	21.8^{b}	22.9^{a}	21.4^{b}	22.9^{b}	0.32	***
Fat content (g kg^{-1})	37.1	36.3	36.4	36.6	0.84	NS
Protein content (g kg^{-1})	32.0^{a}	32.1^{a}	30.8^{b}	31.9^{a}	0.35	**
Lactose content (g kg^{-1})	48.2	48.4	48.3	48.4	0.33	NS
Fat yield (g day^{-1})	806	826	785	837	23.2	NS
Protein yield (g day^{-1})	694^{b}	729^{a}	655^{c}	727^{a}	13.0	***
Lactose yield (g day^{-1})	1049^{b}	1107^{a}	1036^{b}	1107^{a}	18.4	***
Liveweight change (kg day^{-1})	-0.02^{a}	-0.11^{a}	-1.18^{b}	-0.22^{a}	0.36	*

Table 6.4 Rate of decline of milk yield

	A	Ah	R	Rh
Milk yield decline (kg day^{-2})				
First 6 days of each period	+0.030	+0.023	-0.174	-0.099
Last 6 days of each period	-0.230	-0.031	-0.236	-0.065
Entire period	-0.028	-0.013	-0.089	-0.035

dominant effect was a reduced rate of decline for those cows offered hay. Overall, cows in treatment R tended to have a more rapid rate of decline than cows in the other three treatments.

6.3.4 Nutrient intake and output

Cows offered *ad libitum* silage plus hay had the highest ME intake, and cows offered restricted silage the lowest (table 6.5). Despite similar total DM intakes (table 6.5) cows in treatment Rh had higher ME intakes than treatment A, due to the higher ME content of hay than silage. On average ME intake was 99% of ME output.

The intake of RDP was greater than the output at all probable degradabilities, but UDP intake could have restricted animal production if the feed degradabilities approached 90%.

6.3.5 Treatment effects in the first six days of each period

Silage DM intake in the first six days of each period (table 6.6) was similar to the last six days (table 6.2), except that in treatment Ah silage DM intake was higher in the first six days and hay DM intake correspondingly lower at this time. In both treatments Ah and Rh hay DM intakes were lower in the first six days than the last six days, but the relative difference between the two treatments was similar.

In contrast to the significant improvement of milk yield in the last six days when hay was offered, there was only a small effect in the first six days. Feeding hay did, however, immediately increase the milk protein content, although this did not persist into the last six days of the period.

Table 6.5 Intake and output of metabolizable energy, rumen-degradable protein and undegradable protein

	A	Ah	R	Rh	SED	Significance
ME intake (MJ day^{-1})	167^c	179^a	142^d	171^b	1.98	***
ME output (MJ day^{-1})	176^a	179^a	137^b	177^a	11.1	**
RDP intake (g day^{-1})†	1923-2437	2046-2592	1601-2028	1949-2470		
RDP output (g day^{-1})	1299	1398	1104	1335		
UDP intake (g day^{-1})†	270-785	288-835	225-661	274-795		
UDP output (g day^{-1})	427	403	263	421		

† Calculated for the range in degradabilities suggested by ARC (1980): 0.71-0.90 for silage, hay and concentrates.

Table 6.6 Feed intake and milk production in the first 6 days of each period

	A	Ah	R	Rh	SED	Significance
Silage DM intake (kg day^{-1})	7.6^a	6.5^b	5.1^c	5.1^c	0.25	***
Hay DM intake (kg day^{-1})	-	2.3^b	-	2.7^a	0.16	**
Milk yield (kg day^{-1})	22.2	22.7	22.2	23.1	0.45	NS
Fat content (g kg^{-1})	36.2	37.6	37.0	36.5	0.89	NS
Protein content (g kg^{-1})	31.3^{bc}	32.6^a	30.8^c	31.5^b	0.33	***
Lactose content (g kg^{-1})	48.3	48.6	48.4	48.8	0.42	NS

6.3.6 Variation in feed intake and milk yield

The coefficients of variation of hay and forage DM intakes and milk yields over the first and last six days of each period are shown in table 6.7. Variation in hay DM intake was high, particularly in the first six days of the period and when silage was offered *ad libitum* . In the first six days offering hay increased the variation in forage DM intake as cows adjusted to the new feeding system. In the last six days there was no difference in the variation of forage DM intake of cows offered *ad libitum* silage or cows offered *ad libitum* silage plus hay, but variation tended to be less for cows offered restricted silage plus hay compared with cows offered *ad libitum* silage.

The variation in milk yield tended to be reduced by offering hay both in the first and last six days, but restricting the silage ration had no effect. Residual effects of the treatment in the previous period were strong, with those cows offered hay in the previous period having reduced variation in milk yield (appendix 16).

6.3.7 Residual effects

6.3.7.1 Days 1-6 of each period

In the first six days of each period silage DM intake was significantly affected by the residual effects of the previous period, but hay DM intake was not (appendix 16). Milk yield was not significantly affected by residual effects but milk protein content was, with those cows receiving hay in the previous period having higher milk protein contents.

Table 6.7 Coefficients of variation of forage DM intake and milk yield over the first and last six days of each period

CV (%) of	Days of the period	A	Ah	R	Rh	SED	Significance
Hay DM intake	1-6	-	37.9^{a}	-	28.5^{b}	3.57	***
Hay DM intake	15-21	-	21.4	-	19.9	3.22	NS
Forage DM intake	1-6	8.2^{b}	12.9^{a}	6.5^{b}	12.3^{a}	1.63	***
Forage DM intake	15-21	11.2^{a}	11.0^{a}	7.3^{b}	9.8^{ab}	1.44	*
Milk yield †	1-6	5.9	4.6	5.7	4.0	0.82	NS
Milk yield †	15-21	4.7	3.9	5.1	4.3	0.57	NS

† Periods 2, 3 and 4 only.

6.3.7.2 Days 15-21 of each period

In all the feed intake measurements the residual effects were small and non-significant, but they were significant in milk lactose yield and liveweight gain, and other animal production parameters approached significance (eg ME output).

6.4 DISCUSSION

6.4.1 The effect of offering hay

This experiment illustrates the importance of forage quality on voluntary DM intake and milk production. The low quality of the silage restricted total DM intake to 2.6% of live weight in treatment A and offering good quality hay increased total DM intake and milk production. This is in accordance with work by Retter (1978), who found that offering good quality hay with silage of a low intake characteristic increased milk yield, and that the substitution rate of silage DM for hay DM was 0.70, which is similar to the value of 0.67 in this experiment. In subsequent experiments Retter (1978) found that the substitution rate of silage for hay, where both are of similar intake characteristics, is approximately 1.0. Silage DM intake cannot always be predicted from its digestibility (Van Soest, 1982) and cows offered poorly fermented silage will probably have a greater response to hay supplementation.

Some benefit may also be obtained from offering two forages instead of one. Coppock *et al* (1974) found that forage DM intake was increased when hay was offered with silage of similar quality, although hay was not the preferred forage.

Offering hay had no effect on milk composition in this experiment, which is in contrast to the work of Retter (1978), who found that, when milk yield was increased by offering hay, milk fat content tended to decline.

Castle *et al* (1981) found that chopping hay to 12 mm reduced voluntary DM intake compared with long hay, probably because cows found the chopped hay difficult to eat. Hay chop length was not determined in this experiment, although it was similar to that of the hay used in experiment 1 (15 mm). The minimum rate of hay DM intake in this experiment was 35 g DM min^{-1} (if the cows ate for all the 90 minutes allowed) and it is therefore unlikely that the cows found this chopped hay difficult to eat.

In this instance where the buffer feed was of higher quality than the basic forage and was clearly preferred, the duration of access was probably an important determinant of buffer intake. If the cows had had longer than 90 minutes, those offered restricted silage plus hay would probably have increased hay DM intake and had a similar total DM intake to cows offered *ad libitum* silage plus hay.

The reduction in the variation of the milk yield of cows offered hay may have been due to a more stable fermentation pattern. It is however unlikely that this contributed to the increased milk yield of cows offered hay since this was fully accounted for in the energy balance by the extra energy from the hay.

In addition variation in forage DM intake tended to be less for cows offered restricted silage plus hay compared with *ad libitum* silage, but it is not known to what extent variation in feed intake affects milk production.

6.4.2 Restricting silage DM intake

Restricting the silage DM intake to 62% of *ad libitum* intake reduced total ME intake by 25 MJ day^{-1} (15%) and changed the concentrate:forage ratio from 50:50 (treatment A) to 62:38 (treatment R). The absence of a reduction in milk yield and the large loss of live weight in treatment R suggests that during a period of underfeeding cows are initially able to maintain milk yields by mobilizing body fat. If the experiment had been one of continuous design it is likely that milk yield would have been reduced.

The rate of milk yield decline of cows offered restricted silage was increasing through the period, and if this decline was continued for a fourth week the difference in milk yield between treatments A and R would have been the same as that obtained by Rook and Line (1961) for a similar reduction in energy intake over a 28 day period (0.7 kg day^{-1}). Other short-term underfeeding experiments have shown that the depression in milk yield increases with time (compare Gordon and Forbes, 1970; 1971; Broster, 1972).

Cows offered restricted silage tended to have a reduced yield of milk fat. If the crude fibre contents of the feeds are estimated as 360, 290 and 50 g kg^{-1} DM for silage, hay and concentrates (MAFF *et al*, 1975) then the crude fibre contents of the diets in treatments A, Ah, R and Rh were 206, 203, 169 and 192 g kg^{-1} DM respectively. Cows in treatment R, therefore, probably received insufficient fibre to maintain maximum milk fat production (Ekern, 1972).

The restriction of energy intake for cows in treatment R reduced the milk protein content by 1.3 g kg^{-1}. From the survey of underfeeding experiments by Rook and Line (1961) a reduction of 1.9 g kg^{-1} would be expected from these feeding levels, and it is likely that the decline in protein content would have increased over a longer period (Gordon and Forbes, 1971).

6.4.3 The sequence of response to underfeeding and offering hay

6.4.3.1 Underfeeding

In this experiment, where cows had a reasonable level of body fat reserves (condition score 2.4), restricting the silage ration initially caused loss of live weight. It is unlikely that the measurement of this was influenced by the level of gut contents since one week was allowed for adjustment, and also the correlation of ME input and output was high, suggesting that the liveweight change was accurate.

The depression in milk protein content increased from 0.5 g kg^{-1} after 5 days to 1.3 g kg^{-1} after 20 days. The reduction in milk yield was slower to take effect and still was not significant after 18 days, although the rate of decline increased in severity over this time.

Continuation of the feeding treatments beyond 21 days would probably have resulted therefore in a greater decline in milk yield and milk protein content, a reduction in the rate of live weight loss and possibly a reduction in milk fat content (Ekern, 1972).

6.4.3.2 Hay feeding

In the first six days offering hay increased the variation in forage DM intake as the cows adjusted to the new feeding pattern. The level of forage DM intake was still increased, however, which was reflected in increased milk yield and milk protein content.

By the end of the period the variation in forage DM intake for cows offered *ad libitum* silage plus hay was the same as that for cows offered *ad libitum* silage. In addition, the increase in milk yield from offering hay was double that in the first six days. The increase in milk protein content was much smaller, although milk protein yield was still increased.

6.4.4 General considerations

Improving the feeding level by offering hay had no effect on liveweight change. This may be a property of increasing forage DM intake (which will promote a more acetate type of fermentation in the rumen), in contrast to extra concentrate feeding which tends to promote a more propionate type of fermentation in the rumen, and partition nutrients to liveweight gain rather than milk production (Ekern, 1972). An obvious similarity exists between this experiment and experiment 1 where offering hay at pasture increased forage DM intake, and the extra nutrients tended to be partitioned towards increased milk yield.

It is important, therefore, to maintain maximum forage intake, not only because forages are cheaper than concentrates, but also because this will ensure the maximum partition of nutrients to milk production.

Offering hay for 90 minutes with restricted silage compensated for the silage restriction but did not permit maximum forage DM intake. If a buffer feed was made available for a longer period, and the intake was increased, it is likely that there would be substitution of silage for the buffer feed. Maintaining the balance where all the silage available for the winter feeding period is utilized, but maximum forage DM intake is achieved through supplementation with a buffer feed, is likely to be easier if silage were preferred to the buffer feed. However, in view of the marked increase in milk yield obtained in this experiment and the relationship between forage quality and intake, it may be preferable if the silage is of low quality to offer a high quality forage as a buffer feed and restrict the intake.

This experiment also shows that the intake of medium-yielding cows of a low quality silage can be considerably restricted for three weeks without any loss of milk production compared with cows offered *ad libitum* silage.

A further objective of offering hay with silage may be to increase overall farm stocking rates. By purchasing hay, which is a more tradeable commodity than silage, and incorporating it into a silage-based diet, stocking rates may be increased more economically than by purchasing additional concentrates. There may still be justification for purchasing additional concentrates to increase milk production cow^{-1} beyond that possible from forage alone, but only if forage DM intake is maximized.

6.5 SUMMARY

The effects on dairy cow performance of restricting the silage ration in a winter feeding regime, and of offering hay as a buffer feed, were examined in a changeover experiment with three week periods.

Silage (8.2 MJ kg^{-1} DM) was of lower quality than the hay (10.0 MJ kg^{-1} DM). All cows received 9 kg concentrate day^{-1} throughout the experiment.

Restricting the silage ration to 62% of *ad libitum* intake resulted in only a small depression in milk yield, a reduced milk protein content and a high loss of live weight. Offering hay for 90 min day^{-1} increased total DM intake, both when silage was available *ad libitum* and at a restricted level. When silage was offered *ad libitum* the intake of silage DM was reduced by 0.67 kg kg^{-1} hay DM; when silage was offered at the restricted level there was no substitution of silage for hay. At both levels of silage DM intake offering hay increased milk yield but had no effect on milk composition or liveweight change.

CHAPTER 7

EXPERIMENT 5 THE EFFECT OF RESTRICTION OF SILAGE DM INTAKE AND THE PROVISION OF STRAW OR AMMONIA-TREATED STRAW AS A BUFFER FEED ON DAIRY COW PRODUCTION

7.1 INTRODUCTION

In a previous experiment (chapter 6) there was little effect on milk yield of restricting the intake of a low quality silage over three weeks, but offering good hay as a buffer feed increased milk yield. Intakes of the silage were low but restricting the intake of a good quality silage could have a greater effect.

In recent years there has been a revival of interest in straw utilization and in improving its nutritive value by chemical treatment. Initially much of this interest concentrated on sodium hydroxide for improving the straw, but ammonia is a safer chemical, and an excess of ammonia in the ruminant and its excretory products is less of a problem than an excess of sodium and may even be beneficial. In addition, the treatment of straw with aqueous ammonia in a polythene-covered stack offers a system of chemical application with little capital investment.

Previous reports have indicated that straw may be improved up to the value of medium quality hay (eg Sundstol *et al*, 1978) by this method and, whereas such a feed would not be ideal as the sole forage for dairy cows, it could be useful as a buffer feed. In this role it would probably only be eaten when required, in contrast to the hay used in experiment 4, and could therefore be offered *ad libitum*. In addition it would not deteriorate rapidly, which would facilitate *ad libitum* feeding where there is a high variation of DM intake from day to day.

Apart from having potential as a buffer feed, treated straw also provides a means of purchasing an inexpensive feed to increase farm stocking rates. Benefit may also be obtained from the provision of an alkali feed with the acid silage, which would tend to neutralize the total feed intake.

It is not certain whether any benfits from the ammoniation of straw would offset the cost of the treatment, and this experiment, also examines the use of untreated straw as a buffer feed. The experiment therefore examines the effects of restricting a ration of good quality silage and of offering straw or ammonia-treated straw *ad libitum* as a buffer feed.

7.2 MATERIAL AND METHODS

7.2.1 Design

Twelve British Friesian cows were allocated to four treatment groups of a balanced changeover (Latin Square) design (appendix 12): A - *ad libitum* silage; R - restricted silage; Rs - restricted silage + straw and Rt - restricted silage + ammonia-treated straw. In addition, all cows received 8 kg concentrate day^{-1}. The experiment comprised four 3 week periods and ran from 10 December 1981 to 24 February 1982.

Cows were allocated to the three blocks of the Latin Square design so that the cows within each block were as similar as possible in milk yield, live weight, condition score and pre-experimental silage intake. At the start of the experiment average milk yield (kg day^{-1}), live weight (kg) and condition score of the 12 cows were 28.6 (range 21.7-32.9), 615 (range 565-710) and 2.3 (range 1.8-3.0) respectively. Mean calving date was 4 November (range 27 October-13 November).

7.2.2 Dairy cow and feed management

Cows were group housed with access to individual feeding boxes fitted with Calan gates (see section 6.2.2). Before the start of the experiment cows were offered *ad libitum* silage and 8 kg concentrate day^{-1}. In the final week before the start of the experiment cows were also offered straw or ammonia-treated straw for 1 hour day^{-1}; mean intakes were 0.2 kg straw DM day^{-1} and 0.4 kg treated straw DM day^{-1}.

The restricted silage allowance was 75% of the predicted *ad libitum* silage DM intake; the latter was obtained using an equation based on the pre-experimental milk yield and live weight that had been determined from the results of experiment 4.

During the experiment silage refusals were weighed daily after the afternoon milking for those cows receiving silage *ad libitum*, and fresh silage rations for all the cows were then placed in the boxes. Straw or treated straw was offered after morning milking and was available until the afternoon milking when refusals were weighed; this was made possible since cows on the restricted silage ration cleared up their silage before the morning milking. Straw, treated straw and silage (in treatment A) were offered in sufficient quantities to ensure that 10-15% of the original weight was available as a residue. Concentrates were offered at the same level -

8 kg freshweight day^{-1} - to all cows throughout the experiment. Of this 0.5 kg was fed in the parlour at each milking and the remaining 7 kg was offered in two equal feeds beside the relevant forages after morning and afternoon milking. The composition of the concentrate cube is given in appendix 11.

Silage was from a predominantly ryegrass (Lolium perenne) and white clover (Trifolium repens) sward that was harvested as described in section 4.2.3.

Straw was from spring barley, variety Georgie, and alternate bales were sorted from a stack to be either fed untreated or treated with aqueous ammonia (Hargreaves Fertilizer Ind. Ltd, York, UK). Straw was treated on 8 October 1981, in a 150 bale stack covered with polythene (plate 3) (Sundstøl *et al*, 1978). Aqueous ammonia (320 g ammonia kg^{-1} water) was injected into the stack at four points with a lance at an application rate of 100 l $tonne^{-1}$ straw (39 g ammonia kg^{-1} straw DM). The stack was then sealed at the points of injection with adhesive tape. The stack was uncovered after 42 days and allowed to ventilate for 24 hours before chopping the treated straw with a precision-chop forage harvester. Bales in the bottom layer of the stack that had been standing in the aqueous solution were discarded. Untreated straw was chopped at the same time and both straws were stored in a polythene-covered silo until required for feeding.

Water was freely available to all cows in the feeding area. Cows were milked twice daily at 06.30 h and 16.30 h.

1

2

3

Plate 3. Ammonia treatment of straw by the stack method

1) Laying the ground sheet
2) Injecting the stack with ammonia
3) The injection lance.

7.2.3 Dairy cow and feed measurements

Milk yields were recorded at each milking during the last six days of each period, and aliquot samples of milk were taken at each milking in the last three days of each period. Milk samples were analysed for fat, protein and lactose content as in section 6.2.3. Live weight was recorded on six days in the last 15 days of each period and liveweight change was calculated by regression.

Silage and concentrate samples were taken once a week for the determination of chemical composition. Straw and treated straw were sampled weekly and subsampled once in each period for the determination of chemical composition. An oven DM determination of silage, straw and treated straw was performed daily for the calculation of DM intake. ME and RDP/UDP calculations are detailed in section 6.2.3.

7.2.4 Statistical analysis

The significance of treatment differences and residual effects was examined as in section 6.2.4. The health of all animals was satisfactory and there were no missing plots.

7.3 RESULTS

7.3.1 Feed composition

Silage was of good quality with an acetic type of fermentation; both the energy and crude protein content were high (table 7.1).

Straw was of low energy content for spring barley straw and in addition the crude protein and mineral contents were low. Treating

Table 7.1 Chemical composition of the feeds (g kg^{-1} DM unless otherwise stated)

	Silage	Straw	Treated straw	Concentrates
Dry matter (g kg^{-1})	255	821	775	860
ME (MJ kg^{-1} DM)	10.3	5.8	7.6	13.0
Organic matter	880	935	935	910
Crude protein	190	50	93	199
In vitro digestibility	656	434	514	744
Calcium	6.9	4.1	4.0	12.0
Phosphorus	4.6	1.9	1.9	7.0
Magnesium	2.8	0.7	0.7	4.8
Ammonia nitrogen (g kg^{-1} total N)	111	-	-	-
pH (units)	4.2	-	-	-

the straw with aqueous ammonia only increased the ME content by 1.8 MJ kg^{-1} DM but increased the crude protein content by 43 g kg^{-1} DM, although it is doubtful whether the latter was of value as it would have been in the non-protein-nitrogen content of the straw (Gordon and Chesson, 1983). The addition of aqueous ammonia to the straw depressed the DM content by 46 g kg^{-1} and there was evidence of considerable variation in the distribution of the chemical within the straw. When stored in the silo and covered with polythene about 30% of the surface of the treated straw developed a white mould (Aspergillus candidus), probably due to condensation under the polythene.

7.3.2 Feed intake

Restricting the silage ration reduced DM intake by 4.5 kg DM to 58% of *ad libitum* intake (treatment R compared with treatment A, table 7.2). This was a greater restriction than expected because the higher quality of the silage in this experiment compared with experiment 4 (whose results were used to predict *ad libitum* silage intakes) increased the *ad libitum* intakes.

Straw DM intakes were low relative to the restriction of silage and only partially restored forage DM intakes. Treating the straw tended to increase intake but forage DM intake was still depressed relative to *ad libitum* silage. There was no substitution of straw or treated straw for silage.

Table 7.2 Feed intake (kg day^{-1})

	A	R	Rs	Rt	SED	SIGNIFICANCE
Silage DM	10.8^{a}	6.3^{b}	6.1^{b}	6.2^{b}	0.23	***
Straw DM/ treated straw DM	-	-	1.7	2.1	0.19	NS
Forage DM	10.9^{a}	6.3^{c}	7.9^{b}	8.3^{b}	0.28	***
Concentrate DM	6.9	6.9	6.9	6.9	-	-
Total DM	17.7^{a}	13.1^{c}	14.8^{b}	15.2^{b}	0.28	***

7.3.3 Animal production

Milk yield was significantly reduced by restricting the silage (table7.3)and tended to be slightly increased by offering straw or treated straw. There were no significant effects on milk fat content although it tended to be higher for cows in treatment R. Milk protein and lactose content were reduced by restricting the silage ration but were partially restored by offering straw or treated straw. There were no significant treatment differences in milk fat yield but milk protein and lactose yields were reduced by restricting the silage ration.

Cows in treatment A had a high rate of liveweight gain but cows in treatment R lost live weight. Offering treated straw, and to a lesser extent straw, increased liveweight gain relative to treatment R.

7.3.4 Nutrient intake and output

ME intake and output were reduced by restricting the silage (table 7.4)and partially restored by offering straw and treated straw as a buffer feed. Treated straw was superior to straw in increasing ME intakes and output. ME intakes were substantially less than ME outputs, but there were no significant treatment differences in the ratio of ME input:output ($P>0.05$).

The intake of RDP was in excess of requirements but the intake of UDP may have been limiting.

Table 7.3 Animal production

	A	R	Rs	Rt	SED	SIGNIFICANCE
Milk yield (kg day^{-1})	26.9^{a}	24.6^{b}	24.9^{b}	25.0^{b}	0.49	***
Fat content (g kg^{-1})	40.1	41.6	40.1	41.0	1.27	NS
Protein content (g kg^{-1})	32.4^{a}	30.7^{c}	31.3^{b}	31.4^{b}	0.28	***
Lactose content (g kg^{-1})	48.5^{a}	47.5^{c}	48.1^{ab}	47.9^{bc}	0.24	**
Fat yield (g day^{-1})	1080	1020	999	1020	32.4	NS
Protein yield (g day^{-1})	869^{a}	749^{b}	774^{b}	780^{b}	17.3	***
Lactose yield (g day^{-1})	1305^{a}	1170^{b}	1197^{b}	1196^{b}	22.7	***
Liveweight change (kg day^{-1})	$+0.90^{a}$	-0.43^{c}	-0.15^{bc}	$+0.53^{ab}$	0.40	*

Table 7.4 Intake and output of metabolizable energy, rumen-degradable protein and undegradable protein

	A	R	Rs	Rt	SED	SIGNIFICANCE
ME intake (MJ day^{-1})	202^a	154^d	162^c	168^b	2.52	***
ME output (MJ day^{-1})	228^a	178^c	192^{bc}	212^{ab}	13.7	**
RDP intake (g day^{-1})†	2419-3084	1811-2313	1855-2364	1972-2481		
RDP output (g day^{-1})	1566	1198	1273	1319		
UDP intake (g day^{-1})†	343-1028	257-771	257-764	261-770		
UDP output (g day^{-1})	810	532	578	737		

† Calculated for the range in degradabilities suggested by ARC (1980): 0.71-0.90 for silage and concentrates. Straw crude protein was assumed to have a degradability of 0.95 (Aman and Nordkvist, 1983); the extra crude protein from ammoniation of the straw was assumed to be totally degradable.

7.3.5 Variation in feed intake and milk yield

The coefficient of variation of straw and treated straw DM intake over the last six days of each period was high (table 7.5). The variation in forage DM intake was reduced by restricting the silage ration, in particular where straw or treated straw were offered as a buffer feed. Significant residual effects indicated that this difference might have been greater in a continuous experiment (appendix 16).

There was no significant difference in milk yield variation, although it tended to be higher in treatment R.

7.3.6 Residual effects

There were no significant residual effects apart from those referred to in section 7.3.5 in the variation of forage DM intake.

7.4 DISCUSSION

7.4.1 Restricting the silage ration

Restricting the silage ration by 46 MJ of ME day^{-1} (4.5 kg DM) resulted in a decline in milk yield of over 2 kg day^{-1}. This is equivalent to 0.049 kg milk MJ^{-1} ME, which is considerably less than the predicted response of Broster and Alderman (1977) for cows of this yield level of 0.17 kg milk MJ^{-1} ME. The discrepancy probably arises from the large difference in the liveweight change of cows fed *ad libitum* and restricted silage. In experiment 4 there was little effect on milk yield when the silage intake was reduced by 25 MJ of ME day^{-1} (3.0 kg DM) but, in addition to the

Table 7.5 Coefficient of variation of feed intake and milk yield over the last six days of each period

	A	R	Rs	Rt	SED	SIGNIFICANCE
CV (%) of:						
Straw/treated straw DM inake	-	-	35.5	34.7	4.57	NS
Forage DM intake	11.2[a]	8.3[b]	6.8[b]	6.9[b]	1.10	**
Milk yield	4.9	6.0	4.5	4.6	0.98	NS

restriction being greater in this experiment than in experiment 4, the cows were also higher yielding and would therefore have a greater response in milk yield (Broster, 1980).

The absence of any significant effects on milk fat content, when other workers have reported a decline when the forage content of the diet is reduced (Ekern, 1972; Mahanna, 1980), may be due to the fact that, in certain circumstances, changes in milk fat content can take up to three weeks to complete (Storry and Sutton, 1969). The specific effect of underfeeding in depressing milk protein content is demonstrated in this experiment, and the depression in milk lactose content shows that this response is found in early-mid lactation, although it is more prevalent in late lactation (Dawson and Rook, 1972).

The high rate of liveweight gain for cows offered *ad libitum* silage was unusual for cows in this early/mid stage of lactation and may to some extent represent a compensation for undernutrition (and loss of live weight) in previous periods. The absence of significant residual effects may be explained by the small number of animals in this experiment.

7.4.2 Straw treatment

Increases of 140-160 g kg^{-1} DM digestibility are common with ammonia-treatment of straw (Sundstøl *et al*, 1978) but only 70 g kg^{-1} DM was achieved in this experiment. Abidin and Kempton (1981) reported increases in DM digestibility of only 80 g kg^{-1} DM and Sundstøl *et al* (1978) found the response to ammoniation variable.

It has also been found that improvements in the digestibility of straw may be overestimated by *in vitro* measurement (Owen, 1981; Rissanen and Kossila, 1977), and even *in vivo* measurements with sheep at the maintenance level may not accurately reflect the value for a high-yielding dairy cow.

The ME value of untreated straw (5.8 MJ kg^{-1} DM) was less than the value normally attributed to spring barley straw (7.3 MJ kg^{-1} DM; MAFF *et al*, 1975). A similar observation has been made by Lawlor and O'Shea (1979), which suggests that the accepted value is too high.

The most likely reason for the low response in digestibility to ammoniation is the combination of a low temperature (mean minimum and maximum ambient temperatures during the treatment period were 2.9 and 11.1°C respectively) and a relatively short treatment time (42 days). The combined effect of low temperature and short treatment time is more critical for aqueous than anhydrous ammonia since the latter increases temperature in the straw after application quite considerably (Kiangi *et al*, 1981). Optimal treatment length at various temperatures has been extensively investigated and the results reviewed by Borhami and Sundstøl (1982); these varied considerably and were influenced by the moisture content of the straw and the level of ammonia applied.

The existence of mould in the treated straw suggests that the level of ammonia application was insufficient to have a fungicidal activity, and a higher ammonia concentration could have resulted in a greater increase in digestibility. Other factors that could have affected the response to ammoniation include straw variety and moisture content (Horn *et al*, 1983) and the method of distribution of aqueous ammonia within the stack.

The increase in crude protein content of the straw (43 g kg^{-1} DM) was less than the mean value of 50-60 g kg^{-1} DM quoted by Sundstøl *et al* (1978) but similar to the value of 45 g kg^{-1} DM quoted by Lawlor and O'Shea (1979).

7.4.3 The effect of straw or treated straw on animal production

The increase in straw DM intake as a result of ammoniation of the straw (20%) was less than most other reported values, which range from 32% (Coxworth *et al*, 1976) to 70% (Lawlor and O'Shea, 1979) for beef cattle but have reported as low as 13-16% with dairy cattle (Sundstøl *et al*, 1978; Rissanen and Kossila, 1977).

Offering straw or treated straw as a supplement to a restricted ration of silage had little benefit in terms of milk yield but increased milk protein and lactose content. With smaller restrictions of silage DM intake straw is unlikely to be of value as its indigestible nature will reduce rumen volume and may further restrict silage DM intake. This is particularly important in early lactation (Frank, 1982), when rumen volume is most restricting, although it was found in the pre-experimental period that cows offered *ad libitum* or slightly restricted silage rations have very low intakes of straw anyway.

Most of the benefit of straw and treated-straw was partitioned towards liveweight change and Nielson (1961) also concluded on the basis of short-term experiments that the inclusion of straw in dairy cow rations increases live weight. In long-term experiments, however, this increase has not been observed (Frank, 1982), and some of the increase in live weight in this experiment and that of Nielsen (1961) may have been due to an increase in gut contents (Wilkinson and Santillana, 1978). This is supported in this experiment by the fact that it is unlikely that cows in early-mid lactation would partition almost all the extra energy intake to live weight when milk yield was substantially reduced. The ME content of the straw and treated straw may therefore have been overestimated; Frank (1982) found that the actual value of straw when compared with hay as a silage supplement was 2.0 MJ ME kg^{-1} DM less than the predicted value of 6.9 MJ ME kg^{-1} DM.

It is unlikely that the increase in the non-protein-nitrogen content of the straw by ammoniation was beneficial to the cows since levels of RDP intake were considerably in excess of requirements. In addition there appears to have been little benefit of the high pH of ammonia-treated straw (usually pH 8-9; Owen, 1981) as a buffer to silage of a relatively low pH. Terry *et al* (1975) found that calves offered a neutral mixture of silage and alkali-treated straw had a higher DM intake than calves offered just silage or the two feeds unmixed. Mixing the silage and straw in this experiment could have improved DM intake, although the benefits of neutralizing silage with alkali-treated straw may be a palatability effect confined to calves rather than dairy cows.

In addition to intakes of straw and treated straw being too low to restore forage DM intakes to the *ad libitum* level, the coefficient of variation of daily straw DM intakes was high. Consequently amounts considerably in excess of mean daily intake must be fed to ensure *ad libitum* intake every day, and on a farm scale this would hinder the feeding of straw in a feeding passage after one day's silage ration has been cleared up and before the next is offered. Alternative possibilities for feeding straw or treated straw include incorporation into a complete diet mix, division of the feeding passage for different feeds or the provision of the feed in a hopper, rack or circular big bale feeder.

7.4.4 Energy balance

ME intake was consistently about 30 MJ day^{-1} less than ME output, with no significant difference between treatments. The reason for this is not clear - errors in experimental measurements could not account for such a large difference and errors in the assumptions of the energy calculations must be responsible. The most likely source of inaccuracy is in the energy value of liveweight change (Alderman *et al*, 1982; Baker, 1982).

7.5 SUMMARY

The effect on dairy cow performance of restricting the silage ration, and of offering straw or ammonia-treated straw as a buffer feed, were examined in a changeover experiment with three week periods.

Silage was of good quality and in addition all cows received 8 kg concentrates day^{-1}. Spring barley straw was treated in a polythene-covered stack for 42 days with aqueous ammonia (39 g kg^{-1} straw DM), which resulted in an increase in straw digestibility of 40 g kg^{-1} DM.

Restricting the silage ration to 58% of *ad libitum* reduced milk yield and milk protein and lactose content, and cows in this treatment lost live weight whereas those offered *ad libitum* silage had a high rate of liveweight gain.

Offering straw or treated straw with restricted silage partially restored forage DM intake to *ad libitum* levels and there was no substitution of silage for straw. However milk yield was only slightly increased and the depression in milk protein and lactose content was partially restored when straw or treated straw were offered. Most of the extra energy intake from the straw and treated straw was partitioned towards increased live weight. Ammoniation increased straw DM intake by 20% and tended to slightly increase the benefits of improved animal production when untreated straw was offered.

CHAPTER 8

EXPERIMENT 6 THE EFFECT OF RESTRICTION OF SILAGE DM INTAKE AND THE PROVISION OF STRAWMIX AS A BUFFER FEED ON DAIRY COW PRODUCTION

8.1 INTRODUCTION

Restricting the silage ration over three weeks has been shown to result in a rapid decline in live weight (experiments 4 and 5), which probably could not be sustained for long periods of time. A longer restriction is unlikely to be as severe as previously investigated but could penalize heifers more than cows where both feed together.

The benefits of offering hay as a buffer feed were demonstrated in experiment 4 but straw has the advantage of low cost and the potential to increase farm stocking rates. However, the economic advantages of including straw in the diet of dairy cows will not be realized unless the straw can be increased in nutritional value to obtain adequate intakes by dairy cows. Formulation of a strawmix with supplements of molasses, barley, soyabean meal etc. to improve the nutritional value gives the farmer control of the quality and cost of a buffer feed. This flexibility may be utilized to incorporate inexpensive byproducts when available and to modify the formulation to suit dietary requirements.

This experiment therefore examines the effect on cows and heifers of a seven week restriction of silage DM intake to approximately 85% of *ad libitum* and of offering a nutritionally-formulated strawmix *ad libitum* as a buffer feed.

8.2 MATERIAL AND METHODS

8.2.1 Design

Twenty-four British Friesian cows and 24 British Friesian heifers were to allocated the three treatment groups of a continuous design: A - *ad libitum* silage, R - restricted silage and RS - restricted silage + strawmix. In addition all cows received 9 kg concentrate day^{-1}. Although the experiment was originally intended to run for eighteen weeks only the results for the first seven weeks (1 December 1982 - 19 January 1983) are given because concentrate allowances after this period were inaccurate.

Cows were allocated to trios on the basis of milk yield, live weight, condition score and the number of days calved, and within trios were allocated to treatments A, R and RS so as to obtain three balanced treatment groups (appendix 17).

8.2.2 Dairy cow and feed management

Cows were group housed in a cubicle house with access to a feeding passage. Water was freely available to all cows. Cows were milked at 06.30 h and 15.00 h.

Silage was from first-cut swards containing a high proportion of perennial ryegrass (Lolium perenne), Italian ryegrass (Lolium multiflorum) and white clover (Trifolium repens) and was harvested as described in section 4.2.3. It was offered daily after morning milking from a forage box with automatic weight recording. Refusals (in treatment A at least 5% of the amount offered) were weighed back twice weekly. The restricted silage ration was calculated as 85% of the silage intake of cows in treatment A and was adjusted twice weekly according to intakes in the previous week.

The strawmix contained, as a percentage of the freshweight, 60% straw, 15% soyabean meal, 13% molasses, 10% rolled barley and 2% of a general purpose mineral and vitamin supplement. Straw was from winter barley (variety Igri) and was chopped with a precision-chop forage harvester prior to mixing. The strawmix was mixed daily with a shovel with the addition of 160 g hot water kg^{-1} strawmix to facilitate incorporation of the molasses. It was offered between 16.00 h and 09.00 h in a feeding trough that occupied one quarter of the length of the feeding passage of cows in treatment RS (figure 8.1). Refusals (at least 10% of the amount offered) were weighed back daily.

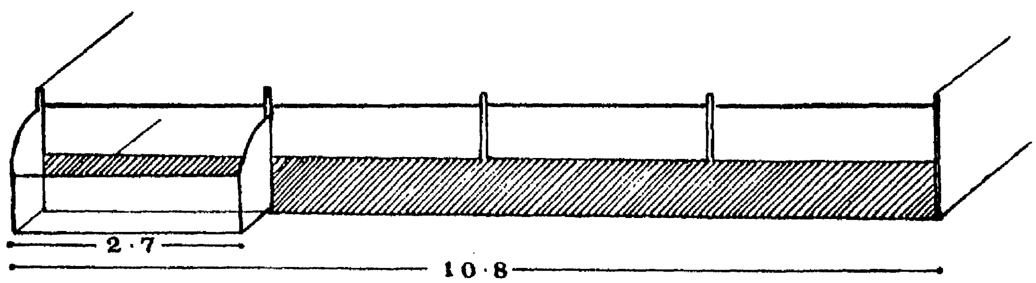


Figure 8.1 Feeding barrier for cows offered restricted silage + strawmix (distances in metres).

Concentrates were offered at the same level - 9 kg freshweight day^{-1} to all cows throughout the experiment. Of this, 5 kg cow^{-1} day^{-1} was fed in the parlour in two equal feeds, the remaining 4 kg cow^{-1} day^{-1} was placed on top of the silage in two equal feeds at 10.00 h and 21.00 h. The composition of the concentrate cube is given in appendix 11.

Between calving and the start of the experiment cows were offered *ad libitum* silage and 9 kg concentrate day^{-1}. In addition for eight days prior to the start of the experiment a variety of strawmix formulations were offered to 16 of the highest yielding cows to find a feed that was of reasonable quality but was not preferred to silage.

After the seven weeks of the experiment cows remained on their respective treatments for a further 11 weeks, but inaccuracies in the concentrate allocation in weeks 8 and 9 prevented the results from being used. After this period all cows received *ad libitum* silage and 9 kg concentrate day^{-1} for 12 days before turnout.

8.2.3 Dairy cow and feed measurements

Milk yields and fat, protein and lactose content of the milk were measured weekly as in section 3.2.2. Live weight was recorded at the start of the experiment and once every week in weeks 4-7 inclusive; liveweight change was calculated by regression of these weights. Condition score was recorded every fortnight and condition score change calculated by regression.

Silage, concentrate and strawmix samples were analysed weekly for chemical composition. An oven DM determination of silage and strawmix samples was performed daily for the calculation of DM intakes. *In vitro* digestibilities of the feeds, and energy and protein intake and output were calculated as in section 6.2.3.

Individual silage DM intakes were calculated by predicting individual ME intakes from animal production (MAFF *et al*, 1975), subtracting the ME from concentrate and strawmix (where applicable) and correcting the derived silage DM intake for the difference between the derived group mean silage DM intake and the observed group mean silage DM intake. Individual strawmix DM intakes were calculated from individual feeding times, adjusted for differences in the rate of eating ME from strawmix and silage.

On two occasions records were made of which cows were feeding by a team of observers at 5 minute intervals over 24 hours. Straw feeding was also recorded by a video-camera (Hitachi FP71) on ten occasions and straw-feeding times determined by recording which cows were feeding at 4 minute intervals during an accelerated replay.

8.2.4 Statistical analysis

The significance of the treatment differences was examined by two factor factorial analysis (Steel and Torrie, 1960), using treatment and parity (cow or heifer) as factors. Differences between individual treatment means were tested by Student's "t" test,and significant differences ($P<0.05$) are indicated by different superscripts.

Missing plots were used for the liveweight change of one cow and the silage feeding times of two cows because of lameness.

8.3 RESULTS

8.3.1 Feed composition

Silage was of good quality with an ME content of 10.3 MJ kg^{-1} DM and a low ammonia-nitrogen content (table 8.1). Strawmix had a similar energy content to moderate quality hay but a higher crude protein content (MAFF *et al*, 1975); both the energy and protein content were less than that of the silage.

8.3.2 Feed intake

Restricting the silage ration reduced silage DM intake by 1.2 kg to 86% of *ad libitum* (table 8.2). This restriction tended to be greater for the heifers than the cows although the treatment: parity interaction was not significant. Offering strawmix restored forage and total DM intakes to *ad libitum* levels, and the substitution rate of silage DM for strawmix DM at the restricted level of silage intake was only 0.07. Cows tended to have a greater intake of strawmix than heifers.

8.3.3 Feeding behaviour

The time spent eating silage was reduced by restricting the silage allowance, particularly in treatment R (table 8.3). There were no significant effects on rate of silage DM intake although this tended to be higher for heifers in treatment R. Overall heifers had significantly lower rates of silage DM intake than cows but similar silage feeding times.

Heifers tended to spend longer eating strawmix than cows but had a significantly lower rate of DM intake. Strawmix was eaten at a slightly slower rate of DM intake than silage.

Table 8.1 Chemical composition of the feeds (g kg^{-1} DM unless otherwise stated)

	Silage	Strawmix	Concentrate
Dry matter (g kg^{-1})	209	704	863
ME (MJ kg^{-1} DM)	10.3	8.2	12.9
Organic matter	904	912	912
Crude protein	140	115	197
In vitro digestibility	644	514	759
Calcium	5.5	8.5	11.2
Phosphorus	3.2	3.3	7.6
Magnesium	2.3	2.0	5.2
Ammonia nitrogen (g kg^{-1} total N)	86	-	-
pH (units)	3.9	-	-

Table 8.2 Feed intake (kg day^{-1})

		A	R	RS	SED + SIGNIFICANCE Treatment	Parity	Interaction
Silage DM	Cows	10.0	8.8	9.2			
	Heifers	7.1	6.0	5.3			
	Mean	8.6	7.4	7.3	0.71 NS	0.58 ***	1.00 NS
Strawmix DM	Cows			1.9			
	Heifers			1.3			
	Mean			1.6		0.28 NS	
Forage DM	Cows	10.0	8.8	11.2			
	Heifers	7.1	6.0	6.6			
	Mean	8.6	7.4	8.9	0.69 NS	0.56 ***	0.97 NS
Total DM	Cows	17.8	16.6	18.9			
	Heifers	14.9	13.7	14.3			
	Mean	16.3	15.2	16.6	0.69 NS	0.56 ***	0.97 NS

Table 8.3 Feeding behaviour

		A	R	RS	SED + SIGNIFICANCE Treatment	Parity	Interaction
Silage feeding time ($h\ day^{-1}$)	Cows	4.3	3.3	3.5			
	Heifers	4.9	3.2	3.7			
	Mean	4.6[a]	3.2[b]	3.6[b]	0.30 ***	0.24 NS	0.42 NS
Strawmix feeding time ($h\ day^{-1}$)	Cows			1.0			
	Heifers			1.2			
	Mean			1.1		8.0 NS	
Silage DM intake rate ($g\ DM\ min^{-1}$)	Cows	45.5	43.8	46.6			
	Heifers	27.2	35.2	23.3			
	Mean	36.3	39.5	34.9	4.35 NS	3.56 ***	6.16 NS
Strawmix DM intake rate ($g\ DM\ min^{-1}$)	Cows			38.5			
	Heifers			21.5			
	Mean			30.0		6.51 *	

The distribution of feeding times through the day is shown in figure 8.2. Cows offered restricted silage consumed most of the silage by early evening, whereas cows receiving silage *ad libitum* distributed silage feeding time fairly evenly from morning milking until midnight. Cows offered restricted silage and strawmix consumed most of their silage by midnight and ate most of the strawmix between 20.00 h and 01.00 h.

8.3.4 Animal production

Milk yield was not significantly affected by restricting the silage but tended to be increased by offering the strawmix (table 8.4). Cows offered restricted silage tended to have a lower milk fat and protein content than cows offered *ad libitum* silage. Offering strawmix tended to increase milk protein content and slightly increase milk fat content. Both milk fat and protein yield tended to be reduced by restricting the silage ration but were restored by offering strawmix.

Restricting the silage reduced liveweight change and condition score change, with no apparent benefit from offering strawmix(table8.5).

8.3.5 Nutrient intake and output

Intake of ME was reduced by 12 MJ day^{-1} by restricting the silage (table 8.6) but this was restored by offering strawmix as a buffer feed. ME output was reduced by 19 MJ day^{-1} by restricting the silage ration but was only partially restored by offering strawmix. ME output closely agreed with ME intake for cows offered *ad libitum* silage but for cows in treatments R and RS output tended to be lower than intake.

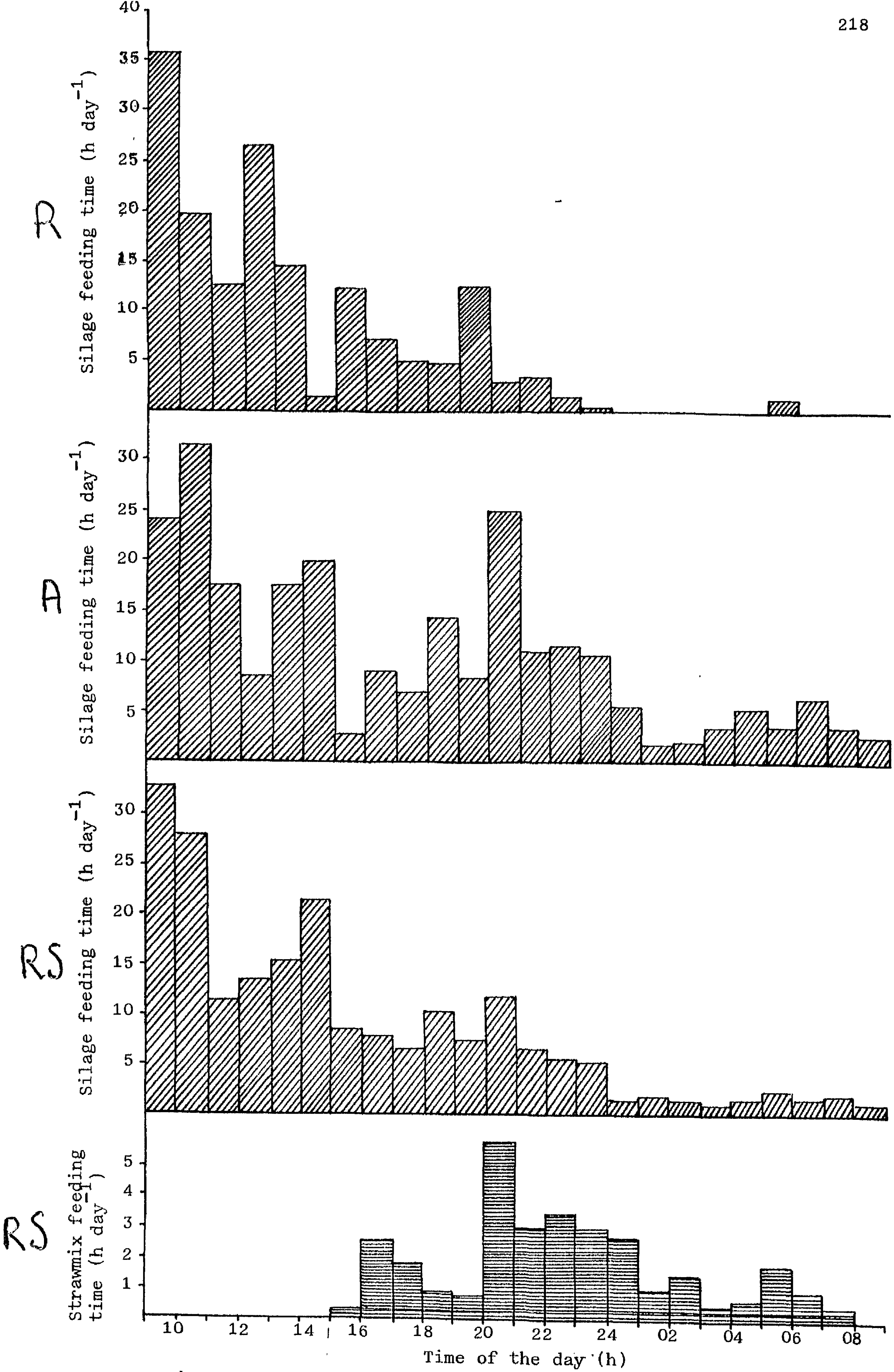


Figure 8.2 The distribution of silage feeding time in the day

Table 8.4 Milk yield and the content and yield of fat, protein and lactose

		A	R	RS	SED + SIGNIFICANCE Treatment	Parity	Interaction
Milk yield (kg day^{-1})	Cows	24.1	24.7	25.2			
	Heifers	18.6	18.1	19.6			
	Mean	21.5†	21.6†	22.0†	0.53† NS	0.71 ***	1.23 NS
Fat content (g kg^{-1})	Cows	41.4	38.2	40.7			
	Heifers	41.8	40.0	39.1			
	Mean	41.3†	39.5†	39.8†	0.95† NS	0.95 NS	1.64 NS
Fat yield (g day^{-1})	Mean	886	843	880	37.8 NS	30.8 ***	53.4 NS
Protein content (g kg^{-1})	Cows	31.4	30.1	31.8			
	Heifers	33.2	31.6	31.8			
	Mean	31.9†	31.2†	31.8†	0.71† NS	0.58 NS	1.00 NS
Protein yield (g day^{-1})	Mean	685	664	701	25.7 NS	21.0 ***	36.3 NS
Lactose content (g kg^{-1})	Cows	48.9	49.4	49.2			
	Heifers	49.4	49.8	49.1			
	Mean	49.1†	49.5†	49.3†	0.27† NS	0.28 NS	0.48 NS
Lactose yield (g day^{-1})	Mean	1050	1074	1088	43.4 NS	35.5 ***	61.4 NS

† Corrected for initial treatment differences by covariate analysis (Steel and Torrie, 1960)

Table 8.5 Live weight and condition score change

		A	R	RS	SED + SIGNIFICANCE Treatment	Parity	Interaction
Liveweight change	Cows	+0.33	-0.28	-0.10			
(kg day^{-1})	Heifers	+0.41	+0.09	-0.06			
	Mean	+0.37^{a}	-0.09^{b}	-0.08^{b}	0.17 *	0.14 NS	0.24 NS
Condition score	Cows	-0.03	-0.57	-0.45			
change	Heifers	-0.01	+0.01	-0.32			
(units experiment^{-1})	Mean	-0.02^{a}	-0.28^{ab}	-0.39^{b}	0.14 *	0.12 *	0.20 NS

Table 8.6 Intake and output of metabolizable energy, rumen-degradable and undegradable protein

		A	R	RS	SED + SIGNIFICANCE Treatment	Parity	Interaction
ME Intake (MJ day^{-1})	Cows	203	191	210			
	Heifers	173	161	165			
	Mean	188	176	188			
ME Output (MJ day^{-1})	Cows	202	182	189			
	Heifers	172	155	157			
	Mean	187^{a}	168^{b}	173^{b}	6.3 *	5.2 ***	8.9 NS
RDP Intake (g day^{-1}) †		1911-2457	1792-2304	1908-2453			
RDP Output (g day^{-1})		1466	1373	1466			
UDP Intake (g day^{-1}) †		273-819	256-762	273-818			
UDP Output (g day^{-1})		427	319	311			

† Calculated for degradabilities of 0.71-0.90 for all the feeds in this experiment (ARC, 1980)

There was an adequate supply of rumen-degradable protein in all treatments, but undegradable protein may have been limiting depending upon the precise degradabilities of the feeds.

8.3.6. Effect of transition from restricted to *ad libitum* silage

For twelve days prior to turnout all cows were offered *ad libitum* silage and 9 kg concentrates day^{-1}. Before this all cows had been on experimental treatment for 18 weeks (although some inaccuracies occurred in the concentrate allowance in weeks 8 and 9).

Cows that had been in treatment R greatly increased silage DM intake on the first day of being offered *ad libitum* silage (table 8.7) and continued to have a higher silage DM intake than cows that had been in treatment A for the remainder of the twelve days. Cows that had been in treatment RS only slightly overcompensated when returned to *ad libitum* silage feeding.

8.4 DISCUSSION

8.4.1 Restricting the silage ration

Restricting the silage ration caused a total restriction of 588 MJ (12 MJ day^{-1} for 49 days). This had a similar effect to an earlier experiment (experiment 4) where the total restriction was 525 MJ - milk yield was not affected but liveweight change was reduced and there was a tendency towards a reduced milk fat and protein content. Total reduction of liveweight change was 20 kg cow^{-1} in this experiment and 24 kg cow^{-1} in experiment 4. In experiment 5 the total restriction was 966 MJ and this caused a reduction in milk yield of over 2 kg cow^{-1} day^{-1} and in liveweight change of 28 kg cow^{-1}.

Table 8.7 *Ad libitum* silage DM intake (kg day^{-1}) during realimentation

Period	A	R	RS
Last week on experiment	7.9	6.6	6.6
Day 1 of *ad libitum* silage	7.9	12.4	8.1
Days 2-12 of *ad libitum* silage	7.7	8.9	7.9

In this series of experiments, therefore, cows were able to endure a restriction of up to 525 MJ by reducing liveweight change, whereas a restriction of approximately 1000 MJ also caused a reduction in milk yield. Mean initial condition scores were between 2.1 and 2.4 in all three experiments, and it is likely that if these had been higher a greater loss of live weight could have been sustained. Land and Leaver (1981) and Neilson *et al* (1983) have demonstrated that cows in higher condition score at calving will mobilize more body fat in early lactation, when nutrient intake is usually too low to sustain the potential milk production without loss of live weight.

It is likely that the yield level of the cow will affect the response to silage restriction, although this may be confounded by a low level of body condition in cows producing high milk yields. Broster (1972) has estimated that the response in milk yield is increased by 0.05 kg milk MJ^{-1} ME for a 10 kg increase in initial milk yield. Heifers, however, may be an exception to this - in this experiment heifers offered restricted silage tended to have a lower milk yield and had less reduction in liveweight change than cows. Conceivably heifers may retain energy for growth at the expense of milk production.

The depression in milk fat content in treatment R agrees with the observations of Ekern (1972) and Mahanna (1980) that milk fat content is depressed when the forage content of the diet is reduced. This is most likely to be an effect of the change in crude fibre intake; if the crude fibre contents of the silage, strawmix and concentrates are estimated as 300, 403 and 50 g Crude fibre kg^{-1} DM

(MAFF *et al*, 1975), then the crude fibre contents of the diets in treatments A, R and RS were 181, 172 and 193 g kg^{-1} DM respectively. In addition, as total DM intake was also reduced in treatment R, the *intake* of crude fibre was reduced by an even greater proportion.

The effect of realimentation of cows that had been offered restricted silage demonstrates the ability of cows to eat up to 150% of *ad libitum* in the first day of *ad libitum* silage feeding after a restriction. This initial increase probably represents filling the rumen volume but the continued high intakes of these cows confirms that thinner cows have a higher voluntary feed intake than fat cows (Bines, 1976).

8.4.2 Offering strawmix as a buffer feed

In contrast to experiment 5, where straw and treated straw were of little value in restoring milk production when this was reduced by restricting the silage ration, in this experiment strawmix rectified the depression in milk protein and fat yield that occurred as a result of silage restriction. The increase in the protein content of the milk occurred as a result of the extra energy from strawmix, whereas the increase in milk fat content probably occurred as a result of the higher crude fibre content of the diet. Strawmix was of no benefit in rectifying the reduction in liveweight and condition score change caused by silage restriction. Loss of liveweight may however have been overestimated for cows offered restricted silage, because the initial live weight was included in the regression as the cows could not be weighed in weeks 1-3, and therefore any decline in gut contents was not allowed for.

The formulation arrived at for the strawmix produced a feed that was eaten in sufficient quantities to rectify the silage restriction but was not eaten in preference to the silage. This is in contrast to the straw and treated straw used in experiment 5, which was not eaten in sufficient quantities to restore forage DM intake even though the predicted energy content of the treated straw was similar to that of the strawmix. The mean coefficient of variation of strawmix DM intake over each week was 20.3%, which is less than for straw or treated straw in experiment 5 but the same as for hay in experiment 4.

In the pre-experimental trial of different strawmix formulations the incorporation of molasses appeared to increase the palatability of the mix as well as being useful as a binding agent. The keeping life of the strawmix was only about one week which necessitates regular mixing. This may either be done with a complete diet feeder or a purpose built system. The latter incorporates a straw chopper and blower, an insulated molasses tank with heater, feed bins with a proportioner and a cyclone and mixing unit (Butler, 1981). The cost $tonne^{-1}$ is likely to be higher than for treated straw but the product is of higher nutritional value and the ingredients can be varied according to dietary requirements and relative costs.

8.4.3 Differences between cows and heifers

In this experiment heifers suffered a greater restriction than the cows - mean restriction in treatments R and RS was 79% of *ad libitum* for heifers compared with 90% of *ad libitum* for the cows. This was probably due to the lower rate of silage DM intake of the heifers as there was little evidence of heifers being prevented from feeding by the cows. Some evidence of heifers being bullied was apparent at the strawmix feeding trough but, as they were able to feed later in the night when the trough was not occupied, the heifers had similar feeding times to the cows.

The lower rate of silage and strawmix DM intake of heifers but similar or slightly higher feeding times to cows is similar to results obtained in experiment 2 with a herbage-based diet. Restricting the silage ration tended to cause heifers to increase silage DM intake rate but not the cows, suggesting that silage feeding rate can be modified in response to a restriction. Leaver and Yarrow (1977) found that the rate of eating màize silage was increased by 6-13 g OM min^{-1} by restricting DM intake to 93-96% of *ad libitum*, and Reynolds and Campling (1981) found that where silage availability and feeding space are restricted the silage DM intake is related to dominance.

In this experiment the rate of silage DM intake was positively correlated with live weight (x) by the following equations:

Cows: $y = 0.077x$ $(r = 0.55^{**})$ equation 10

Heifers: $y = 0.059x$ $(r = 0.41^{*})$ equation 11

Overall: $y = 0.067x$ $(r = 0.63^{***})$ equation 12

Burt (1957) has also reported that cows eat faster relative to live weight than heifers, which suggests a late development of the muscles associated with eating or the buccal area.

8.5 SUMMARY

The effect on dairy cow performance and feeding behaviour of restricting the silage ration in a winter-feeding regime, and of offering strawmix as a buffer feed, were examined in a seven week experiment of continuous design. The strawmix contained, as a percentage of the freshweight, 60% straw, 15% soyabean meal, 13% molasses, 10% rolled barley and 2% minerals/vitamins. Silage (10.3 MJ kg^{-1} DM) was of higher quality than the strawmix (8.2 MJ kg^{-1} DM). All cows received 9 kg concentrate day^{-1} throughout the experiment.

Restricting the silage ration to 86% of *ad libitum* had no effect on milk yield but reduced liveweight change and tended to depress milk fat and protein content. In addition, feeding time was reduced and the rate of silage DM intake tended to be increased. Heifers (group-fed with cows in a 50:50 ratio) suffered a slightly greater restriction than cows.

When strawmix was offered *ad libitum* with restricted silage, forage DM and ME intakes were restored to the levels of *ad libitum* silage and there was very little substitution of silage for strawmix. Offering strawmix restored milk fat and protein yields but had no effect on liveweight change.

CHAPTER 9

GENERAL DISCUSSION

9.1 BUFFER FEEDS WITH GRAZED HERBAGE

In this series of experiments offering a buffer feed in the grazing season usually increased animal production, though not always for the same reason. Possible restrictions of nutrient intake from herbage, and means of buffering these limitations, are shown in figure 9.1.

One of the most important uses of a buffer feed in the grazing season was to increase production when herbage intake declined to a low level during inclement weather. Further work is needed to elucidate the reason for the low herbage DM intakes, although low bite size (g DM) may be implicated (experiment 3).

A second benefit was obtained from offering a buffer feed at low herbage heights. The critical herbage height is likely to vary with the yield level of the cows and stage of the grazing season but a height of 6 cm has been suggested for continuously-grazed swards (Le Du and Hutchinson, 1982). A decline in herbage height reduces bite size and increases grazing time and biting rate (experiments 2 and 3). These changes are apparent before herbage DM intake is depressed (experiment 2) and represent the ability of the cow to buffer changes in herbage availability by modifying grazing behaviour (figure 9.2). Similar changes may be brought about by an increase in herbage dead matter content as occurs over the course of the grazing season. This effectively raises the grazed horizon (Barthram, 1981) and increases the effects of a declining herbage height.

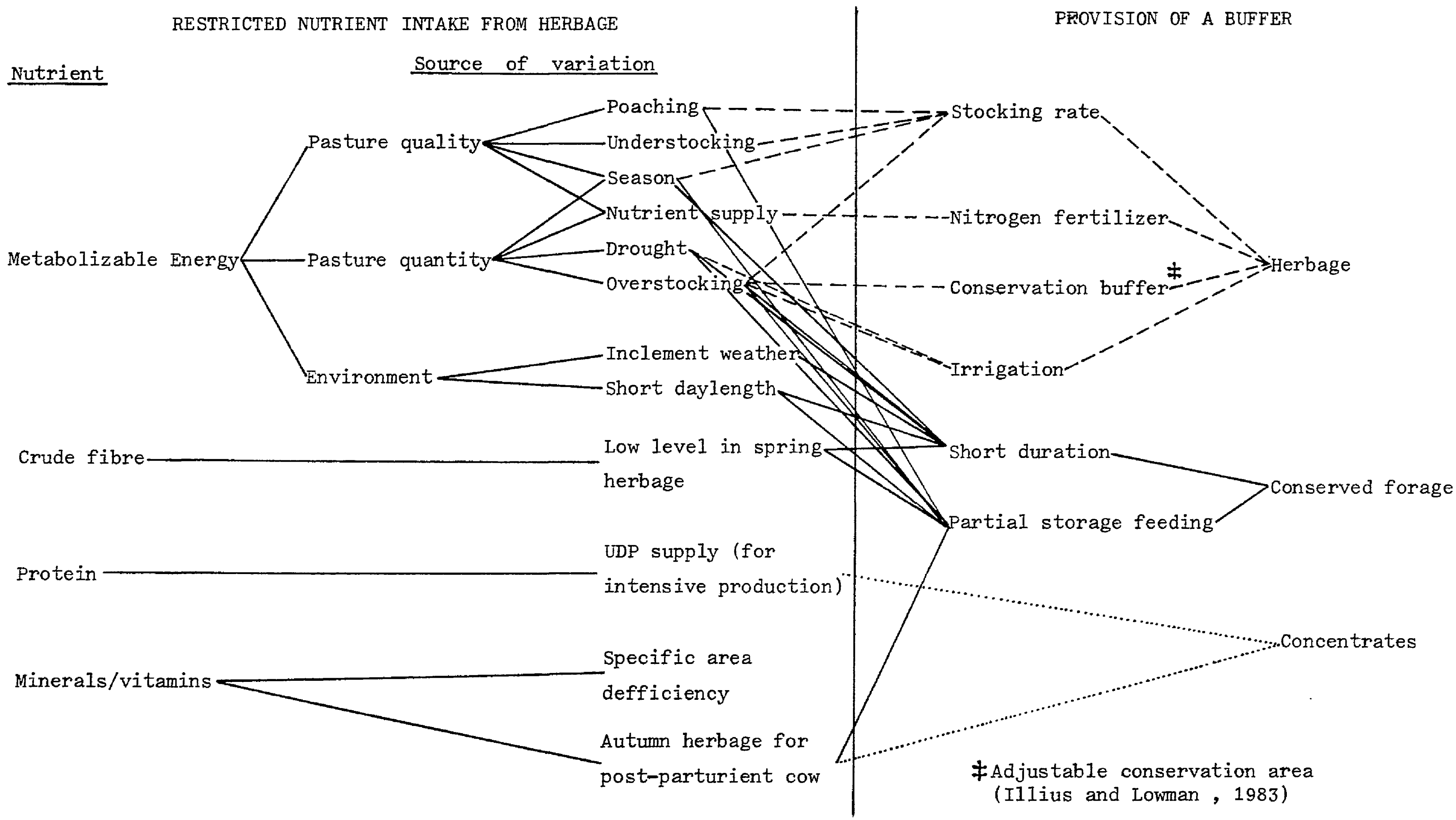


Figure 9.1 Buffering a restricted nutrient intake from herbage

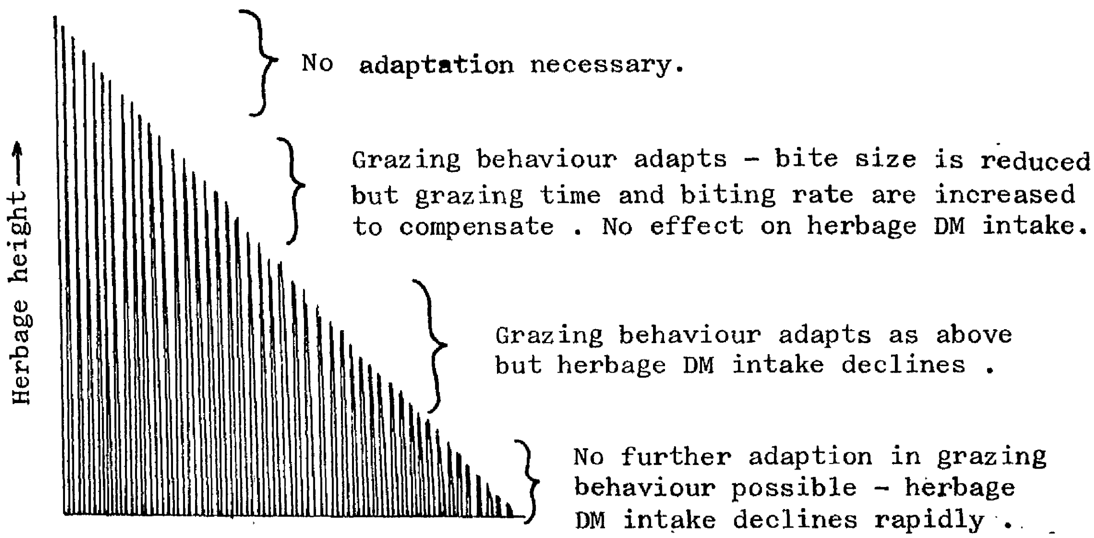


Figure 9.2 Effect of declining herbage height on grazing behaviour and herbage DM intake

Benefit was greatest when a buffer feed was offered to high-yielding, spring-calving cows. Cows are reluctant to graze for more than 8-9 hours day^{-1} (Leaver, 1981), and unrestricted grazed herbage will therefore only support dairy cow maintenance and the production of 20-25 kg milk day^{-1}. By offering a buffer feed that is consumed at between two and four times the rate of grazed herbage (table 9.1) total DM intake and milk yield are increased.

Table 9.1 Rate of DM intake of herbage and buffer feeds in experiment 1-3

	HERBAGE		BUFFER FEED	
	Period	Rate of DM intake (g day^{-1})	Type	Rate of DM intake (g day^{-1})
Experiment 1	Whole season	23	Hay	50
Experiment 2	Spring	26	Silage	63
Experiment 3	Autumn	18	Silage	70

A further benefit of offering a buffer feed with spring herbage is the increase in milk fat production. Spring herbage is critically short of fibre due to its immature stage of growth and, if a reasonable quantity of conserved herbage is included in the diet, the crude fibre content of the diet is increased. This results in a higher proportion of acetate to propionate in the rumen which favours milk fat production. It is not certain whether these benefits are obtainable in the second half of the grazing season, when the herbage is more mature, or whether the increase in milk fat production when silage was offered in experiment 3 was due to increased energy intake, or a specific property of silage compared with herbage. The optimum fibre content of the diet is hard to determine (Van Soest, 1982), but theoretically maximum milk fat production cow^{-1}

is obtained from feeds that have both a high digestibility and adequate crude fibre content. Such feeds would produce both a high ratio of acetate to propionate and a high total VFA production in the rumen.

Silage offered as a buffer feed will probably increase milk fat production more than additional herbage because of its higher crude fibre content. In addition, silage produces more UME ha^{-1} due to its more rapid growth rate at a higher Leaf Area Index than continuously-grazed herbage. In experiments 2 and 3 (with appropriate estimation for grazing between the two experiments) it can be calculated that the output of UME in 1982 was 105 GJ ha^{-1}. Potential increases with silage offered as a buffer feed are shown in table 9.2.

Table 9.2 Potential increases in UME (GJ ha^{-1}) from offering silage with grazed herbage

UME (GJ ha^{-1}) from	% increase in UME from silage compared with herbage	
	10	20
Grazing only	105	105
Grazing + silage after morning milking	107	109
Grazing + *ad libitum* silage overnight	110	116

When high quality silage is offered overnight in autumn the desire for herbage might not be sufficient to maintain a short, leafy sward. However, UME production at this time is low - less than one fifth of the total UME output is achieved in the last third of the grazing season (experiments 1 and 3) - and any reduction in UME output from pasture is therefore small.

Offering silage overnight is a buffer feeding policy that could be preferred due to increased milk fat production in early season and the ability to maintain high total DM intakes, particularly in late season. In addition, cows do not have to be collected from the fields before morning milking, and only about one third of the faeces is deposited on the pasture, thus creating the opportunity for the remainder to be efficiently utilized. If cows are milked three times a day offering the buffer feed between the last milking at night and the morning milking will permit maximum buffer feed intake without restricting grazing time.

In a system where silage is offered overnight grassland could be divided into two separate areas - grazed and conserved - which would permit the use of species/varieties most suited to these harvesting methods eg the conserved area could have a high proportion of clover in the sward. This is possible because in experiments 2 and 3 the seasonal change in herbage DM intake closely paralleled the normal seasonal change in herbage production, and it would therefore be possible to have a constant stocking rate throughout the grazing season.

An alternative method of offering a buffer feed that does not restrict intake is to place it in the field (ESCA, 1981). However this can result in poaching around the feeder, feed wastage (Plate 4) (Wallace and Parker, 1966) and a high input of labour and machinery.

PLATE 4

Supplementing grazed herbage with a buffer feed offered in the field.

Offering a buffer feed in a feeding passage after morning milking cannot compensate for large reductions in herbage DM intake (experiments 1 and 3) but offering it twice a day after each milking could be more beneficial. As cows prefer to graze during daylight hours it is preferable not to offer the buffer feed for too long during the day, especially in autumn when daylight hours are restricted. Buffer feeds offered once a day must not deteriorate rapidly as waste will be reduced if refusals are left from day to day. Refusals in this system of buffer feeding are generally high if the feed is available *ad libitum* because of the high variation in daily intake. Unlike buffer feeds offered overnight which are eaten in considerably greater quantities, a buffer feed offered once a day is likely to be purchased rather than homegrown. Such feeds as hay, alkali-treated straw and a range of byproducts of the food and drinks industries may therefore be suitable.

9.2 BUFFER FEEDS WITH A SILAGE-BASED DIET

Intentional or not, there are obvious advantages to the dairy farmer in restricting the silage ration in a winter-feeding regime: stocking rates can be increased, feed refusals are eliminated and silage is expensive relative to the other basic forage offered to dairy cows-grazed herbage. These experiments have demonstrated that both the magnitude and duration of a restriction will determine the response. Total restrictions of 500 MJ cow^{-1} will be tolerated without loss of milk production,but a restriction of 1000 MJ cow^{-1} will cause a considerable reduction in milk yield. The duration of the restriction is probably less important than the degree of the total restriction in determining the nature of the response, although very severe restrictions will cause an immediate reduction in milk production (Smith *et al*, 1938). In addition, milk protein content is reduced when silage is restricted and milk fat content is likely to be depressed by the increase in concentrate:forage ratio.

Further work is required to determine the effect of a restriction applied over the whole winter feeding period, but a long-term restriction is more likely to be survived without loss of milk production if applied in mid-late lactation. Feed restrictions in early lactation will also extend the calving to conception interval (Haresign, 1981). Clearly there is some scope with autumn-calving cows for moderate silage restrictions at the end of the winter-feeding period, followed by compensatory liveweight gain at pasture if this is available *ad libitum*.

Although the mean response to a restriction of silage is most important, the response of individual animals must also be considered. Dominant cows will eat more than their share of silage if the feeding space is restricted (Reynolds and Campling, 1981), and heifers are more restricted than cows due to their lower rate of silage DM intake relative to live weight (experiment 6).

In certain circumstances major restrictions of silage DM intake occur and milk production will only be maintained if a good quality buffer feed is available. To ensure full utilization of the available silage, the buffer feed must not be eaten in preference to the silage or it must be offered in restricted amounts. If the buffer feed is not to be preferred to silage, it must be of lower quality (in which case it could be of little value to the dairy cow eg straw), or it could be rendered unpalatable by the addition of substances such as salt or animal excreta (MAFF, 1968). If the buffer feed is of higher quality and is offered in restricted amounts it will not act as a buffer to short-term variation in silage availability, although it is likely that this variation can be survived without loss of milk production (Robinson and McGowan, 1980). A compromise may be reached by offering a good quality buffer feed *ad libitum* for a short time eg 1 hour, and some daily adjustment of intake is then possible by altering the rate of intake.

Formulating a buffer feed as a home-produced mix, incorporating straw as a base and byproducts when available, gives the farmer considerable flexibility and will enable the production of feeds of similar quality to silage at only slightly higher cost. Palatability of the feedstuffs, however, must be considered in relation to the feed intake requirement - the addition of molasses, for example, increases the palatability of the mix.

A further aspect requiring investigation is the degree to which the cows can withstand changes in the proportions of different forages in the diet. Hutton and Parker (1965) found that cows offered a 50:50 mixture of a high and low quality forage will not produce any more milk than cows first offered the high quality forage at 100% then the low quality forage at 100%. Indeed, higher overall milk yields were obtained when all the high quality forage was offered in the earlier stage of lactation. This suggests that maintaining exactly constant proportions of the basic forage to the buffer feed throughout the winter is not important.

9.3 THE EFFECTS OF INCREASING FARM STOCKING RATES AND OF OFFERING A BUFFER FEED ON PROFITABILITY

Increasing the stocking rate increases grassland utilization and output of UME ha^{-1}. From Gordon (1973) it can be calculated that a 50% increase in stocking rate increased UME by 13, 10 and 18% in three successive years and Baker (1980) found that a 36% increase in stocking rate over the first eight weeks of the grazing season increased UME over this period by 30%. However herbage availability could be reduced and milk production consequently decline, although to some extent tissue mobilization buffers changes in feed intake. If animal production is reduced the proportion of the feed used for the maintenance of the cow is increased and efficiency declines. In addition, fixed costs ha^{-1} increase and it is the balance between all of these factors that determines the optimum stocking rate.

However, farmers usually operate below this level partly because higher stocking rates, although increasing mean annual income, also increase the variation in annual income (Newton and Brockington, 1975). Stability of annual income is more important than increasing mean annual income (Johnson and Bastiman, 1981). In addition, tradition and shortages of buildings and labour deter many farmers from increasing stocking rates (Forbes *et al*, 1980). The problem of low stocking rates is not one of recognition but of incentive and capital constraints (Forbes *et al*, 1980).

The provision of supplementary feed reduces the variation in annual income and may increase the actual income, depending on the type, cost and effectiveness of the feed (Newton and Brockington, 1975). The most efficient way to counteract variation in forage intake is to offer a buffer feed - a purchased or homegrown feed, offered *ad libitum*, that is eaten when the nutrient intake from the basic forage is restricted but not in preference to the basic forage (Greenhalgh, 1975). The amount of buffer feed needed is determined by the variation in forage intake and the forage quality and length of the cycle of variation determine the type of buffer feed that can be used. For example the annual variation in herbage yield is relatively low (Garwood *et al*, 1977) and there is less need for a buffer feed, which could only be supplied by feeds that can be stored between years (table 9.3).

Diurnal variation in silage intake in a winter-feeding regime is low; this is supported by the fact that the variation in milk fat content is considerably less than during the grazing season (Clapperton *et al*, 1978).

Some variation in forage availability can be predicted eg the spring flush component of seasonal variation in herbage production, and buffers planned - in this case conservation. Later in the year, herbage yield is more variable due to the increased range in precipitation (Garwood *et al*, 1977).

An advantage of rectifying a forage restriction with additional forage rather than concentrate feed is that it promotes a more

Table 9.3 Sources of variation in herbage intake and buffers available

Duration of variation	Diurnal	Seasonal	Annual
Source of variation	Weather, herbage DM content and availability†	Herbage availability	Herbage yield
Buffer feeds	Zero-grazed herbage Conserved forage	Conserved forage, roots, brassicas	Dried grass, hay Silage?
Alternative buffers	Animal tissue mobilization	Irrigation, nitrogen application	Irrigation, stocking rate, fertilizers

† rotationally-grazed swards only

acetate type of fermentation in the rumen, and most of the extra energy intake is used to increase milk production rather than liveweight gain. In addition, the cost of extra forage is considerably less than that of extra concentrates (Lazenby and Doyle, 1981). However the substitution rates of additional forages may be higher than additional concentrates (Hijink, 1978), and this requires investigation.

Further investigation is also needed into the reason for, and extent of, variation in herbage DM intake. In particular knowledge of the ingestive limitations of grazing dairy cows at high stocking rates, and the effects of inclement weather, would help to identify the need for buffer feeds.

APPENDIX 1

References for section 1.1.1.2: effect of a reduction in herbage intake on animal production

Freer, 1960

Greenhalgh *et al*, 1966; 1967

Greenhalgh and Reid, 1968

Gordon, 1973

Hutton and Douglas, 1975

Bryant, 1978

Rogers and Porter, 1978

Pankhurst and McGowan, 1978

Combellas and Hodgson, 1979

Le Du *et al*, 1979

Rogers, 1979

Santamaria *et al*, 1979

Grainger and Wilhelms, 1979

Beilhartz *et al*, 1980

Grainger *et al*, 1980

Rogers and Robinson, 1980 a and b

Rogers *et al*, 1980

Santamaria and Rogers, 1980

Stewart *et al*, 1980

Chalmers and Leaver, 1981

Le Du *et al*, 1981

Meijs, 1981 a and b

APPENDIX 2 EFFECT OF A 10% REDUCTION IN TOTAL DM INTAKE 1) BY RESTRICTION OF HERBAGE INTAKE, 2) BY THE REPLACEMENT OF HERBAGE WITH SILAGE

% change in milk production associated with a 10% reducton in total DM intake	Restriction of herbage intake (section 1.1.1.2)	Replacement of herbage with silage (section 1.2.1.1.2)
Milk yield	-5.6%	-5.2
Milk fat content	-1.1	-2.2
Milk protein content	-1.5	-2.2
Milk fat yield	-4.5	-4.8

APPENDIX 3 INITIAL TREATMENT MEANS (EXPERIMENT 1)

	Number of cows	Milk yield (kg day^{-1})	Live weight (kg)	Condition score	Number of days calved	Parity
MARKER COWS						
High stocking rate (H)	12	28.5	567	2.13	50	3.6
High stocking rate + hay (Hh)	12	28.7	581	2.10	46	3.4
Low stocking rate (L)	12	28.3	568	2.02	47	3.0
Low stocking rate + hay (Lh)	12	28.4	587	2.06	46	3.5
MEAN		28.5	573	2.08	47	3.4
ADDITIONAL COWS (Early season)						
High stocking rate (H)	6	21.2	611	2.30		4.0
High stocking rate + hay (Hh)	6	22.3	614	2.58		3.3
Low stocking rate (L)	4	21.9	617	2.30		5.0
Low stocking rate + hay (Lh)	4	22.6	611	2.25		3.0
MEAN		22.0	613	2.36		3.8
GRAZING OBSERVATION COWS						
High stocking rate (H)	6	31.2	592		43	
High stocking rate + hay (Hh)	6	30.7	586		46	
Low stocking rate (L)	6	30.7	592		46	
Low stocking rate + hay (Lh)	6	31.1	589		39	
MEAN		30.9	590		44	

APPENDIX 4 FERTILIZER APPLICATION IN GRAZING EXPERIMENTS

EXPERIMENT 1 (1981)	Fertilizer application (kg ha^{-1})		
	N	P	K
Dayfield and nightfield early season (10.8 ha)			
17 March	99	-	-
14 May	72	12	12
15 June	64	11	11
14 July	56	14	11
7 August	65	17	13
Total	356	54	47
Silage aftermath (4.2 ha)			
30 March	148	-	-
8 June	95	48	48
14 July	64	17	13
18 August	71	18	15
Total	378	83	76
EXPERIMENTS 2 and 3 (1982)†			
5 March	96	-	-
4 May	54	14	11
24 May	57	15	12
16 June	54	14	11
14 July	66	15	15
3 August	66	15	15
3 September	57	13	13
Total	450	86	77

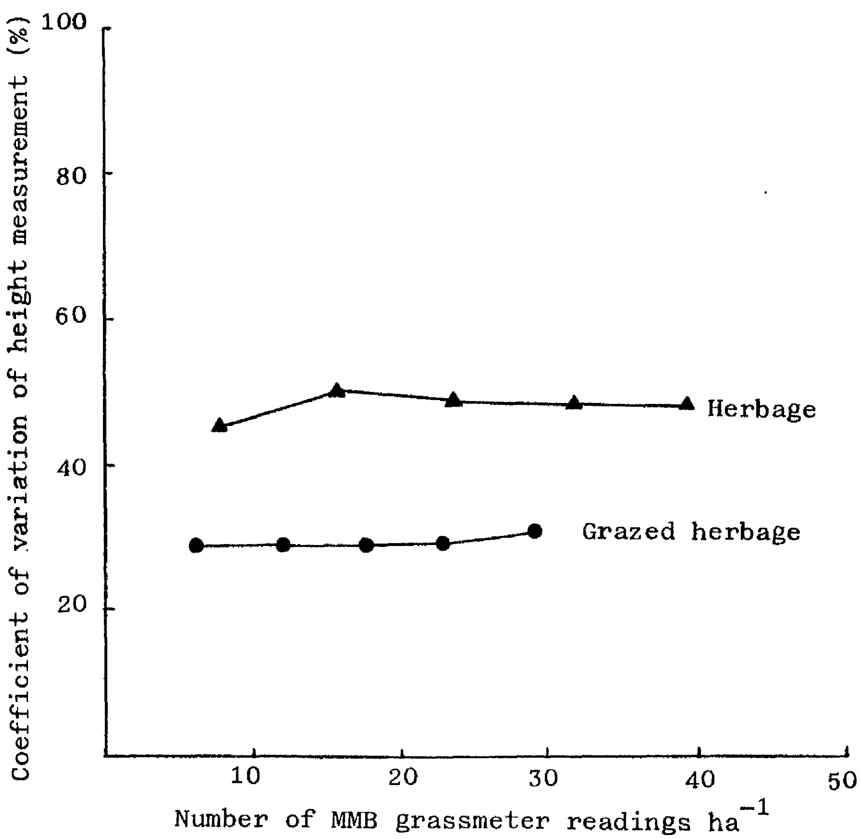
† Experiment 2 (4.7 ha) 21 April - 14 July
Experiment 3 (3.6 ha) 4 August - 6 October

APPENDIX 5 AN INVESTIGATION INTO THE IMPROVEMENT OF HERBAGE HEIGHT MEASUREMENTS IN EXPERIMENT 1

METHOD: Forty measurements of herbage height ha^{-1} were taken on 9 ha of the grazing area used in experiment 1 with both the MMB rising plate meter and the grass disc described by Castle (1976). In addition those readings occurring in areas of rejected herbage were recorded to enable grazed herbage height to be determined.

RESULTS: Increasing the number of herbage height measurements from 8 ha^{-1} to 40 ha^{-1} had no effect on the coefficient of variation (appendix figure 1) of either herbage or grazed herbage height. Mean coefficient of variation of grazed herbage height was less than that of herbage height, as found in experiment 1. Mean coefficients of variation for 20 recordings of herbage height in each treatment area (20 measurements $recording^{-1}$) were 48.4 and 51.6% for the MMB rising plate meter and the grass disc respectively. These were not significantly different ($P>0.05$).

CONCLUSIONS: It was concluded that there was no advantage to be gained from increasing the number of herbage height measurements ha^{-1} or from changing from the MMB grass meter to the grass disc.



Appendix Figure 1 The effect of increasing the number of herbage height measurements on CV%

APPENDIX 6 CONCENTRATE SUPPLEMENTATION IN EXPERIMENT 1 (1981)

Mean grass height (cm)	Milk yield above which supplementation required (kg day^{-1}) PERIOD					
	1	2	3	4	5	6
10	29.0	26.0	23.0	20.0	17.0	14.0
9	28.5	25.5	22.0	19.5	16.0	14.0
8	27.5	24.0	21.0	18.0	15.0	12.5
7	26.0	22.0	19.0	16.0	13.0	10.5
6	23.5	20.0	16.0	13.0	10.0	7.5
5	20.0	16.0	12.0	9.0	6.0	3.5
4	15.5	11.0	7.0	3.5	0.0	0.0
3	9.0	4.0	0.0	0.0	0.0	0.0

Period 1: 15 April - 12 May
2: 13 May - 9 June
3: 10 June - 8 July
4: 9 July - 5 August
5: 6 August - 2 September
6: 3 September - 30 September

Concentrates were offered at a rate of 0.45 kg kg^{-1} mean milk yield of cows on the low stocking rate above the yield level attributable to the grass height of the low stocking rate treatment areas. Concentrate level was fixed at 4 kg day^{-1} at the start of the experiment and the maximum reduction of concentrates in one week was set at 1 kg day^{-1}.

APPENDIX 7 EQUATIONS USED TO PREDICT THE METABOLIZABLE ENERGY CONTENT OF THE FEEDS

EQUATION

A1 Silage M/D (MJ kg^{-1} DM) = 0.249 x *In vitro* OMD (%) - 0.00716 x DM content (g kg^{-1}) - 4.21

A2 Herbage) Hay) Concentrate) Straw) M/D = 0.235 x *In vitro* OMD (%) - 4.45

A3 Silage M/D = $[(In\ vitro\ OMD\ (\%) \times 0.907 + 6.03) \times \frac{OM\ (g\ kg^{-1})}{1000}] \times 0.16$

A4 Herbage) Hay) Concentrate) Straw) M/D = $[(In\ vitro\ OMD\ (\%) \times 1.207 - 10.21) \times \frac{OM\ (g\ kg^{-1})}{1000}] \times 0.16$

ME content of the feeds was predicted using equations 1 and 2 in experiments 1, 2, 4 and 5. In experiments 3 and 6 equations 3 and 4 were used.

APPENDIX 8 METEOROLOGICAL RECORDS FOR EXPERIMENTS 1, 2 AND 3

	Rainfall ($mm\ day^{-1}$)	Mean daily temperature (°C) Maximum	Minimum	Sunshine ($hours\ day^{-1}$)	Wind run (km)
EXPERIMENT 1 (1981)					
April	1.4	11.8	2.8	5.9	3,999
May	2.7	15.3	6.6	5.3	4,905
June	2.3	16.0	9.1	5.1	5,363
July	2.6	17.6	10.9	4.0	4,722
August	0.4	19.0	11.1	4.9	3,824
September	6.0	16.7	9.6	3.7	4,722
Total/mean	2.7	16.1	8.4	4.8	27,535
EXPERIMENTS 2 and 3 (1982)					
April	0.7	13.3	4.2	6.0	
May	2.0	14.9	4.3	6.0	
June	2.6	17.6	8.7	4.2	
July	1.6	20.0	10.6	5.6	
August	2.5	18.0	10.6	4.6	
September	3.8	15.2	8.8	3.3	
Total/mean	2.2	16.5	7.9	5.0	
MEAN 1951-80					
April	1.8	11.5	3.3	4.9	
May	2.3	14.8	6.0	5.8	
June	2.1	17.8	9.0	6.1	
July	2.5	18.3	10.6	5.1	
August	3.0	18.1	10.5	4.9	
September	3.5	15.9	8.9	3.7	
Total/mean	2.5	16.1	8.1	5.1	

APPENDIX 9 GRAZING BEHAVIOUR (EXPERIMENT 1)

Activity (hours day^{-1})		H	Hh	L	Lh	SED	Significance: Hay	Significance: Stocking rate	Period effect: SED	Period effect: Significance
Grazing	E	8.6	8.1	8.0	8.3	0.29	NS	NS		
	M	9.9	9.0	9.8	9.5	0.41	NS	NS		
	L	8.8	8.5	8.4	7.9	0.31	NS	NS		
		9.1	8.5	8.7	8.6	0.27	NS	NS	0.29	***
Standing and ruminating	E	1.3	1.7	1.1	1.4	0.16	*	NS		
	M	2.2	2.0	1.4	1.9	0.21	NS	NS		
	L	0.9	0.9	1.0	0.9	0.12	NS	NS		
		1.5	1.5	1.2	1.4		NS	NS	0.15	***
Standing†	E	3.5	2.9	3.6	3.5	0.21	NS	NS		
	M	2.5	2.6	2.8	2.5	0.17	NS	NS		
	L	3.1	2.6	2.9	2.8	0.17	NS	NS		
		3.0	2.7	3.1	2.9	0.14	NS	NS	0.17	***
Lying and ruminating	E	4.9[b]	5.6[a]	5.4[ab]	5.0[ab]	0.23	NS Interaction *	NS		
	M	5.4	5.4	5.4	5.3	0.40	NS	NS		
	L	5.8	6.1	6.0	6.1	0.35	NS	NS		
		5.4	5.7	5.6	5.5	0.25	NS	NS	0.28	**
Lying	E	4.4	3.9	4.6	3.8	0.40	NS	NS		
	M	2.7	3.2	3.4	3.0	0.28	NS	NS		
	L	4.4	4.2	4.5	4.4	0.37	NS	NS		
		3.8	3.8	4.2	3.7	0.29	NS	NS	0.30	***

cont/..

APPENDIX 9 GRAZING BEHAVIOUR (EXPERIMENT 1) CONTINUED

Activity (hours day^{-1})		H	Hh	L	Lh	SED	Significance Hay	Significance Stocking rate	Period effect SED	Period effect Significance
Walking	E	1.4	1.3	1.3	1.3	0.049	NS	NS		
(including to/	M	1.5	1.5	1.4	1.4	0.040	NS	NS		
from milking)	L	1.1	1.1	1.2	1.2	0.021	NS	***		
		1.3	1.3	1.3	1.3	0.051	NS	NS	0.035	***
Walking	E	0.35	0.28	0.22	0.24	0.051	NS	NS		
(at pasture)	M	0.21	0.22	0.16	0.16	0.040	NS	NS		
	L	0.11	0.08	0.04	0.03	0.025	NS	*		
		0.22	0.19	0.14	0.14	0.040	NS	*	0.035	***
Number of	E	1.1	0.8	0.8	1.3	0.29	NS	NS		
drinks	M	0.9	1.7	1.7	1.7	0.37	NS	NS		
	L	1.3	1.6	1.0	1.5	0.21	NS	NS		
		1.1	1.4	1.1	1.5	0.20	NS	NS	0.26	NS

E = early season
M = mid season
L = late season

Means with different superscripts differ significantly
† approximately 80% of standing time occurred at milking times

APPENDIX 10 WEATHER CONDITIONS FOR GRAZING OBSERVATIONS (EXPERIMENT 1)

Season	Early		Mid		Late	
Observation date	12/5	3/6	3/7	5/8	28/8	30/9
Rainfall (mm day^{-1})	0	8.4	1.0	0	0	7.2
Wind run (km)	74	161	61	69	44	70
Maximum temperature (°C)	21.0	15.9	15.6	19.0	21.9	15.4
Minimum temperature (°C)	8.6	11.5	9.1	14.2	11.4	9.2
Visibility at 09.30 hours (m)	2170	2170	NA	7240	430	12060
Sunshine (hours)	13.9	5.0	10.6	3.7	9.6	4.4
Daylength (hours)	16.7	18.8	18.0	16.8	15.8	12.8
Grazed herbage height (cm)	6.7	5.8	5.6	5.4	4.6	3.7

APPENDIX 11 CONCENTRATE INGREDIENTS

% by weight	1	2	3	4
Barley	14.5	14.0	21.7	24.3
Maize	39.0	7.0	-	-
Maize gluten	10.0	10.0	20.3	20.2
Wheat	-	29.0	20.0	20.0
Wheatfeed	9.5	9.5	15.0	8.0
Soya	15.0	14.5	11.0	15.0
Fishmeal	2.5	2.5	2.5	2.5
Molasses	5.0	7.5	4.0	5.0
Fat supplement	1.3	3.0	2.5	2.0
Dicalcium phosphate	0.9	-	0.5	0.5
Mineral/vitamin	2.3	3.0	2.5	2.5

Concentrate 1 was used in experiment 4

2 was used in experiments 2, 5 and the last 4 weeks of experiment 1

3 was used in experiment 3

4 was used in experiment 6

APPENDIX 12 CHANGEOVER DESIGNS EMPLOYED IN EXPERIMENTS 2, 3, 4 AND 5

Design 1

1	2	3	4
2	4	1	3
3	1	4	2
4	3	2	1

Design 2

1	2	3		1	2	3
2	3	1		3	1	2
3	1	2		2	3	1

In these designs rows represent periods of the experiment and columns are experimental units (cows).

In experiments 2, 4 and 5 there were 8, 4 and 3 blocks respectively of design 1.

In experiments 3 there were 3 pairs of the orthoganol pair of Latin Square blocks of design 2.

Design 1 was also employed in experiment 2 as a rota for daily treatment allocation to the four set-stocked areas. In this instance columns and rows were treatments and days respectively. Design 2 was similarly employed in experiment 3.

Source: Patterson and Lucas (1962).

APPENDIX 13 BLOCK MEANS AT THE START OF EXPERIMENTS 2 AND 3

EXPERIMENT 2	Production level	Milk yield	Live weight	Condition score	Calving date	Lactation no.
Autumn-calving cows	High	26.3	665	2.1	13 September	5.3
	Medium	23.2	631	1.8	18 October	2.8
	Low	22.5	645	1.9	2 November	5.5
Autumn-calving heifers	-	18.5	551	2.3	10 November	-
Spring-calving cows	-	27.2	674	2.4	18 March	4.3
Spring-calving heifers	High	22.1	491	1.6	10 February	-
	Medium	19.1	468	1.7	28 January	-
	Low	17.0	485	2.2	28 February	-
EXPERIMENT 3						
Spring-calving cows	High	22.1	627	1.3	11 March	5.3
	Low	18.7	641	2.1	20 February	4.0
Spring-calving heifers	High†	18.8	594	1.8	15 January	-
	Medium†	16.3	562	2.3	8 January	-
	Low	15.5	495	2.0	27 January	-
	Very low	14.5	483	1.8	10 February	-

† This group contained one cow and two heifers

APPENDIX 14 ANALYSIS OF VARIANCE OF A BALANCED CHANGEOVER DESIGN

Example - Milk yield (kg day^{-1}), experiment 2

Source of variation	Degrees of freedom	Sum of squares	Mean square	'F' ratio	Significance
Blocks	7	1289	184	183	***
Period	3	737	246	244	***
Period x blocks	21	82	3.9	3.9	***
Cows within blocks	24	281	11.7	11.6	***
Breakdown of treatment effects					
Direct effects (ignoring residual effects)	3	20.8	6.9	6.9	***
Residual effects	3	6.1			
Direct effects	3	24.5			
Residual effects (ignoring direct effects)	3	2.5	0.82	0.82	NS
Error	66	66	1.01		
Total	127	2481			

Treatment	Direct means	Residual effects
G	19.9	-0.02
GMS	19.6	-0.08
GRS	18.9	0.29
GAS	18.9	-0.19
SED	0.26	0.32

APPENDIX 15 SIGNIFICANT RESIDUAL EFFECTS IN EXPERIMENTS 2 AND 3

EXPERIMENT 2	G	GMS	GRS	GAS	SED	SIGNIFICANCE
Silage DM intake (kg day^{-1})	(-0.81^{b})	-0.37^{b}	$+0.68^{a}$	$+0.50^{a}$	0.30	***
ME intake (MJ day^{-1})	$+4.2^{a}$	-11.7^{b}	$+6.8^{a}$	$+0.6^{a}$	6.26	*
Milk fat content (g kg^{-1})	-0.2^{bc}	-1.3^{c}	$+0.4^{ab}$	$+1.1^{a}$	0.60	**
Milk protein content (g kg^{-1})	-0.4^{bc}	-0.2^{ab}	$+0.5^{a}$	0.0^{ab}	0.39	*
Milk fat yield (g day^{-1})	-3.4^{ab}	-23.6^{bc}	$+13.5^{a}$	$+13.4^{a}$	15.0	*
Milk protein content (g day^{-1})	-10.7^{b}	-11.2^{b}	$+29.9^{a}$	-8.0^{b}	13.7	**
Grazing bites day^{-1}	$+1559^{a}$	$+317^{ab}$	-111^{b}	-765^{b}	930	*
Grazing time (h day^{-1})	$+0.48^{a}$	-0.06^{b}	-0.32^{b}	-0.10^{b}	0.16	***
EXPERIMENT 3						
Herbage DM intake (kg day^{-1})	$+1.1^{a}$	-1.2^{b}	-	$+0.1^{a}$	0.78	*
Milk protein yield (g day^{-1})	-7.6^{b}	-17.4^{b}	-	$+25.0^{a}$	14.0	*
Grazing time (h day^{-1})	-0.16^{b}	-0.34^{b}	-	$+0.45^{a}$	0.24	**
Grazing bite size (g DM day^{-1})	$+0.07^{a}$	-0.06^{b}	-	-0.01^{b}	0.03	**
Herbage intake rate (g DM min^{-1})	$+4.4^{a}$	-3.6^{b}	-	-0.8^{b}	2.45	*

Residual effects in all other parameters in experiments 2 and 3 were not significant

APPENDIX 16 SIGNIFICANT RESIDUAL EFFECTS IN EXPERIMENTS 4 AND 5

EXPERIMENT 4	A	Ah	R	Rh	SED	SIGNIFICANCE
Milk lactose yield (g day^{-1})	-34.4^{b}	-8.8^{ab}	$+16.2^{a}$	$+27.0^{a}$	22.2	*
Liveweight change (kg day^{-1})	$+0.10^{ab}$	$+0.58^{a}$	$+0.04^{ab}$	-0.72^{b}	0.44	*
CV of milk yield (%)	$+0.7^{ab}$	-1.0^{bc}	$+0.9^{a}$	-0.6^{b}	0.69	*
Silage DM intake (days 1-6) (kg day^{-1})	-0.4^{b}	$+0.2^{ab}$	-0.3^{b}	$+0.5^{a}$	0.30	*
Protein content (days 1-6) (g kg^{-1})	-0.8^{c}	$+0.2^{b}$	-0.7^{c}	$+1.3^{a}$	0.43	***

Results given are for days 15-21 of each period unless otherwise specified.

EXPERIMENT 5	A	R	Rs	Rt	SED	SIGNIFICANCE
CV of forage DM intake (%)	$+2.0^{a}$	-0.2^{ab}	-2.0^{b}	$+0.1^{ab}$	1.32	*

APPENDIX 17 TREATMENT MEANS FOR COWS AND HEIFERS AT THE START OF EXPERIMENT 6

		Treatment		
		A	R	RS
Milk yield (kg day^{-1})	Cows	23.5	23.8	23.3
	Heifers	20.3	20.3	20.7
	Mean	21.9	22.1	22.0
Live weight (kg)	Cows	577	581	578
	Heifers	531	524	522
	Mean	554	553	550
Condition score	Cows	1.8	2.0	1.9
	Heifers	2.2	2.2	2.3
	Mean	2.0	2.1	2.1
Number of days calved	Cows	35	35	32
	Heifers	70	71	71
	Mean	53	53	51
Parity	Cows	4.0	4.3	4.5

LIST OF REFERENCES

ABIDIN, Z and KEMPTON, T J, 1981. Effects of treatment of barley straw with anhydrous ammonia and supplementation with heat-treated protein meals on feed intake and liveweight performance of growing lambs. Anim Feed Sci&Technol 6: 145-155.

ADAS, 1978. Higher yields from dairy herds. Profitable Farm Enterprises Booklet No 12, 2nd ed p 21.

ARC, 1980. The Nutrient Requirements of Ruminant Livestock. Commonwealth Agricultural Bureaux, Slough.

ALDERMAN, G; BROSTER, W H and STRICKLAND, M J, 1982. The energy value of liveweight change in the lactating dairy cow. Anim Prod 34: 399-400 (Abstr).

ALEXANDER, R H and McGOWAN, MARY, 1961. A filtration procedure for the *in vitro* determination of herbage. J Br Grassld Soc 16:275-277.

ALEXANDER, R H and McGOWAN, MARY, 1966. The routine determination of *in vitro* digestibility of organic matter in forages - an investigation of the problems associated with continuous large-scale operation. J Br Grassld Soc 21: 140-147.

ALEXANDER, R H and McGOWAN, MARY, 1969. The assessment of the nutritive value of silage by determination of *in vitro* digestibility on homogenates prepared from fresh undried silage. J Br Grassld Soc 24: 195-198.

AMIR, S; KALI, J; NEUMARK, H and BLAIBERG, M, 1970. All-pelleted straw-concentrate rations to dairy cows in mid-laction. J Dairy Sci 53: 672-673.

AMAN, P and NORDKVIST, E, 1983. Chemical composition and *in vitro* degradability of botanical fractions of cereal straw. Swed J agric Res 13: 61-67.

ANNISON, E F; BICKERSTAFFE, R and LINZELL, J L , 1974. Glucose and fatty acid metabolism in cows producing milk of low fat content. J agric Sci, Camb 82: 87-95.

ANNISON, E F; LEWIS, D and LINDSAY, D B, 1959. The metabolic changes which occur in sheep transferred to lush spring grass. 1. Changes in blood and rumen constituents. J agric Sci, Camb 53: 34-45.

ARNOLD, G W and HOLMES, W, 1958. Studies in grazing management. VII. The influence of strip grazing versus controlled free grazing on milk yield, milk composition, and pasture utilization. J agric Sci, Camb 51: 248-256.

ASHFORD, R and TROELSEN, J E, 1965. The effect of nitrogen fertilizer and clipping frequency upon the yield and *in vitro* digestibility of intermediate wheatgrass. J Br Grassld Soc 20: 139-143.

ASTRUP, H N; BAEVRE, L; VIK-MO, L and EKERN, A, 1980. Effect on milk lipolysis of restricted feeding with and without supplementation with protected rape seed oil. J Dairy Res 47: 287-294.

BAILEY, P J; BISHOP, A H and BOORD, C T, 1974. Grazing behaviour of steers. Proc Aust Soc Anim Prod 10: 303-306.

BAKER, ANNE-MARIE C, 1980. A study of herbage production and its utilization by dairy cattle from continuously grazed swards. M Sc thesis, University of Glasgow.

BAKER, ANNE-MARIE C; CHALMERS, J S and LEAVER, J D, 1980. The effect of stocking rate in spring on the production of set-stocked dairy cows. Crichton Royal Farm Annual Report 1980, The West of Scotland Agricultural College, pp 27-28.

BAKER, R D, 1982. Estimating herbage intake from animal performance. In Leaver, J D (ed) Herbage Intake Handbook pp 73-93. British Grassland Society, Hurley.

BAKER, R D; ALVAREZ, F and LE DU. Y L P, 1981a. The effect of herbage allowance upon the herbage intake and performance of suckler cows and calves. Grass and Forage Sci, 36: 189-199.

BAKER, R D; LE DU, Y L P and ALVAREZ, F, 1981b. The herbage intake and performance of set-stocked cows and calves. Grass and Forage Sci 36: 201-210.

BALCH, C C, 1971. Proposal to use time spent chewing as an index of the extent to which diets for ruminants possess the physical property of fibrousness characteristic of roughages. Br J Nutr 26: 383-392.

BALCH, C C and LINE, C, 1957. Weight changes in grazing cows. J Dairy Res 24: 11-20.

BARTHRAM, G T, 1981. Sward structure and the depth of the grazed horizon. Grass and Forage Sci 36: 130-131 (Abstr).

BATH, I H and ROOK, J A F, 1961. The effect of stage of growth of S23 perennial ryegrass on the production of volatile fatty acids in the rumen of the cow. Proc Nutr Soc 20: 15 (Abstr).

BATH, I H; ROOK, J A F and ROWLAND, S J, 1962. Effects of grazing on the ruminal production of volatile fatty acids in relation to the protein and fat contents of milk. Proc XVIth Int Dairy Congr 1: 49-53, Copenhagen.

BEEVER, D E; CAMMELL, S B; TERRY, R A and THOMSON, B J, 1975. Production of volatile fatty acids during the digestion of feeds by ruminants. Annual Report, 1975, Grassland Research Institute, Hurley, pp 83-84.

BEEVER, D E; TERRY, R A and CAMMELL, S B, 1977. The digestion of spring and autumn-cut ryegrass by sheep. Annual Report 1977, Grassland Research Institute, Hurley, p 83.

BEILHARTZ, M; HODGE, A; ROBINSON, I and PORTER, R, 1980. The effect of stage of growth of ryegrass-white clover pasture on milk production. Ellinbank Dairy Research Station Annual Report 1980, Victoria Department of Agriculture, pp 62-63.

BIGGS, D A , 1979. Performance specification for infra-red milk analysis. J Ass off agric Chem 62: 1211-1214.

BINES, J A, 1976. Regulation of food intake in dairy cows in relation to milk production. Livest Prod Sci 3: 115-128.

BLAXTER, K L; WAINMAN, F W; DEWEY, P J S; DAVIDSON, J; HENDERLEY, H and GUNN, J, 1971. The effects of nitrogenous fertilizer on the nutritive value of artificially dried grass. J agric Sci, Camb 76: 307-319.

BORHAMI, B E A and SUNDSTØL, F, 1982. Studies on ammonia-treated straw. 1. The effects of type and level of ammonia, moisture content and treatment time on the digestibility *in vitro* and enzyme soluble organic matter of oat straw. Anim Feed Sci & Technol 7: 45-51.

BOSWELL, C C, 1971. Fouling of pastures by grazing cattle. J Br Grassld Soc 24: 194 (Abstr).

BREIREM, K; HOMB, T; PRESTHEGGE, K and ULVESLI, O, 1959. Some results of fifteen years research on grassland products in the feeding of ruminants. Meld Norg LandbrHøisk 38 (Dept Anim Nutr, Agric Univ Norway, Tech Bull 9, 35 pp).

BROADBENT, P J; McINTOSH, J A R and SPENCE, A, 1970. The evaluation of a device for feeding group-housed animals individually. Anim Prod 12: 245-252.

BROCKINGTON, N R, 1972. A mathematical model of pasture contamination by grazing cattle and the effects on herbage intake. J agric Sci, Camb 79: 249-257.

BROOM, D M; PAIN, B F and LEAVER, J D, 1975. The effect of slurry on the acceptability of swards to grazing cattle. J agric Sci, Camb 85: 331-336.

BROSTER, W H, 1972. Effect on milk yield of the cow of the level of feeding during lactation. Dairy Sci Abstr 34: 265-288.

BROSTER, W H, 1980. Developments in feeding dairy cows. ADAS Q Rev 39: 234-255.

BROSTER, W H and ALDERMAN, G, 1977. Nutrient requirements of the high yielding cow. Livest Prod Sci 4: 263-275.

BRUMBY, P J, 1959. The grazing behaviour of dairy cattle in relation to milk production, live weight, and pasture intake. N Z Jl agric Res 2: 797-807.

BRYANT, A M, 1978. Summer supplementary feeding. Proc Ruakura Farmers Conf Week, 1978, article no 163.

BRYANT, A M, 1979. Effects of nutrition on milk composition. Proc Ruakura Farmers Conf Week, 1979, pp 121-130.

BRYANT, A M and DONNELLY, P E, 1974. Yield and composition of milk from cows fed pasture herbage supplemented with maize and pasture silages. N Z Jl agric Res 17: 299-304.

BURT, A W A, 1957. The effect of variations in nutrient intake upon the yield and composition of milk. II Factors affecting rate of eating roughage and responses to an increase in the amount of concentrates fed. J Dairy Res 24: 296-315.

BUTLER, B, 1981. Treated straw - a feed for the dairy herd. MMB Farm Management Services Report No 28, pp 21.

BUTTERY, P J and LEWIS, D, 1982. Nitrogen metabolism in ruminants. In Thomson, D J; Beever, D E and Gunn, R G (eds) Forage Protein in Ruminant Animal Production pp 1-11. British Society of Animal Production Occasional Publication No 6.

CAMPLING, R C, 1966. The intake of hay and silage by cows. J Br Grassld Soc 21: 41-49.

CAMPLING, R C and BALCH, C C, 1961. Factors affecting the voluntary intake of food by cows. 1. Preliminary observations on the effect, on the voluntary intake of hay, of changes in the amount of reticulo-ruminal contents. Br J Nutr 15: 523-530.

CAMPLING, R C and HOLMES, W, 1958. Winter feeding of dairy cows. V. A comparison of the relative value for milk production of artificially dried cocksfoot and a timothy/meadow-fescue mixture grown both in spring and in autumn. J Dairy Res 25: 147-153.

CAMPLING, R C and MILNE, J A, 1972. The nutritive value of processed roughages for milking cattle. Proc Br Soc Anim Prod 53-60.

CAMPLING, R C and MORGAN, C A, 1981. Eating behaviour of housed dairy cows - a review. Dairy Sci Abstr 43: 57-63.

CAMPLING, R C; MacLUSKY, D S and HOLMES, W, 1958. Studies in grazing management. VI. The influence of free- and strip-grazing and of nitrogenous fertilizers on production from dairy cows. J agric Sci, Camb 52: 62-69.

CARSTAIRS, J A; NEITZEL, R R and EMERY, R S, 1981. Energy and phosphorus status as factors affecting postpartum performance and health of dairy cows. J Dairy Sci 64: 34-41.

CASTLE, M E, 1972. A study of the intake of drinking water by dairy cows at grass. J Br Grassld Soc 27: 207-210.

CASTLE, M E, 1976. A simple disc instrument for estimating herbage yield. J Br Grassld Soc 31: 37-40.

CASTLE, M E and WATSON, J N, 1973. The intake of drinking water by dairy cows. The effect of water availability. J Br Grassld Soc 28: 203-207.

CASTLE, M E and WATSON, J N, 1978. A comparison of continuous grazing systems for milk production. J Br Grassld Soc 33: 123-129.

CASTLE, M E; DRYSDALE, A D and WATSON, J N, 1960. The effect of feed supplements on the yield and composition of milk from cows grazing good pasture. J Dairy Res 27: 419-426.

CASTLE, M E; FOOT, A S and HALLEY, R J, 1950. Some observations on the behaviour of dairy cattle with particular reference to grazing. J Dairy Res 17: 215-230.

CASTLE, M E; GILL, M S and WATSON, J N, 1981. Silage and milk production: a comparison between long, chopped and ground hays as supplements to silage of high digestibility. Grass & Forage Sci 36: 91-96.

CHALMERS, J S, 1980. A comparison of two techniques for controlling cows at a self-feed silage face. Crichton Royal Farm Annual Report, 1980, The West of Scotland Agricultural College, pp 25-26.

CHALMERS, J S and LEAVER, J D, 1981. The effect of stocking rate in early season and the level of supplementation on the production of set-stocked dairy cows. Crichton Royal Farm Annual Report, 1981, The West of Scotland Agricultural College, pp 25-27.

CHENOST, M and DEMARQUILLY, C, 1982. Measurement of herbage intake by housed animals. In Leaver, J D (ed) Herbage Intake Handbook, pp 95-112. British Grassland Society, Hurley.

CHESTNUTT, D B; MURDOCH, J C; HARRINGTON, F J and BINNIE, R C, 1977. The effect of cutting frequency and applied nitrogen on production and digestibility of perennial ryegrass. J Br Grassld Soc 32: 177-183.

CLAPPERTON, J L; REID, D and WILSON, AGNES G, 1978. Daily variation in the composition of cows' milk. Proc Nutr Soc 37: 72A (Abstr).

CLARK, R M; HOLTER, J B; COLOVOS, N F; HAYES, H H, 1972. Effect of postural position and position changes on energy expenditure in fasting dairy cattle. J Dairy Sci 55: 257-260.

COMBELLAS, T and HODGSON, J, 1979. Herbage intake and milk production by grazing dairy cows. 1. The effect of variation in herbage mass and daily herbage allowance in a short term trial. Grass and Forage Sci 34: 209-214.

COMBELLAS, T; BAKER, R D and HODGSON, J, 1979. Concentrate supplementation, and the herbage intake and milk production of heifers grazing *Cenchrus ciliaris*. Grass and Forage Sci 34: 303-310.

COOK, C W, 1964. Symposium on nutrition of forages and pastures: collecting forage samples representative of ingested material of grazing animals for nutritional studies. J Anim Sci 23: 265-270

COPPOCK, C E, 1977. Feeding methods and grouping systems. J Dairy Sci 60: 1327-1336.

COPPOCK, C E; EVERETT, R W; SMITH, N E; SLACK, S T and HARNER, J P, 1974. Variation in forage preference in dairy cattle. J Anim Sci 39: 1170-1179.

CORBETT, J L; LANGLANDS, J P and REID, G W, 1963. Effects of season of growth and digestibility of herbage on intake by grazing dairy cows. Anim Prod 5: 119-129.

CORBETT, J L; LANGLANDS, J P; McDONALD, I and PULLAR, J P, 1966. Comparison by direct animal calorimetry of the net energy values of an early and a late season growth of herbage. Anim Prod 8: 13-27.

COXWORTH, E; KERNAN, J; NICHOLSON, H; CHAPLIN, R and MANNS, J, 1976. A report on a search for economical farm scale methods of improving the feeding value of straws of the Canadian prairies ... use of ammonia and other bases. Proceedings of the 12th Annual Nutrition Conference for Feed Manufacturers, Toronto, Canada. Cited by Sundstøl *et al* (1978).

CURRAN, M K and HOLMES, W, 1970. Prediction of voluntary intake of food by cows. 2. Lactating grazing cows. Anim Prod 12: 213-224.

DAVIES, L H, 1962. Intake studies in sheep involving high fluid intake. Proc Aust Soc Anim Prod 4: 167-171.

DAVISON, T M; MARSCHKE, R J and BROWN, G W, 1982. Milk yields from feeding maize silage and meat- and-bone meal to Friesian cows grazing a tropical grass and legume pasture. Aust J exp Agric Anim Husb 22: 147-154.

DAWSON, R R and ROOK, J A F, 1972. A note on the influence of stage of lactation on the response in the lactose content of milk to a change of plane of energy nutrition in the cow. J Dairy Res 39: 107-111.

DECAEN, C and JOURNET, M, 1966. Influence saisonnière sur la production et la composition du lait (seasonal effects on production and composition of milk). Annls Zootech 15: 259-277.

DENT, J W and ALDRICH, D T A, 1968. Systematic testing of quality in grass varieties. 2. The effect of cutting dates, season and environment. J Br Grassld Soc 23: 13-19.

DODDS, G L and GALT, D, 1981. Planning guide for grazing and forage needs. Co-operative Extension Service Circular R-581, North Dakota State University.

DODSWORTH, J L and CAMPBELL, W H McK, 1953. Report on a further experiment to compare the fattening values, for beef cattle, of silage made from grass cut at different stages of growth, together with the results of some supplementary experiments. J agric Sci, Camb 43: 166-177.

DOYLE, C; CORRALL, J; LE DU, Y and THOMAS, C, 1982. The integration of conservation with grazing. In Thomas, C and Young, J W O (eds) Milk from Grass pp 59-74. ICI Agricultural Division, Billingham and Grassland Research Institute, Hurley.

DUCKHAM, A N, 1967. Buffers in grassland systems. In Wilkins, R J (ed) Fodder Conservation, pp 1-12. British Grassland Society Occasional Symposium No 3.

DUCKWORTH, J E and SHIRLAW, D W, 1958a. The value of animal behaviour records in pasture evaluation studies. Anim Behav 6: 139-146.

DUCKWORTH, J E and SHIRLAW, D W, 1958b. A study of factors affecting feed intake and the eating behaviour of cattle. Anim Behav 6: 147-154.

ESCA, 1981. Buffer feeding of silage in late summer. The Langhill Dairy Cattle Breeding Project Annual Report 1981, pp 32-34, The East of Scotland College of Agriculture.

EKERN, A, 1972. Feeding of high yielding dairy cows. II. The effect of *ad libitum* versus restricted forage feeding on milk yield and composition. Meld Norg LandbHøisk 51:31 (Dept Anim Nutr, Agric Univ Norway, Tech Bull 148, 31 pp).

EKERN, A and VIK-MO, L, 1979. Conserved forages as feeds for dairy cows. In Broster, W H and Swan, H (eds) Feeding Strategy for the High Yielding Dairy Cow, pp 322-376. Granada Publishing, London for the Eur Ass Anim Prod.

ELDRIDGE, G A and KAT, C, 1980. The effect of hay supplementation and pasture availability on pasture selection and substitution. Proc Aust Soc Anim Prod 13: 245-248.

FISHER, L J, 1979. Supplementation with protected lipid as a means of alleviating "spring pasture" induced milk fat depression. Can J Anim Sci, 59: 707-712.

FISHER, L J; DONNELLY, P E; HUTTON, J B and DUGANZICH, D M, 1975. Relationships between levels of feeding and certain blood metabolites in dairy cows in mid lactation. J agric Sci, Camb, 84: 29-37.

FORBES, T J, DIBB, C; GREEN, J O; HOPKINS, A and PEEL, S, 1980. Factors affecting the productivity of permanent grassland: a national farm study. Grassland Research Institute and ADAS Joint Permanent Pasture Group, Hurley.

FRANK, B, 1982. Untreated barley straw in dairy cow rations. Swed J agric Res 12: 137-147.

FREER, M, 1960. The utilization of irrigated pastures by dairy cows. II. The effect of stocking rate. J agric Sci, Camb, 54: 243-256.

FRIEND, T H; POLAN, C E and McGILLIARD, M L, 1977. Free stall and feed bunk requirements relative to behaviour, production and individual feed intakes in dairy cows. J Dairy Sci 60: 108-116.

GALE, G E and KNIGHT, A C, 1979. Apparatus and procedure for the accurate assessment of forage chop length. In Thomas, C (ed) Forage Conservation in the 80's, pp 335-338. British Grassland Society Occasional Symposium No 11.

GARDINER, K D and McGANN, T C A, 1968. Survey of milk composition in the Dublin liquid milk area. Ir J agric Res, 7: 37-48.

GARSTANG, J R and MUDD, C H, 1971. The rejection of contaminated herbage by dairy cows. J Br Grassld Soc 26: 194 (Abstr).

GARWOOD, E A; TYSON, K C and CLEMENT, C R, 1977. A comparison of yield and soil conditions during 20 years of grazed grass and arable cropping. Grassland Research Institute (Hurley) Technical Report No 21.

GORDON, A H and CHESSON, A, 1983. The effect of prolonged storage on the digestibility and nitrogen content of ammonia-treated barley straw. Anim Feed Sci and Technol, 8: 147-153.

GORDON, C H; DERBYSHIRE, J C; ALEXANDER, C W and McCLOUD, D E, 1966. Effects of grazing pressure on the performance of dairy cattle and pastures. Proc Xth Int Grassld Cong Helsinki, pp 470-479.

GORDON, F J, 1973. The effect of high nitrogen levels and stocking rates on milk output from pasture. J Br Grassld Soc 28: 193-201.

GORDON, F J and FORBES, T J, 1970. The associative effect of level of energy and protein intake in the dairy cow. J Dairy Res 37: 481-491.

GORDON, F J and FORBES, T J, 1971. Effect of fibre level in the diet of the dairy cow on milk yield and composition. J Dairy Res 38: 381-391.

GRAINGER, C and WILHELMS, G, 1979. Effect of duration and pattern of underfeeding in early lactation on milk production and reproduction of dairy cows. Aust J exp Agric Anim Husb, 19: 395-401.

GRAINGER, C; DAVEY, A W F; HOLMES, C W and MacKENZIE, D D S, 1980. Factors affecting the differences in yield of milk solids between genetically high and low producing cows. Ellinbank Dairy Research Station Annual Report 1980, Victoria Department of Agriculture, pp 44-47.

GREENHALGH, J F D, 1975. Factors limiting animal production from grazed pasture. J Br Grassld Soc 30: 153-160.

GREENHALGH, J F D and REID, G W, 1968. The effects of grazing intensity on herbage consumption and animal production. III. Dairy cows grazed at two intensities on clean or contaminated pasture. J agric Sci, Camb, 71: 223-228.

GREENHALGH, J F D and RUNCIE, K V, 1962. The herbage intake and milk production of strip- and zero-grazed dairy cows. J agric Sci, Camb, 59: 95-103.

GREENHALGH, J F D; REID, G W and AITKEN, J N, 1967. The effects of grazing intensity on herbage consumption and animal production. II. Longer-term effects in strip-grazed dairy cows. J agric Sci, Camb, 69: 217-223.

GREENHALGH, J F D; REID, G W; AITKEN, J N and FLORENCE, E, 1966. The effects of grazing intensity on herbage consumption and animal production. I. Short-term effects in strip-grazed dairy cows. J agric Sci, Camb, 67: 13-23.

GRENET, E and DEMARQUILLY, C, 1983. Utilization of nitrogen from fresh forage, silage and hay by growing sheep. In Corrall, A J (ed) Efficient Grassland Farming (Proc 9th Gen Meet Eur Grassld Fed 1982), British Grassland Society Occasional Symposium No 14 pp 241-245.

GRIEVE, D G; STONE, J B; MacLEOD, G K and CURTIS, R A, 1980. All silage forage programs for dairy cattle. II. Performance through three lactations. J Dairy Sci 63: 594-600.

HALLEY, R J and DOUGALL, B M, 1962. The feed intake and performance of dairy cows fed on cut grass. J Dairy Res 29: 241-248.

HANCOCK, J, 1950. Studies in monozygotic cattle twins. IV. Uniformity trials: grazing behaviour. N Z Jl Sci Technol A 32: 22-59.

HANCOCK, J, 1952. Grazing behaviour of identical twins in relation to pasture type, intake and production of dairy cattle. Proc VIth Int Grassld Cong Pennsylvania, pp 1399-1407.

HANCOCK, J, 1953. Grazing behaviour of cattle. Anim Breed Abstr 21: 1-13.

HARDISON, W A; REID, J T; MARTIN, C M and WOOLFOLK, P G, 1954. Degree of herbage selection by grazing cattle. J Dairy Sci 37: 89-102.

HARESIGN, W, 1981. Body condition, milk yield and reproduction in cattle. In Haresign, W and Cole, D J A (eds) Recent Developments in Animal Nutrition, pp 1-16. Butterworths, London.

HAUFE, W O, 1982. Growth of range cattle protected from horn flies (Haematobia irritans) by ear tags impregnated with fenvalerate. Can J Anim Sci 62: 567-573.

HELMINEN, J, 1979. The importance of AIV silage in the feeding of dairy cows. In Kreula, M (ed) AIV Silage, pp 81-88. Valio, Helsinki.

HILDEBRANDT, Von H H, 1958. Untersuchungen über die Wirkung verschiedener Weidebeifuttermittel auf den prozentischen Fettgehalt der Milch beim Weidegang von Milchkühen (Studies on fat per cent in milk as affected by various supplementary rations fed to grazing dairy cows). Kieler milchw ForschBer, 10: 137-163.

HIJINK, J W F, 1978. Snijmais bijvoeren aan koeien inde weideperiode (Supplementary feeding of maize silage to dairy cows during the grazing season). Proefstation voor de Rundveehouderij, Lelystad (Holland), Publication No 12, 72 pp.

HIJINK, W F; LE DU, Y L P; MEIJS, J A C; MEIJER, A B, 1981. Supplementation of the grazing dairy cow. Paper for the IV European Grazing Workshop. Institute for Livestock Feeding and Nutrition Research, Lelystad (Holland), Report No 141, 12 pp.

HILLMAN, D; LASSITER, C A; HUFFMAN, C F and DUNCAN, C W, 1958. Effect of all-hay vs all-silage rations on dry matter intake of lactating dairy cows: moisture and pH as factors affecting appetite. J Dairy Sci 41: 720 (Abstr).

HINCH, G N; THWAITES, C J and LYNCH, J J, 1982. A note on the grazing behaviour of young bulls and steers. Anim Prod 35: 289-291.

HODGSON, J, 1982. Ingestive behaviour. In Leaver, J D (ed) Herbage Intake Handbook, pp 113-138. British Grassland Society, Hurley.

HODGSON, J; RODRIGUEZ CAPRILES, J M and FENLON, J S, 1977. The influence of sward characteristics on the herbage intake of grazing calves. J agric Sci, Camb 89: 743-750.

HOLMES, W, 1956. Winter feeding of dairy cows. II. Dried grass produced in spring and in autumn compared with other concentrates and with spring grazing. J Dairy Res 23: 13-20.

HOLMES, W (ed), 1980. Grass, its production and utilization p 267. Blackwell Scient Publ, Oxford for the British Grassland Society.

HOLMES, J C and LANG, R W, 1963. Effects of fertilizer nitrogen and herbage dry matter content on herbage intake and digestibility in bullocks. Anim Prod 5: 17-26.

HOLMES, W; CAMPLING, R C and JOSHI, N D, 1972. A comparison between a rigid rotational grazing system for dairy cows and a system in which grazing is alternated with cutting. Anim Prod 14: 283-294.

HOLMES, W; CAMPLING, R C; JOSHI, N D and THOMSON, E F, 1971. A comparison of the influence of repeated grazing and of grazing alternated with cutting on the performance of milk cows. Anim Prod 13: 380 (Abstr).

HOLTER, J B; URBAN, W E Jr; KENNETT, W S and SNIFFEN, C J, 1973. Corn silage with and without grass hay for lactating dairy cows. J Dairy Sci 56: 915-922.

HOPKINS, A, 1983. Efficiency of utilization: an analysis of grazing data from recorded farms in England and Wales. In Corrall, A J (ed) Efficient Grassland Farming (Proc 9th Gen Meet Eur Grassld Fed 1982), British Grassland Society Occasional Symposium No 14, pp 161-164.

HORN, G W; BATCHELDER, D G; MANOR, G; STREETER, C L and McLAUGHLIN, G L, 1983. Ammoniation of wheat straw and native grass hay during baling of large round bales. Anim Feed Sci and Technol 8: 35-46.

HORNE, B and BARBER, W P, 1971. The influence of supplementation with concentrate, or concentrates and straw on the grazing intake of dairy cows. Anim Prod 13: 380-381 (Abstr).

HULL, J L; MEYER, J H and KROMANN, R, 1961. Influence of stocking rate on animal and forage production from irrigated pasture. J Anim Sci 20: 46-52.

HUTTON, J B, 1962a. Studies of the nutritive value of New Zealand dairy pastures. II. Herbage intake and digestibility studies with dry cattle. N Z Jl agric Res 5; 409-424.

HUTTON, J B, 1962b. The maintenance requirements of New Zealand dairy cattle. Proc N Z Soc Anim Prod 22: 12-34.

HUTTON, J B and DOUGLAS, J A, 1975. Growing and using maize on the dairy farm. Proc Ruakura Farmers Conf Week, 1975, pp 76-82.

HUTTON, J B and PARKER, O F, 1965. Making the most of a limited amount of grass after calving. Proc Ruakura Farmers Conf Week, 1965, pp 182-193.

HUTTON, J B and PARKER, O F, 1966. The effect of grazing time and supplementary feeding of hay on production per cow in early lactation. Proc N Z Soc Anim Prod 26: 71-85.

HUTTON, J B; HUGHES, J W; NEWTH, R P and WATANABE, K, 1964. The voluntary intake of the lactating dairy cow and its relation to digestion. Proc N Z Soc Anim Prod 24: 29-42.

ILLIUS, A W and LOWMAN, B G, 1983. Methods of reducing risk in high output grazing systems. In Corrall, A J (ed) Efficient Grassland Farming (Proc 9th Gen Meet Eur Grassld Fed), British Grassland Society Occasional Symposium No 14, pp 193-195.

JACKSON, M G, 1977. The alkali treatment of straws. Anim Feed Sci and Technol 2: 105-130.

JAMIESON, W S, 1975. Studies on the herbage intake and grazing behaviour of cattle and sheep. Ph D thesis, University of Reading.

JAMIESON, W S and HODGSON, J, 1979. The effect of daily herbage allowance and sward characteristics upon the ingestive behaviour and herbage intake of calves under strip-grazing management. Grass and Forage Sci 34: 261-271.

JOHNSON, J and BASTIMAN, B, 1981. Social and human factors in grassland farming. In Jollans, J L (ed) Grassland in the British Economy (Centre for Agricultural Strategy Paper 10), pp 268-288. CAS, Reading.

JOHNSTONE-WALLACE, D B and KENNEDY, K, 1944. Grazing management practices and their relationship to the behaviour and grazing habits of cattle. J agric Sci, Camb 34: 190-197.

JONES, M B; COLLETT, B and BROWN, S, 1982. Sward growth under cutting and continuous stocking managements: sward canopy structure, tiller density and leaf turnover. Grass and Forage Sci, 37: 67-73.

JOURNET, M and DEMARQUILLY, C, 1979. Grazing. In Broster, W H and Swan, H (eds) Feeding Strategy for the High Yielding Dairy Cow pp 295-321. Granada Publishing, London for the Eur Ass Anim Prod.

KAUFMANN, W, 1976. Influence of the composition of the ration and the feeding frequency on pH regulation in the rumen and on feed intake in ruminants. Livest Prod Sci 3: 103-114.

KEEN, R M and KROGER, M, 1975. *In vivo* modification of milk fat and body fat composition in ruminants. A review. Milchwissenschaft 30: 532-536.

KEENER, H A; ALLEN, F E; COLOVOS, N F; PAUL, ANN C and DAVIS, H A, 1958. Value of adding corn silage and limited quantities of hay to a grass silage limited grain ration for dairy heifers. J Dairy Sci 41: 429-437.

KESLER, E M and SPAHR, S L, 1964. Physiological effects of high level concentrate feeding. J Dairy Sci 47: 1122-1128.

KIANGI, E M I; KATEGILE, J A and SUNDSTØL, F, 1981. Different sources of ammonia for improving the nutritive value of low quality roughages. Anim Feed Sci and Technol 6: 377-386.

KING, K R and STOCKDALE, C R, 1981. Hay supplements to overcome underfeeding of dairy cows. 2. Late lactation. Aust J exp Agric Anim Husb 21: 157-162.

KING, K; PATTERSON, I and STOCKDALE, R, 1977. The effect of restriction of pasture intake, and the supplementation with low and high quality hay in early lactation. Ellinbank Dairy Research Station Annual Report 1977, Victoria Department of Agriculture, pp 71-72.

LAND, CAROLYN and LEAVER, J D, 1981. The effect of body condition at calving on the production of Friesian cows and heifers. Anim Prod 32: 362-363 (Abstr).

LAWES AGRICULTURAL TRUST, 1980. Genstat V Mark 4.03. Rothamsted Experimental Station.

LAWLOR, M J and O'SHEA, J 1979. The effect of ammoniation on the intake and nutritive value of straw. Anim Feed Sci and Technol 4: 169-175.

LAZENBY, A and DOYLE, C J, 1981. Grassland in the British economy - some problems, possibilities and speculations. In Jollans, J L (ed) Grassland in the British Economy (Centre for Agricultural Strategy Paper 10) pp 14-50. CAS, Reading.

LE DU, Y and HUTCHINSON, M, 1982. Grazing. In Thomas, C and Young, J W O (eds) Milk from Grass pp 43-57. ICI Agricultural Division, Billingham and Grassland Research Institute, Hurley.

LE DU, Y L P and NEWBERRY, R D, 1981. The effect of periods of grass shortage on the milk production of grazing dairy cows. Grass and Forage Sci 36: 134-135 (Abstr).

LE DU, Y L P; BAKER, R D and NEWBERRY, R D, 1981. Herbage intake and milk production by grazing dairy cows. 3. The effect of grazing severity under continuous stocking. Grass and Forage Sci 36: 307-318.

LE DU, Y L P; COMBELLAS, J; HODGSON, J and BAKER, R D, 1979. Herbage intake and milk production by grazing dairy cows. 2. The effects of level of winter feeding and daily herbage allowance. Grass and Forage Sci 34: 249-260.

LEAVER, J D, 1981. The contribution of grass and conserved forages to the nutrient requirements for milk production. In Haresign, W and Cole, D J A (eds) Recent Developments in Animal Nutrition pp 71-80. Butterworths, London.

LEAVER, J D, 1982. Grass height as an indicator for supplementary feeding of continuously stocked dairy cows. Grass and Forage Sci 37: 285-290.

LEAVER, J D and YARROW, N H, 1977. The intake of maize silage by self-fed heifers allowed restricted access. J Br Grassld Soc 32: 165-169.

LEAVER, J D; CAMPLING, R C and HOLMES, W, 1968. Use of supplementary feeds for grazing dairy cows. Dairy Sci Abstr 30: 355-361.

LEONHARD-KLUZ, IRENA; BIELAK, F; BARABASZ, J and ZYWCZOK, H, 1979. Estimation of straw usefulness in the aspect of milk quality improvement of cows fed with green crops out of high nitrogen fertilization. Proc 30th Ann Meet Eur Ass Anim Prod, Harrogate C3.7, 4 pp.

LOGAN, V S; FISHER, L J and HAYDEN, P S, 1968. Effect of variety of ensiled corn and hay supplementation on milk production. Can J Anim Sci 48: 41-46.

LONSDALE, C R and TAYLER, J C, 1971. The effect of season of harvest and of milling on the nutritive value of dried grass. Anim Prod 13: 384 (Abstr).

MacLUSKY, D S, 1955. The quantities of herbage eaten by grazing dairy cows. Proc Brit Soc Anim Prod 1955: 45-51.

MacLUSKY, D S, 1959. Drinking habits of grazing cows. Agriculture Lond 66: 383-386.

MacLUSKY, D S, 1960. Some estimates of the areas of pasture fouled by the excreta of dairy cows. J Br Grassld Soc 15: 181-188.

McCLYMONT, G L, 1950. The relation of the type and quantity of roughage and grazing to the fat content of the milk. Aust vet J 26: 111-121.

MacDIARMAID, B N and WATKIN, B R, 1972. The cattle dung patch. 3. Distribution and rate of decay of dung patches and their influence on grazing behaviour. J Br Grassld Soc 27: 48-54.

McGOWAN, A, 1980. Summary of short term responses to increased feeding in recent Ellinbank experiment. Ellinbank Dairy Research Station Annual Report 1980, Victoria Department of Agriculture, pp 72-77.

McMEEKAN, C P and WALSHE, M J, 1963. The inter-relationships of grazing method and stocking rate in the efficiency of pasture utilization by dairy cattle. J agric Sci, Camb 61: 147-163.

MAHANNA, W C, 1980. Ways around the hay shortage. Dairy Herd Management, September, 1980 pp 20-24.

MARSH, R, 1975. A comparison between spring and autumn pasture for beef cattle at equal grazing pressures. J Br Grassld Soc 30: 165-170.

MARTEN, G C and DONKER, J D, 1964. Selective grazing induced by animal excreta. II. Evidence of occurrence and superficial remedy. J Dairy Sci 47: 773-776.

MARTEN, G C and DONKER, J D, 1966. Animal excrement as a factor influencing acceptability of grazed forage. Proc Xth Int Grassld Cong, Helsinki, pp 359-363.

MASON, V C, 1981. Upgrading of low quality forages by chemical treatment. Proceedings of British Grassland Society Silage Additive Conference 1981 (London) pp 4.1-4.10.

MEIJS, J A C, 1981a. Herbage intake by grazing dairy cows. PUDOC Agricultural Research Report No 909, 264 pp. Centre for Agricultural Publishing and Documentation, Wageningen.

MEIJS, J A C, 1981b. Het effect van krachtvoerbijvoedering op de grasopname van weidende melkkoeien. 1. Verslag van de grasepnameproef in 1981 (The influence of concentrate supplementation on herbage intake by grazing dairy cows. 1. Report of the experiment on herbage intake in 1981.) Institut voor Veevoedingsonderzoek "Hoorn" (Lelystad) report no 143, 72 pp.

MILLER, W J; CLIFTON, C M; MILLER, J K and FOWLER, P R, 1965. Effects of feeding unlike forages, singly and in combination, on voluntary dry matter consumption and performance of lactating cows. J Dairy Sci 48: 1046-1052.

MAFF, 1968. Rejection of grass by cows. Great House EHF Annual Report 1968 pp 28-29.

MAFF, 1969a. Pasture contamination. Rosemaund EHF Annual Report 1969 pp 28-30.

MAFF, 1969b. Summer milk production trial. Trawsgoed EHF Annual Report 1969 pp 7-11.

MAFF, 1969c. Intensive paddock grazing. Great House EHF Annual Report 1969 pp 28-32.

MAFF, 1969d. The dairy cow and the use of land. Bridgets EHF Annual Report 1969 pp 14-19.

MAFF, 1982. Grasping at straws. Boxworth EHF Annual Report pp 29-31.

MAFF, DAFS and DANI, 1975. Energy allowances and feeding systems for ruminants. Technical Bulletin 33. Her Majesty's Stationary Office, London.

MOATE, P; ROGERS, G and ROBINSON, I, 1980. The effect of silage supplements on milk yield and composition of cows offered two levels of pasture. Ellinbank Dairy Research Station Annual Report 1980, Victoria Department of Agriculture, pp 65-66.

MOE, P W; TYRRELL, H F and FLATT, W P, 1971. Energetics of body tissue mobilization. J Dairy Sci 54: 548-553.

MOISEY, F R, 1981. Losses during the ensiling of grass. Crichton Royal Farm Annual Report 1981, The West of Scotland Agricultural College pp 34-35.

MOORE, L A; THOMAS, J W and SYKES, J F, 1960. The acceptability of grass/legume silage by dairy cattle. Proc VIIIth Int Grassld Cong, Reading, pp 701-704.

MORRISON, S H and DEAL, J F, 1952. Grass silage vs hay as the supplementary roughage for milking cows on good pasture. J Dairy Sci 35: 501 (Abstr).

MURDOCH, J C, 1980. The conservation of grass. In Holmes, W (ed) Grass, its Production and Utilization pp 174-215. Blackwell Sci Publ, Oxford for the British Grassland Society.

NIRD, 1977. Dairy cow condition scoring. Paper No 4468 NIRD, Reading (Mulvany, P).

NRC, 1978. Nutrient requirements of dairy cattle. In Nutrient Requirements of Domestic Animals, No 3 National Academy of Science - National Research Council, Washington DC.

NEILSON, D R; WHITTEMORE, C T; LEWIS, M; ALLISTON, J C; ROBERTS, D J; HODGSON-JONES, L S; MILLS, J; PARKINSON, H and PRESCOTT, J H D, 1983. Production characteristics of high-yielding dairy cows. Anim Prod 36: 321-334.

NEWTON, J E and BROCKINGTON, N R, 1975. A logical approach to the study of grazing systems. In Hodgson, J (ed) Pasture Utilization by the Grazing Animal pp 29-37. British Grassland Society Occasional Symposium No 8.

NICHOLSON, J W G and PARENT, R C, 1957. Various combinations of grass silage and hay for dairy cattle. Can J Anim Sci 37: 64-67.

NIELSEN, E, 1961. Forsøg med halm. Oversigt over kvaegforsøg 1933-1959. 328 beretning fra forsøglaboratoriet, Copenhagen pp 113-116. Cited by Frank (1982).

NORMAN, M J T and GREEN, J O, 1958. The local influence of cattle dung and urine upon the yield and botanical composition of permanent pasture. J Br Grassld Soc 15: 39-45.

OPSTVEDT, J; BALDWIN, R L and RONNING, M, 1967. Effect of diet upon activities of several enzymes in abdominal adipose and mammary tissues in the lactating cow. J Dairy Sci 50: 108-109.

ØRSKOV, E R and McDONALD, I, 1980. Utilization of volatile fatty acids for maintenance and for energy retention. In Mount, LE (ed) Energy Metabolism (Proc 8th Symp on Energy Metabolism, Eur Ass Anim Prod Publ No 26), pp 147-150. Butterworths, London.

ØRSKOV, E R; FLATT, W P; MOE, P W; MUNSON, A W; HEMKEN, R W and KATZ, I, 1968. The influence of ruminal infusion of volatile fatty acids on milk yield and composition and on energy utilization by lactating cows. Br J Nutr 23: 443-453.

ØRSKOV, E R; REID, G W and TAIT, C A G, 1983. Ammonia-treated straw and sodium hydroxide-treated or rolled barley for dairy cows. Anim Prod 36: 511 (Abstr).

OSBOURN, D F, 1980. The feeding value of grass and grass products. In Holmes, W (ed) Grass, its production and utilization pp 70-124. Blackwell Scient Publ, Oxford for the British Grassland Society.

OSBOURN, D F; TERRY, R A; CAMMELL, S B and OUTEN, G E, 1969. Some effects of feeding supplements of maize meal and sodium bicarbonate upon the digestion of forage cellulose by sheep. Proc Nutr Soc 29: 12A.

OWEN, E, 1981. Straw: research work. Proceedings of MAFF seminar (London) Upgrading of Crops and By-products by Chemical or Biological Treatment pp 1-9.

OWEN, E; ALAWA, J; THOMAS, C and WILKINSON, J M, 1980. Sodium hydroxide-treated wheat straw - a comparison of farm-treated and industrially-treated straw as partial replacers for grass silage in diets for beef cattle. Anim Prod 30: 488-489 (Abstr).

PAIN, B F and BROOM, D M, 1978. The effects of injected and surface-spread slurry on the intake and grazing behaviour of dairy cows. Anim Prod 26: 75-83.

PANKHURST, I and McGOWAN, A, 1978. The effect of pasture quality on the response of cows in mid-lactation to a supplement of silage. Ellinbank Dairy Research Station Annual Report 1978, Victoria Department of Agriculture, pp 52-54.

PARKER, O F, 1966. Supplementary feeding of hay to dairy cows after calving. Proc Ruakura Farmers Conf Week, 1966, pp 159-167.

PATTERSON, H D and LUCAS, H L, 1962. Change-over designs. North Carolina Agricultural Experiment Station and United States Department of Agriculture Technical Bulletin No 147, 53 pp.

PERCIVAL, J C, 1955. The intakes of grass and silage by dairy cows during the summer. Proc N Z Soc Anim Prod 15: 74-79.

PETERS, R R; CHAPIN, L T; EMERY, R S and TUCKER, H A, 1981. Milk yield, feed intake, prolactin, growth hormone and glucocorticoid response of cows to supplemental light. J Dairy Sci 64: 1671-1678.

PETERS, R R; CHAPIN, L T; LEINING, K B and TUCKER, H A, 1978. Supplemental lighting stimulates growth and lactation in cattle. Science, NY 199: 911-912.

PETERSEN, R G; LUCAS, H L and WOODHOUSE, W W, 1956. The distribution of excreta by freely grazing cattle and its effect on pasture fertility: I Excretal distribution. Agron J 48: 440-444.

PHIPPS, R H, 1978. Utilization of maize silage for milk production. In Bunting, E S; Pain, B F; Phipps, R H; Wilkinson, J M and Gunn, R E (eds) Forage Maize, production and utilization pp 263-295. ARC, London.

REED, K F M, 1978. The effect of season of growth on the feeding value of pasture. J Br Grassld Soc 33: 227-234.

REID, G W; GREENHALGH, J F D and AITKEN, J N, 1972. The effects of grazing intensity on herbage consumption and animal production. J agric Sci, Camb 78: 491-496.

RETTER, W C, 1978. The production and utilization of high quality grass silage by dairy cows. Ph D thesis (Hannah Research Institute) University of Glasgow.

RETTER, W C and CASTLE, M E, 1982. Silage and milk production: comparisons between hays of different digestibilities as silage supplements. Grass and Forage Sci 37: 129-137.

REYNOLDS, VIVIEN S and CAMPLING, R C, 1981. Competition for feed between dairy cows. Anim Prod 366 (Abstr).

RICHARDS, I R, 1977. Influence of soil and sward characteristics on the response to nitrogen. Proc Int Meet Anim Prod Temperate Grassld (Dublin) (Ir Grassld and Anim Prod Ass) pp 45-49.

RISSANEN, H and KOSSILA, V, 1977. Untreated and ammonized straw with or without silage to dairy cows. Inst för Husdjurens Utfodring och vard (Uppsala) Report no 54 Quality of Forage pp 177-180.

ROBINSON, I and McGOWAN, A, 1980. Relationship between intake and liveweight loss during fasting. Ellinbank Dairy Research Station Annual Report 1980, Victoria Department of Agriculture pp 78-80.

ROGERS, G L, 1969. A comparison of hay etc. Ellinbank Dairy Research Station Annual Report 1969, Victoria Department of Agriculture pp 25-26.

ROGERS, G L, 1979. Wilted silage as a supplement for pasture fed cows in late lactation. Ellinbank Dairy Research Station Annual Report 1979, Victoria Department of Agriculture, pp 57-58.

ROGERS, G L, 1980. The effects of forage diets on milk fat composition. Ellinbank Dairy Research Station Annual Report 1980, Victoria Department of Agriculture, pp 58-59.

ROGERS, G and PORTER, R, 1978. Wilted silage as a supplement for pasture fed cows. Ellinbank Dairy Research Station Annual Report 1978, Victoria Department of Agriculture, pp 55-56.

ROGERS, G and ROBINSON, R, 1980a. Wilted fine chop pasture silage as a supplement to cows in late lactation grazing dry summer pasture. Ellinbank Dairy Research Station Annual Report 1980, Victoria Department of Agriculture, pp 67-68.

ROGERS, G and ROBINSON, I, 1980b. Comparison of high moisture and wilted silage as supplements to pasture for cows in late lactation. Ellinbank Dairy Research Station Annual Report 1980, Victoria Department of Agriculture, pp 63-64.

ROGERS, G; ROBINSON, I and PORTER, R, 1980. The utilization of perennial ryegrass and white clover by lactating dairy cows. Ellinbank Dairy Research Station Annual Report 1980, Victoria Department of Agriculture, pp 54-55.

ROHR, K and KAUFMANN, W, 1967. Untersuchungen zur Trockensubstanzaufnahme von Milchkühen bei Weidegang (Investigations on the intake of dry matter by dairy cows grazing pasture). Wirtschaftseigene Futter 13: 85-93.

RONNING, M and LABEN, R C, 1966. Response of lactating cows to free-choice feeding of milled diets containing 10-100 per cent concentrates. J Dairy Sci 49: 1080-1085.

ROOK, J A F, 1961. Variations in the chemical composition of the milk of the cow - Part 1. Dairy Sci Abstr 23: 251-258.

ROOK, J A F, 1964. Ruminal volatile fatty acid production in relation to animal production from grass. Proc Nutr Soc 23: 71-80.

ROOK, J A F and LINE, C, 1961. The effect of the plane of energy nutrition of the cow on the secretion in milk of the constituents of the solids-not-fat fraction and on the concentrations of certain blood-plasma constituents. Br J Nutr 15: 109-119.

ROOK, J A F and ROWLANDS, S J, 1959. Effect of spring grazing on the constituents of the solids-not-fat of milk. Proc XVth Int Dairy Congr, London, 1: 204-207.

ROOK, J A F and STORRY, J E, 1964. Energy nutrition and milk secretion in the dairy cow. Chemy Ind 83: 1778-1787.

RUCKEBUSCH, Y and BUENO, L, 1978. An analysis of ingestive behaviour and activity of cattle under field conditions. Appl Anim Ethol 4: 301-313.

SANTAMARIA, A and ROGERS, G, 1980. Comparative effects of white clover and perennial ryegrass on milk yield and composition of the grazing cow. Ellinbank Dairy Research Station Annual Report 1980, Victoria Department of Agriculture, pp 56-57.

SANTAMARIA, A; ROGERS, G and PORTER, R, 1979. The effect of stage of growth of ryegrass-white clover pasture on milk production. Ellinbank Dairy Research Station Annual Report 1979, Victoria Department of Agriculture pp 61-63

SCHMIDT, G H and VAN VLECK, L D, 1974. Principles of Dairy Science pp 71 and 94. W H Freeman & Co, San Francisco.

SCOTT, J D J; RATTRAY, P V and SMEATON, D C, 1976. Environmental factors associated with summer-autumn growth rates of cattle and sheep. Proc N Z Soc Anim Prod 36: 103-119.

SEATH, D M and ELLIOTT, R F, 1950. Efficiency of silage and extra grain feeding for maintaining summer milk production. J Dairy Sci 388-389 (Abstr).

SEATH, D M and MILLER, G D, 1947. Effect of hay feeding in summer on milk production and grazing performance of dairy cows. J Dairy Sci 30: 921-926.

SEATH, D M; LASSITER, C A; DAVIS, C; RUST, J W and COLE, M, 1955. How hay feeding to cows on pasture affected their milk production, dry matter intake and body weight. J Dairy Sci 38: 612 (Abstr).

SJOLLEMA, B, 1950. On the influence of the composition of pasture herbage on the production of dairy cows and on the benefit of supplementing the grass with protein poor foods. J Br Grassld Soc 5: 179-194.

SMITH, C A, 1955. Studies on the Northern Rhodesia Hyparrhenia veld. J agric Sci, Camb 52: 369-375.

SMITH, J A B; HOWAT, G R and RAY, S C, 1938. The composition of the blood and milk of lactating cows during inanition, with a note on an unidentified constituent present in certain samples of abnormal milk. J Dairy Res 9: 310-322.

SONNEVELD, A, 1965. Dry matter intake of cattle fed on grass. Grassland Research Institute (Hurley) Technical Report No 1 pp 1-3.

SPEDDING, A, 1983. 'Grasp' - a grassland planning program for the HP41C calculator. British Society of Animal Production, summaries of Winter Meeting 1983, Poster 154.

STEEL, R G D and TORRIE, J H, 1960. Principles and procedures of statistics. McGraw-Hill Book Co, Inc, New York.

STEHR, W and KIRCHGESSNER, M, 1976. The relationship between the intake of herbage grazed by dairy cows and its digestibility. Anim Feed Sci and Technol 1: 53-60.

STEWART, J; TAYLOR, J and COOKE, B, 1980. Effect of restricted grazing post-calving on heifer milk production. Ellinbank Dairy Research Station Annual Report 1980, Victoria Department of Agriculture, pp 40-41.

STOBBS, T H, 1973. The effect of plant structure on the intake of tropical pastures. 1. Variation in the bite size of grazing cattle. Aust J agric Res 24: 809-819.

STOBBS, T H, 1974. Components of grazing behaviour of dairy cows on some tropical and temperate pastures. Proc Aust Soc Anim Prod 10: 299-302.

STOCKDALE, C R; KING, K R; PATTERSON, I F and RYAN, D T, 1981. Hay supplements to overcome underfeeding of dairy cows. 1. Early lactation. Aust J exp Agric Anim Husb 21: 148-156.

STORRY, J E and SUTTON, J D, 1969. The effect of change from low-roughage to high-roughage diets on rumen fermentation, blood composition and milk fat secretion in the cow. Br J Nutr 23: 511-521.

STUTH, J W; KIRBY, D R and CHMIELEWSKI, R E, 1981. Effect of herbage allowance on the efficiency of defoliation by the grazing animal. Grass and Forage Sci 36: 9-15.

SUNDSTØL, F; COXWORTH, E and MOWAT, D N, 1978. Improving the nutritive value of straw and other low-quality roughages by treatment with ammonia. Wld Anim Rev 26: 13-21.

SUTTON, J D; BROSTER, W H; SCHULLER, E; SMITH, T and NAPPER, D J, 1977. Long term effect of level of intake and diet composition on the performance of lactating dairy cows. 3. Milk composition and rumen fermentation. Proc Nutr Soc 36: 147A.

TAYLER, J C, 1953. The grazing behaviour of bullocks under two methods of management. Br J Anim Behaviour 1: 72-77.

TAYLER, J C, 1954. Technique of weighing the grazing animal. Proc Br Soc Anim Prod 1954: 3-16.

TAYLER, J C and RUDMAN, J E, 1966. The distribution of herbage at different heights in 'grazed' and 'dung patch' areas of a sward under two methods of grazing management. J agric Sci, Camb 66: 29-39.

TERRY, R A; SPOONER, M C and OSBOURN, D F, 1975. The feeding value of mixtures of alkali-treated straw and grass silage. J agric Sci, Camb 84: 373-376.

THOMAS, G; MATTHEWS, G and CHAPMAN, H, 1980. The effect of supplementation of dairy cows in the immediate post-calving period on immediate and residual milk responses. Ellinbank Dairy Research Station Annual Report 1980, Victoria Department of Agriculture, pp 69-71.

THOMAS, J W; MOORE, L A; OKAMOTO, M and SYKES, J F, 1961. A study of factors affecting rate of intake of heifers fed silage. J Dairy Sci 44: 1471-1483.

THOMAS, P C, 1980. Influence of nutrition on the yield and content of protein in milk: dietary protein and energy supply. In Factors Affecting the Yields and Contents of Milk Constituents of Commercial Importance, International Dairy Federation Document 125 pp 142-151.

THOMAS, P C and ROOK, J A F, 1977. Manipulation of rumen fermentation. In Haresign, W and Lewis, D (eds) Recent Advances in Animal Nutrition - 1977. Butterworths, London.

THORNTON, R F and MINSEN, D J, 1973. The relationship between apparent retention time in the rumen, voluntary intake, and apparent digestibility of legume and grass diets in sheep. Aust J agric Res 24: 889-898.

TRIBE, D E, 1950. Influence of pregnancy and social facilitation on the behaviour of the grazing sheep. Nature, Lond 166: 74.

Van der KLEY, F K, 1956. A simple method for the accurate estimation of daily variations in the quality and quantity of herbage consumed by rotationally grazed cattle and sheep. Neth J agric Sci 4: 197-204.

Van KEUREN, R W; SHAUDYS, E T; BAKER, R H and PRATT, A D, 1966. Economy of grazing, soilage and stored feeding method for summer feeding of dairy cattle. Proc Xth Int Grassld Cong Helsinki, pp 505-510.

Van SOEST, P J, 1963. Ruminant fat metabolism with particular reference to factors affecting low milk fat and feed efficiency. A review. J Dairy Sci 46: 204-216.

Van SOEST, P J, 1982. Nutritional Ecology of the Ruminant. O and B Books Inc, Oregon.

VÉRITÉ, R and JOURNET, M, 1970. Influence de la teneur en eau et de la déshydration de l'herbe sur sa valeur alimentaire pour les vaches laitières (Effect of the water content of grass and dehydration at low temperature upon its feeding value for dairy cows). Annls Zootech 19: 255-268.

VIK, E, 1956. Samanlikning mellom berre dagbeitung med døgerbeitung for mjølkekyr (comparison between day pasturing and day- and-night pasturing for dairy cows). Beiterforsoksgarden, Apelsvoll (Forsk Fors Landbr) Report No 23 pp 109-128.

WAITE, R, 1965. The chemical composition of grasses in relation to agronomical practice. Proc Nutr Soc 24: 38-46.

WAITE, R and BOYD, J, 1953. The water-soluble carbohydrates of grasses. II. Grasses cut at grazing height several times during the growing season. J Sci Fd Agric 4: 197-261.

WAITE, R; CASTLE, M E and WATSON, J N, 1960. The effect on milk composition of feeding spring grass to cows. J Dairy Res 26: 173-180.

WAITE, R; MacDONALD, W B and HOLMES, W, 1951. Studies in grazing management. III. The behaviour of dairy cows grazed under the close-folding and rotational systems of management. J agric Sci, Camb 41: 163-172.

WAITE, R; WHITE, J C D and ROBERTSON, A, 1956. Variations in the chemical composition of milk with particular reference to the solids-not-fat. 1. The effect of stage of lactation, season of year and age of cow. J Dairy Res 23: 65-81.

WALDERN, D E, 1972. Effects of supplemental hay on consumption of low and medium dry matter corn silage by high-producing dairy cows. Can J Anim Sci 52: 491-495.

WALLACE, L R and PARKER, O F, 1966. Comparison of three systems of feeding silage after calving. Proc Ruakura Farmers Conf Week, 1976 pp 148-158.

WALSH, A, 1982. The contribution of grass to profitable milk production. The Rex Paterson Memorial Study Report (British Grassland Society Winter Meeting 1982).

WALSH, J P, 1969. Effect of feeding on composition of cows' milk in late winter-early spring. Ir J agric Res 8: 319-327.

WARDROP, J C, 1953. Studies in the behaviour of dairy cows at pasture. Br J Anim Behav 1: 23-31.

WEEDA, W C, 1967. The effect of cattle dung patches on pasture growth, botanical composition and pasture utilization. N Z Jl agric Res 10: 150-159.

WHEELER, J S; SCOTT, J; MURRAY, J B; HOCKINGS, B; NEWTH, M and MUNFORD, R R, 1972. Summer supplementary feeding of dairy cows. Dairy fmg A, 1972 pp 50-55.

WHITE, D J; WILKINSON, J M and WILKINS, J, 1983. Support energy use in animal production. In Corrall, A J (ed) Efficient Grassland Farming (Proc 9th Gen Meet Eur Grassld Fed 1982), British Grassland Society Occasional Symposium No 14 pp 33-42.

WILHELMS, G and GRAINGER, C, 1978. Effects of hay supplementation in early lactation on milk production of grazing dairy cows. Ellinbank Dairy Research Station Annual Report 1978, Victoria Department of Agriculture, pp 48-49.

WILKINS, R J; MORRISON, J and CHAPMAN, P F, 1981. Potential production from grasses and legumes. In Jollans, J L (ed) Grassland in the British Economy (Centre for Agricultural Strategy Paper 10) pp 390-413 CAS, Reading.

WILKINSON, J M, 1981. Potential changes in efficiency of grass and forage conservation. In Jollans, J L (ed) Grassland in the British Economy (Centre for Agricultural Strategy Paper 10) pp 414-428 CAS, Reading.

WILKINSON, J M and SANTILLANA, R G, 1978. Ensiled alkali-treated straw. II. The nutritive value for young beef cattle of mixtures of ensiled or frozen alkali-treated straw and ryegrass silage. Anim Feed Sci & Technol 3: 133-142.

WILSON, G F, 1978. Effect of water content of Tama ryegrass on voluntary intake of sheep. N Z J exp Agric 6: 53-54.

ZOBY, J L F and HOLMES, W, 1983. The influence of size of animal and stocking rate on the herbage intake and grazing behaviour of cattle. J agric Sci, Camb 100: 139-148.