THE UTILIZATION OF SILAGE BY DAIRY COWS WITH SPECIAL REFERENCE TO SUPPLEMENTATION

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by

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DEDICATED

TO MY FAMILY

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ABBREVIATIONS

ADAS	=	Agricultural Development and Advisory Service
ARC	=	Agricultural Research Council
concs	=	concentrates
CP	=	crude protein
DCP	=	digestible crude protein
DM	=	dry matter
DOM	=	digestible organic matter
DOMD	=	digestible organic matter in the dry matter
Expt	=	experiment
FCM	=	fat corrected milk
Fig	=	figure
g/kg^{-1}	=	grams per kilogram
h or hrs	=	hours
ME	=	metabolizable energy
MJ	=	megajoule
MAFF	=	Ministry of Agriculture, Fisheries and Food
mm	=	millimeter
min	=	minutes
MF	=	modulus of fineness
NPN	=	non-protein-nitrogen
RDP	=	rumen degradable protein
SNF	=	solids-not-fat
TMP	=	tissue protein supplied from microbial protein synthesis alone
TP	=	tissue protein
UK	=	United Kingdom

SUMMARY

A series of six feeding experiments with Ayrshire dairy cows was conducted to investigate the effect of different types and amounts of feeds when used as supplements for grass silage offered *ad libitum*. The effects of the supplements on feed intake, milk yield, milk composition and liveweight were measured. In three experiments, the effects of giving concentrates at different frequencies per 24 hrs was investigated also. A study of the feeding behaviour of the cows was made in one of these experiments. The experiments had cyclic, Latin Square and crossover designs with experimental periods of either 3 or 4 weeks.

In Expt 3.1 grass silage with an *in vitro* D-value of 69.8 was offered *ad libitum* to twelve cows in a 16-week experiment. In addition, supplements of hay in the long, short (12.1 mm) and ground and cubed form (modulus of fineness = 0.80) with *in vitro* D-values of 59.7, 59.4 and 61.9, and concentrates (203 g CP/kg DM) at either 2 or 4 kg per 10 kg milk were given. The hay in the ground and cubed form gave marked increases in the total intakes of forage dry matter of 9.9 and 8.6% compared with the long and short hays respectively at the low concentrate rate, and 14.2 and 14.9% at the high concentrate rate. The average reduction in the forage DM intake per kg concentrate DM consumed was 0.50 kg. At the low rate of concentrate intake, hay in the ground and cubed form gave marked increases in milk yield of 10.2 and 7.8% compared with the long and short hays respectively. At the high rate of concentrate intake, the ground and cubed hay gave smaller increases of 1.5 and 3.1%. The hay treatments had only small and non-significant effects on milk composition.

In Expt 3.2, grass silage with an *in vitro* D-value of 61.6 was offered *ad libitum* to six cows in a 12-week experiment. On the control treatment, the silage was supplemented with soyabean meal only, and on the other two treatments barley and sugarbeet pulp were given in equal amounts on a dry matter basis plus the same weight of soyabean meal as on the control treatment. The highest daily silage DM intake of 11.26 kg per cow occurred on the soyabean meal only treatment, and the differences in silage intake between barley and sugarbeet pulp treatments were not significant. On average, for 1 kg of barley and sugarbeet pulp DM consumed, the reductions in the intake of silage DM were 0.44 and 0.36 kg respectively. The daily milk yields were 20.5 and 20.8 kg per cow on the barley and the sugarbeet pulp treatments respectively and were not significantly different. The fat, solids-not-fat, crude protein and lactose concentrations in the milk, and the liveweight of the cows were not significantly different on the barley and sugarbeet pulp treatments.

In Expt 3.3, grass silages with low D-values of 62.6 and 65.5, and high D-values of 69.7 and 68.6 were offered *ad libitum* to twelve cows in a 16-week experiment. In addition, a supplement of high-protein concentrates (362 g CP/kg DM) was given at a flat rate of 1.5, 3.0 and 4.5 kg per cow/day. There were no significant changes in the daily silage DM intakes when increasing amounts of the concentrate supplement were consumed. The milk yields increased significantly as the concentrate intake increased with both the low and the high D-value silages. The fat, total solids and the lactose concentrations in the milk were not significantly different on the different treatments. However, the crude protein and the solids-not-fat concentrations in the milk increased as the concentrate intake increased with both the low and the high D-value silages.

In Expts 3.4, 3.6 and 3.7, the effects of giving the total daily allowance of concentrate supplements at different frequencies per 24 hrs was investigated. The silages, with *in vitro* D-values of 65.5 in Expts 3.4 and 3.6 and 58.7 in Expt 3.7, were given *ad libitum*. In Expt 3.4, concentrate supplements with high (202 g CP/kg DM) and low (128 g CP/kg DM) crude protein contents were offered at the rate of 4 kg/10 kg milk in 2, 4 and 22 feeds per 24 hrs to twelve cows in a 16-week experiment. The high- and low-protein concentrates in Expt 3.6 were the same as in Expt 3.4 and were given at a flat rate of 5 kg per cow/day in either 2 or 22 feeds per 24 hrs to four non-lactating cows in a 15-week experiment. In Expt 3.7, concentrate supplements of either barley or soyabean meal were offered at a flat rate of 5 kg per cow/day in either 2 or 22 feeds per 24 hrs to four lactating cows in a 12-week experiment.

In Expt 3.4, the intake of silage DM and the milk yields were not significantly different when the two concentrates were offered in 2, 4 and 22 feeds per 24 hrs. Similarly in Expt 3.7, the different frequencies of feeding the barley and soyabean meal had little effect on the daily intake of silage DM and milk yields. There were no significant differences in the milk composition on the different frequency treatments in Expts 3.4 and 3.7. However, small increases in the milk fat concentration were noted when the concentrate supplements were given in more than two feeds per 24 hrs in both experiments. In Expt 3.6, the feeding behaviour of the cows was similar when concentrate supplements were supplied on either 2 or 22 feeds per 24 hrs. In Expt 3.4 and 3.7, milk yields were significantly higher on the high- than on the low-protein supplements.

From a practical point of view it is suggested that three findings in these experiments should be considered.

1. The feeding of hay in the ground and cubed form as a silage supplement when the rate of concentrate feeding is low.

2. The use of high-protein concentrates as supplements for silage, especially in the declining part of the lactation.

3. There is no need to give concentrates in more than 2 feeds per 24 hrs when silage is available *ad libitum*.

C H A P T E R 1

INTRODUCTION

INTRODUCTION

The amount of silage made in the United Kingdom (UK) has increased dramatically in the last decade and is now the main source of nutrients from conserved forages on large dairy farms with larger dairy herds. The history of silage making in the UK is briefly reviewed in the following chapter and shows the great advances which have been made in silage making and feeding, particularly in the last few years. Silages with a metabolisable energy (ME) content almost as high as those in concentrated feeds can now be made commercially on the farm by following a set of relatively simple rules, and this silage can make a major contribution to the supply of energy to the dairy cow in the winter months. The level of milk production from such silages is also reviewed in this thesis, but it is apparent that some supplementation of silage is normally required. This subject is reviewed next and forms an introduction to a series of feeding experiments to investigate the value of certain silage supplements which could be used on dairy farms.

REVIEW OF LITERATURE

History of silage making in the United Kingdom

In the UK, silage making only gained widespread acceptance after the second world war (1939-45) although old paintings found in Egypt (1000 - 1500 BC) suggest that the Egyptians were already familiar with the art of ensiling. Cato in 100 AD mentioned that green fodder was stored in pits and then covered with dung, and that air-tight sealing was an important condition for success in conservation (Schukking, 1976).

The Journal of the Royal Agricultural Society of England in 1884 included two papers on silage. The first paper by Jenkins (1884) gave a detailed report on the practice of ensilage at home and abroad, and the main principles adopted for silage making on some 40 farms were outlined. Silos were built either above or below the ground and on slopes, and their roofs were made of boards, corrugated iron and iron-slate tiles. The process of filling the silos was given as follows:- chopping the crop (or leaving unchopped), putting into the silo, treading, covering and weighting. Chopping enabled larger quantities of fodder to be stored in the silo, and thus helped in the expulsion of air. Chopped crops also required less treading and weighting than unchopped crops. The transfer of the crops from the field to the silos built above the ground was made using "elevating chaff-cutters", and the treading of the pitted crops was done by horses and men. The crops were generally covered by boards which were closely fitted together. Iron weights, steel ingots and heavy blocks served the purpose of weighting down the crops. The use of salt (sodium chloride) as an additive was considered worthwhile if the green crop was dry outside and not succulent. Jenkins (1884) also discussed the use of various crops for preservation, and green maize was suggested as being the most suitable crop by its composition for preservation by ensilage. The second paper by Voelcker (1884) on the chemistry of ensilage gave information on a study of a large number of silage samples. The effect of the temperature in the silo, the presence of air, the covering and weighting of the crops on the fermentation and growth of mould on the silage were all reported.

Silage making became fairly popular in the UK in the period 1890 - 1900 when the French method of Goffart and Viscomtedo was introduced (Watson and Smith, 1951). In this method, grassland herbage and maize were ensiled in trenches lined with wood and this method was based on rapid filling, complete exclusion of air followed by thorough sealing. A roof was sometimes built over the silo to give protection against the rain. In 1885 the introduction of the method of "sweet ensilage" by George Fry was a major setback to the development of silage production in the UK (Watson and Smith, 1951). With this method, the silage was extremely palatable but the over-heating of the silo mass to temperatures over 48°C gave a product of low digestibility.

During the following 50 years, research work established the main chemical changes that occurred in the ensiled green crop and the rôle of the various micro-organisms. A restriction of the amount of air in the silo and the rapid increase in the acidity of the silo mass were the major requirements of good silage making. This development and research work was reviewed fully by Watson (1939) in his book "The science and practice of conservation: grass and forage crops". Details of the designs of silos, the losses involved in silage making, and the effects of stimulants and chemical additives on the preservation of crops were discussed. The silos were classified into stack, clamp, trench, pit and tower (Watson, 1939) and most of these types were used on commercial farms. During the war (1939-45) small cylindrical silos either portable or erected on permanent sites were popular also (Morrison and Moore, 1954). The disadvantage of the cylindrical silos was the difficulty with roofing, and the silage was exposed to the air and thus the rain water seeped down inside the walls and caused much side wastage.

In the late 1940s, the increase in silage production led to an increase in the popularity of trench and pit silos (Morrison et al, 1953). This type of silo was filled by tractor-mounted buckrakes and, when lined with concrete, it resulted in small losses of material. A particular disadvantage of the trench and pit silos compared to tower silos was that they had large surface areas of silage exposed which required covering. Sometimes a simple roof made of curved corrugated iron sheets prevented deterioration in the quality of top layers of silage. After the 1939-45 war the use of tower silos continued in a small way but the main disadvantage was the cost of the accessory equipment required for filling and unloading the silage (Addison and Joce, 1966). These researchers suggested that conventional clamp silos and a self-feed system could be extremely efficient for small dairy herds, and preferable to tower silos.

The stimulation of a lactic acid fermentation in silage was found to be a major factor in controlling changes in the silo (Watson, 1939). This controlled fermentation was done by either the addition of suitable organisms to the cut crop or the addition of readily fermentable carbohydrate for the development of the micro-organisms already present on the green crop. Inoculation with bacterial cultures

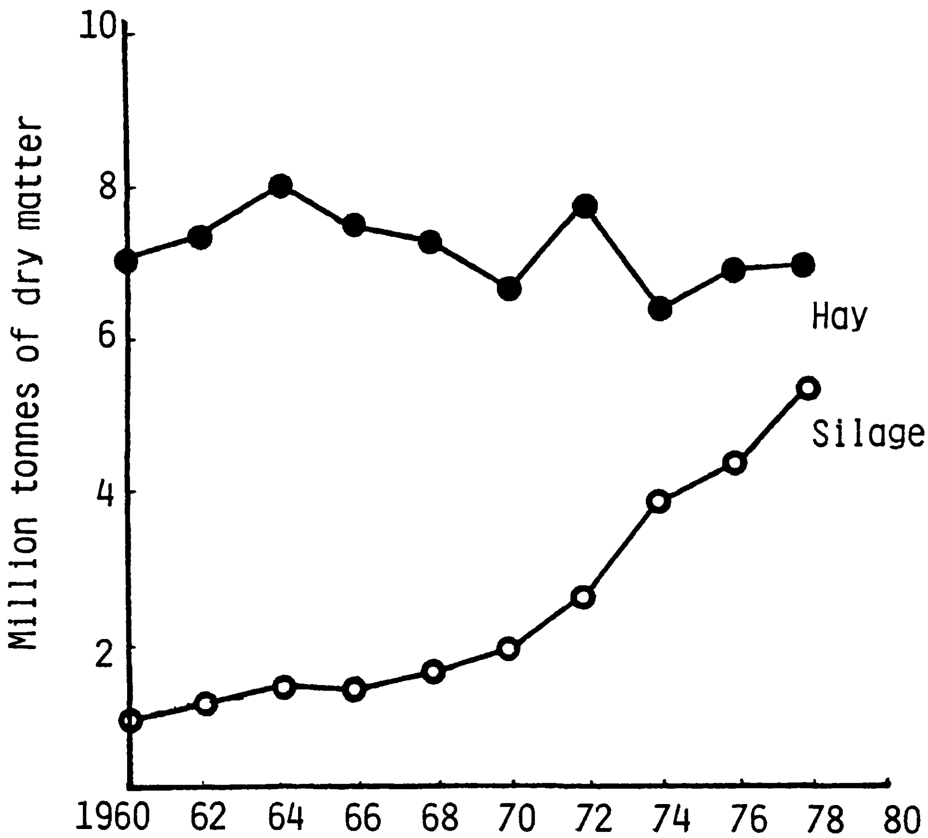


Fig. 1.1 Conservation of grass as hay and silage in the UK (Wilkinson, 1981)

never became popular because the freshly-cut crop had an extensive microflora which was capable of lactic acid fermentation. Ensiling with molasses as an additive was developed to a marked extent in Germany by Völtz in the 1920s (Watson, 1939), but the use of molasses was not recommended in the UK until the early 1940s (McLean, 1943).

The addition of acids was found to be extremely valuable with crops which were deficient in readily fermentable carbohydrates and were thus not able to produce a high concentration of lactic acid rapidly (Watson, 1939). The early work on acidification of green crops dates back to 1885 in Italy, but the final establishment of acidification in the making of silage and its commercial application was due to A. I. Virtanen in 1925, and hence the process was called the AIV method (Watson, 1939). The AIV process was introduced in the UK by ICI Ltd in 1932 (Crowther, 1933) but this method never became popular because of the special precautions required in handling the dangerous mineral acids and also because molasses was easily available during that period (Watson and Smith, 1951).

Although the main requirements for successful ensiling, such as the need to exclude air from the silo throughout the storage period, the need to achieve low pH conditions and to prevent secondary fermentation, were well established (Watson and Nash, 1960), it was not until the late 1960s that an expansion in silage making occurred in the UK (Fig. 1.1). As late as 1968 only 12 - 15% of the total conserved grass dry matter (DM) was conserved as silage. During the following years the amount of silage made increased sharply, and by 1973 it accounted for 28% of the conserved forage DM and the present figure (in 1978) is about 45% (Wilkinson, 1981). Despite this increase in the amount and proportion of crop DM conserved in the form of silage, hay

Table 1.1 Number of forage harvesters in the UK (Agricultural Statistics, 1966-77, UK)

Year	No.
1966-67	28,220
1968-69	30,490
1970-71	33,750
1972	34,750
1973	37,750
1974	35,440
1975	39,460
1976-77	40,640

still remains the dominant method of conservation (Fig. 1.1). At present about 6 million tonnes of silage DM are produced annually and this is given a value of about £300 millions (Wilkins, 1980).

This recent increased interest in silage making in the UK has been mainly due to the facilities available on the farm for short chopping, rapid filling of the silo, efficient exclusion of air throughout the storage period and the control of clostridial fermentation (Wilkins, 1980). The harvesting and ensiling of grass was a highly labour-intensive process until the mid-1940s (Hebblewaite et al, 1959). Indeed, with the exception of the mower and the tower silo all the other processes were mainly manual. The green crop was loaded onto carts and trailers powered by horses and tractors, and the filling of the silo by hand was followed by trampling to exclude the air. By 1945, silage machines which could cut, chop and blow the grass into trailers were available (Murdoch, 1957). This introduction of high-output forage harvesters led to an increased work rate in the field but there was still a problem of ensiling the grass at the same rate at the silo (Willows, 1959-60). This problem was overcome by using a tractor and buckrake. The increase in silage production from the mid 1960s was associated with an increase in the number of forage harvesters (Table 1.1). The availability of double and precision-chop forage harvesters in the early 1960s gave both fast work rates and short chopping (Wilkins, 1980). A further major breakthrough in reducing silage losses and hence encouraging silage making was the use of polythene sheets which prevented air entry into the silo. This use of polythene sheets was first investigated in the United States of America (USA) in the mid 1950s (Larrabe and Spraque, 1957) and was introduced to the UK soon afterwards (Watson and Nash, 1960). The

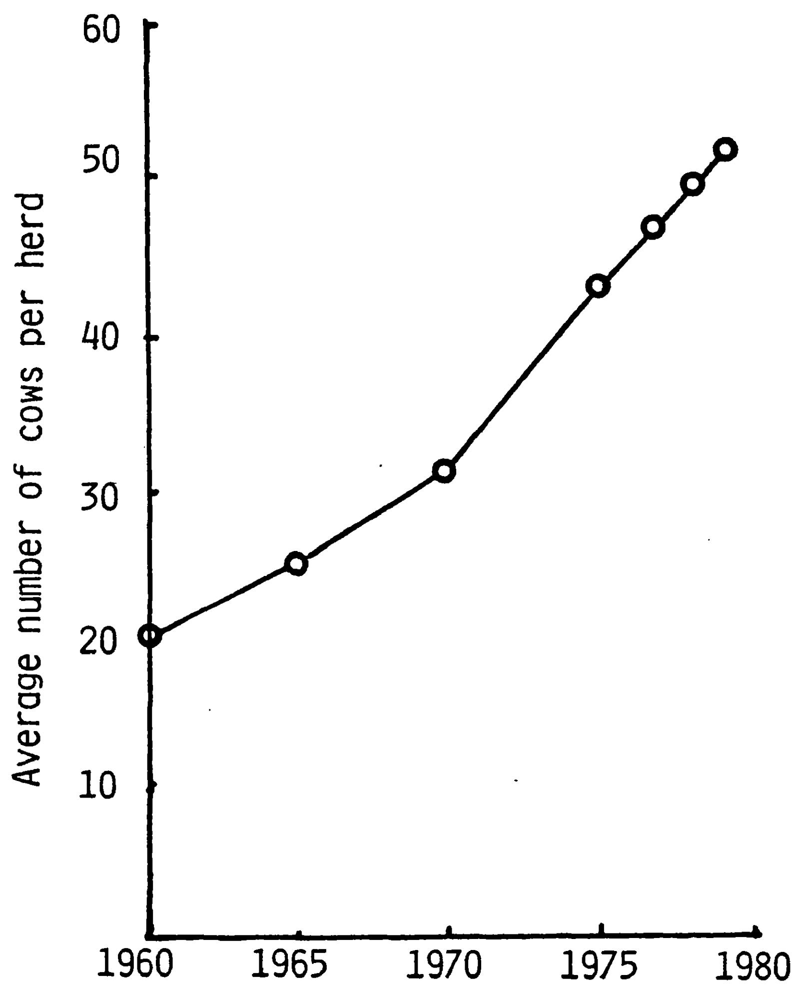


Fig. 1.2 Average size of dairy herd
(Dairy Facts and Figures, 1980, UK)

development of the Dorset Wedge System of filling the silos in the late 1960s also allowed the sealing of the silo with polythene sheets when filling was not in progress (Raymond et al, 1972). In this system of filling, heating through respiration was restricted and thus more water-soluble carbohydrates (WSC) were available for lactic acid fermentation. Clamp silos of today are gaining wide popularity because they generally have air-tight walls at two sides and at one end and are now covered by polythene sheets and a roof to give protection against rain (Retter, 1978). The development of effective silage additives containing formic acid over the past 20 years also coincided with a large increase in the amount of silage (Drysdale and Berry, 1980). Coupled with these additives was the availability of simple and cheap gravity-drip applicators, which were highly effective for mixing the additives with the forage at the time of ensiling (Wilkins, 1980).

By the end of the 1960s and in the early 1970s all these technical developments offered ways for the effective and safe preservation of grass on farms throughout the UK. However, interest in silage making developed to a greater extent on farms which had relatively high requirements for forage (Wilkinson and Wilkins, 1980) and on farms which had sufficient labour available to organise work in teams of either three or more persons (MAFF, 1978). The adoption of silage making was also associated with increases in the size of dairy herds in the UK (Fig. 1.2). This increase in the number of cows per herd increased the total requirement for conserved forage on the individual farm and thus the choice of silage, rather than hay, was made. This choice was partly determined by the fact that the silage was less dependent on the weather than hay, and also by advances in silage mechanisation and the control of fermentation. During the immediate post-war (1939-45) period the feeding of silage was generally a manual process, and this was a prime factor which inhibited the development of silage production at that time. The successful introduction of a self-feeding system from the USA in 1953 (Turner, 1953-54) was a major factor in the growth of silage making as this system removed the practical disadvantages of giving silage to cows in individual stalls. At this time, there were also developments in the loose housing of cows which fitted in extremely well with the self-feeding of silage. Silage making thus became popular on large farms and by 1974 about 74% of farms with more than 2400 standard-man days (i.e. 8 hours work) relied on silage for winter feeding, compared with 17% of dairy farms with only 275 - 599 standard-man days (Wilkins, 1980).

In the winter, silage now contributes a major part of the forage ration offered to dairy cows, and at the present time about 50% of the total nutrient energy from forages comes from silage (Castle, 1981). On some individual farms, the contribution from silage to the total nutrient requirements of the dairy herd can be exceedingly high if the silage has both a high percentage of digestible organic matter in the dry matter (D-value) and high intake characteristcs. For example, in a herd of 240 cows producing a mean daily milk yield of 17.5 kilogrammes (kg) per cow in the mid-winter period, 83% of the ME was reported to come from grass silage (A. Webb, personal communication, 1981). This is, of course, an exceptionally high proportion but clearly indicates the enormous potential of silage for feeding dairy cows.

The advances in silage making and silage feeding have been exceedingly rapid in the last few years but there is still an important place for the wise use of supplements with silage diets. This aspect of silage feeding will be reviewed next and will be

Table 1.2 Silage D-value and intake, milk yield and composition and liveweight change on diets of silage only

Reference	Silage D-value	Silage DM intake (kg/cow/day)	Milk yield (kg/cow/day)	Milk composition ($g\ kg^{-1}$)					Liveweight change (kg/cow/day)
				Fat	SNF	Total solids	Crude* Protein	Lactose	
Castle and Watson (1975)	70.4	11.6	14.5	43.4	82.0	125.4	29.9	44.4	-
Castle and Watson (1976)	70.3	10.8	14.6	41.9	83.7	125.6	29.0	46.9	- 0.97
Castle *et al* (1977a)	68.4	11.3	14.8	40.2	84.0	124.2	30.3	45.4	- 0.21
Castle *et al* (1977b)	71.0	10.4	15.1	41.8	82.9	124.7	29.6	45.6	- 0.52
Castle *et al* (1977b)	70.6	10.7	13.3	42.7	84.1	126.8	29.5	46.5	- 0.31
Castle *et al* (1977b)	71.2	10.9	13.7	44.8	83.9	128.7	30.1	45.8	- 0.12
Retter (1978)	68.3	11.7	13.5	41.6	85.0	126.6	32.4	44.7	- 0.45
Castle *et al* (1980)	71.2	12.8	16.0	40.5	86.6	127.1	32.5	46.3	- 0.52
MEAN	70.2	11.3	14.4	42.1	84.0	126.1	30.4	45.7	- 0.44

*N x 6.38

followed by a description of a series of feeding experiments to investigate some aspects of this complex topic.

Effects of supplements on silage intake

Rations of silage alone are generally inadequate as a source of energy for high yielding cows, although in one experiment a daily milk yield of 21.8 kg per cow was obtained when the cows ate 68.2 kg per day of wet silage made from young short grass (Crichton, 1941). This was, however, an exceptional result, and from a recent series of feeding trials (Table 1.2) a mean milk yield of 14.4 kg per cow/day was reported when the sole feed was silage with a mean D-value of 70.2 offered *ad libitum* to the dairy cows. Milk yields of 7.4 and 10.8 kg per cow/day were obtained by Brown (1959) when dairy cows were offered medium and good quality silage diets *ad libitum*. More recently, Mo (1980) estimated a maximum milk production in the lactation of 4000 kg of fat-corrected milk (FCM) on a good quality, all silage ration. There are circumstances in which low yields of this level may be acceptable, but the relatively low solids-not-fat (SNF) content of the milk and the loss of weight by the cows (Table 1.2) make this system of feeding unacceptable, especially with cows of high-yield potential. The feeding of silage as the sole constituent of the diet is a major factor limiting milk production, although in theory, milk yields of up to 20 kg per cow/day can be obtained if silage intakes were 2.9 to 3.0% of liveweight (Rook, 1981). In one experiment (Rook, 1981) a milk yield of 19.7 kg per day was obtained from three cows when silage having a D-value of 71.2 was consumed, with an average intake equivalent to 3.02% of liveweight. This was, however, an isolated and exceptional example.

Table 1.3 The decrease in the intake of silage dry matter caused by feeding different types and levels of supplements

Reference	Silage D-value	Supplementary food	Level of supplementation (kg/cow/day)	Reduction in silage intake (kg/kg of supplement)
Castle and Watson (1975)	70.4	Barley	3.3	0.58
			4.6	0.41
			6.0	0.58
Castle and Watson (1975)	70.4	Ground-pelleted dried grass	3.4	0.44
			4.6	0.28
			6.3	0.34
Castle *et al* (1977a)	68.4	Groundnut cake	1.2	- 0.08†
			2.3	- 0.13†
			3.4	0.03
Castle *et al* (1977b)	71.0	Cube (38% CP)	2.3	- 0.26†
	70.6		2.3	- 0.22†
	71.2		2.4	- 0.04†
Castle and Watson (1976)	70.3	Barley	4.7	0.47
		Groundnut cake	1.5	- 0.20†
		Barley and groundnut cake (83:17)	4.7	0.32
Retter (1978)	68.3	Hay	4.0	0.87
		Soyabean meal	1.8	- 0.06†
		Hay and soyabean meal (68:32)	5.6	0.61
Retter (1978)	59.8	Hay	0.8	0.87
			1.6	0.93
Retter (1978)	64.6	Hay	3.6	0.67
Clapperton (private communication 1981)		Medium fat concentrate	4.4	0.47
		High fat concentrate	3.9	0.90

†Intake increased

Concentrate supplements are normally offered with silage to increase the overall concentration of nutrients in the diet and to increase the total DM intake and milk production (Castle and Watson, 1975, 1977a; Mo, 1980). It has been stressed by Broster (1974) that it is important to maximise the peak yield to improve the total lactation yield, and this cannot be obtained without high concentrate feeding during early lactation. However, most of the studies of Broster (1974) were done with rations of hay, and there are now indications that lower levels of concentrate feeding given on a flat-rate system with silage *ad libitum* may be highly effective (Østergaard, 1979; Steen and Gordon, 1980b). Supplements offered to dairy cows normally decrease the silage intake, and the size of the decrease depends on the type and the amount of supplements offered (Table 1.3). It can be seen that supplements of dried grass cubes, groundnut cake, high-protein cubes and soyabean meal have a lesser effect on silage intake than supplements of barley, hay and high-fat concentrate (Table 1.3). In the four comparisons in which dairy cows were offered silage of 70.4 D-value *ad libitum* (Castle and Watson, 1975, 1976), the mean reduction in the daily silage DM intake was 0.51 kg per kg of barley when barley DM intakes ranged from 3.3 to 6.0 kg per cow. A reduction of 0.64 kg silage DM per kg of barley DM intake was found by Ettala and Lampila (1978) using 296 Ayrshire cows. Barley depresses the silage intake because of the effect of the starch on ruminal digestion of silage (Thomas and Castle, 1978). The supplements of barley offered with silage reduced the digestibility of the cell wall constituents to a greater extent than silage offered alone (Morgan *et al*, 1980; Thomas *et al*, 1980b). The reduction in the cellulolytic activity of the rumen micro-organisms can reduce both the rate of disappearance and the rate

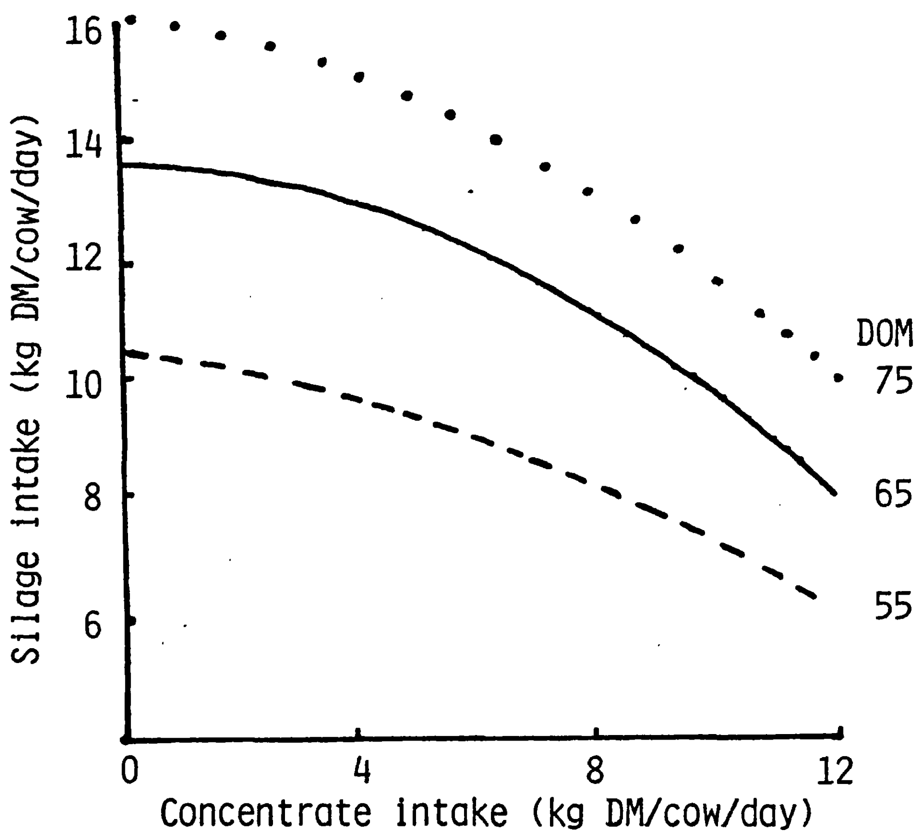


Fig. 1.3 The effect of the digestibility of the organic matter (DOM) in silage on silage intake at different levels of concentrate intake (Østergaard, 1979)

Table 1.4 The effect of stage of lactation on substitution rate (kg silage DM/kg concentrate DM)

Experiment	Lactation weeks			
	3 - 6	7 - 12	13 - 18	19 - 26
1	0.95	0.70	0.58	0.31
2	0.91	0.76	0.48	0.36

Ekern (1972)

of feed passage from the rumen (Osbourn, 1980). A diet of silage offered with cereals reduces the ammonia in the rumen compared with silage offered alone (Wernli, 1971; Thomas et al, 1980a) and this results in large improvements in nitrogen retention (Griffiths et al, 1971; Morgan et al, 1980; Thomas et al 1980a). Østergaard (1979) showed that as the concentrate intake increased, silage intake decreased (Fig. 1.3) but with a net increase in the total DM intake and energy intake as in the experiments with barley supplements. A summary of 16 recent feeding trials which examined the effects of level of concentrate input on the intake of cows given silage ad libitum was analysed by Thomas (1980). The mean reduction in the silage DM intake was 0.50 ± 0.07 kg per kg of concentrate DM intake (Thomas, 1980). There were, however, trends in this study for the substitution rate to be greater (0.88 ± 11) in the trials involving high-yielding cows. This may have been a reflection of the higher levels of concentrate input per se given to the high-yielding groups of cows. Østergaard (1979) has also suggested that the substitution rate increases with increasing level of concentrate intake. The trend towards a higher substitution rate with high-yielding cows may also be associated with the stage of lactation, as Ekern (1972) showed that substitution rates declined as the lactation progressed (Table 1.4). The amount of concentrates offered to dairy cows in early lactation was higher than in late lactation and it was therefore not surprising that the depressive effect of the concentrate feeding appeared to be more pronounced during peak lactation.

Dried grass cubes as a supplement for silage have a similar effect to barley, but the reduction in the intake of silage DM with a dried grass is generally smaller than with a supplement of barley

(Castle and Watson, 1975). It has been suggested by Campling (1966) that cereal-based concentrates which have a high starch content may induce conditions in the rumen which are unsuitable for the digestion of fibrous components of the forage. This was confirmed by Porter et al (1972) who found that bacteria isolated from the ruminal fluid of cows on a high-cereal ration were only weakly cellulolytic. However, Wilkins (1970) suggested that because dried grass has a low starch content, this food may have a limited effect on the bulk of ingesta in the rumen. As a result, it is thus possible that increasing proportions of dried grass in the concentrate part of the ration may result in an increase in the digestibility of the crude fibre in the diet and this in turn may influence the silage intake. Castle and Watson (1975) obtained a mean reduction of 0.35 kg silage DM per kg of dried grass DM when intakes ranged from 3.4 to 6.3 kg DM per cow/day. However, results given by other workers have shown considerable differences. For example, Tayler and Aston (1973) working with dairy cows given grass silages (D-value 63 - 65) ad libitum reported an increase of 16% and 26% in the silage intake when dried grass pellets (D-value 65) formed 33% and 66% of the concentrate ration, respectively. On the other hand, McIlmoyle et al (1975) showed smaller increases in silage intake of 9% and 10% with dried grass composing 25% and 50% of the concentrate pellets, respectively. Tayler and Aston (1976a) also obtained higher intakes of silage with either dried grass pellets (modulus of fineness 0.9) or a mixture of 66% dried grass and 34% barley than with the same quantity of DM offered as mixtures of barley and groundnut. In contrast, Gordon (1975) using a medium-quality grass silage obtained only a small increase in the silage DM intake with increasing levels of dried grass in the concentrate pellets. However, the protein content of the dried grass and concentrate feeds can also have an important effect on the intake of silage. In the experiments of McIlmoyle and Murdoch (1977a, b) where a supplement of dried grass cobs was compared with a concentrate containing a similar protein content, the response in the intake of silage was less consistent, with some results showing an increase in silage intake with dried grass and others not. Similarly, Tetlow and Wilkins (1980) reported a small increase in the intake of silage with dried grass when both the dried grass and the barley mixture contained similar levels of protein.

The physical form of dried grass can also influence silage intake. Most dehydrated forage is processed into pellets, cobs or wafers before feeding (Shepperson _et al_, 1972). This processing of the dried grass reduces the modulus of fineness (MF) which has been shown to increase the DM intake of silage offered _ad libitum_ (Tayler, 1970; Tayler and Aston, 1972). In a recent study (Tayler and Aston, 1976a), dairy cows were offered grass silages (mean DM digestibility 60.2) _ad libitum_ with equal quantities of dried grass DM in the form of wafers (MF 2.63), cobs (MF 2.78) and pellets (MF 0.63), and the animals consumed 11% more silage with pellets than with wafers. Silage contributed 57% of the daily DM intake with supplements of wafers and cobs and 60% with the pellet supplement. High quality dried grass is thus an excellent supplement to silage and a useful protein source but it is not widely available (Castle and Watson, 1975), and, for this reason, protein sources from other supplements have been studied.

The use of groundnut as a supplement does not reduce the intake of silage and in two experiments (Castle and Watson, 1976; Castle _et al_, 1977a), the mean intake of silage DM increased by 0.14 kg per kg of supplement up to a maximum of 3.4 kg per cow/day. These researchers suggested that the high protein content of this type of supplement reduced the level of starch content in the diet and thus had a beneficial effect on silage intake and also supplied more protein to the animals. A similar effect was observed in a large-scale experiment (Laird et al, 1979) when concentrates of 14% and 18% crude protein (CP) were compared to an all-silage diet. The intake of grass silage was increased by 10% when a concentrate containing the high protein content was offered. Gordon (1979) studied the response of a wide range of protein contents in the concentrates as the supplements to a high digestibility grass silage. The concentrates were offered at equal levels on the various treatments and there was a trend in the reduction in the silage intake when the lowest protein concentrate was used. There are also beneficial effects from the feeding of protein from sources such as groundnut with barley on a silage diet. For example, Castle and Watson (1976) showed that groundnut added to barley partially offsets the adverse effects of barley alone. In this experiment, the reduction in silage DM intake was 0.32 kg with a mixture of 83% barley and 17% groundnut, compared to 0.46 kg on barley only. Similarly, Murdoch (1962) reported an average increase of 11% in silage intake when 16% and 25% of the concentrate mixtures were in the form of groundnut compared to zero and 8% of the mixtures.

Soyabean meal had a similar effect to groundnut and increased the silage DM intake by 0.06 kg per kg of soya when the soya DM intake was 1.8 kg per cow/day (Retter, 1978). In another feeding experiment, the daily intake of silage DM was increased from 7.5 to 8.5 kg per cow when groundnut was replaced by soyabean meal on an equal DM weight basis (Castle and Watson, 1979). In the experiment of Morgan et al, (1980), a supplement of soyabean meal did not depress the intake of silage to the same extent as a supplement of barley; the digestibility of the cell wall constituents was markedly increased with the supplement of soyabean meal.

The high cost of cereals and their relatively low output per unit area has led to alternative feeds being studied (Gordon, 1976). Brassica crops are highly digestible (Ørskov et al, 1969; Kay et al, 1970) and have the potential to produce higher outputs of animal food per unit area than cereals (Kay, 1974) and thus offer possibilities as supplements in silage based diets. Kale has been tried as a replacement for cereal-based concentrates for cows with ad libitum access to grass silage (Gordon, 1976). This worker found that replacing a part of the concentrate by an equal weight of kale DM resulted in a depression in silage intake of 9%. The inclusion of kale in the diet did not depress the forage digestibility to the same extent as that obtained when a starch-type of supplement was used (El-Shazly et al, 1961), and this may be due to higher rumen pH values on diets containing kale. Tilley et al (1964) have suggested that the maintenance of a high pH in the rumen is an important factor in providing a favourable environment for cellulolytic and other micro-organisms capable of digesting plant fibre.

Hay is sometimes used as a supplement for silage in the diet of the dairy cow. In the study by Ettala and Lampila (1978), a reduction of 1.15 kg silage DM per kg hay DM was found. A series of experiments by Retter (1978) also showed a mean reduction in the silage intake of 0.84 kg per kg hay DM (Table 1.3). This high value was obtained with hays having D-values ranging from 58 to 70 and with silages ranging from 59.8 to 68.3. The level of reduction in the silage DM intake by the hay was not affected when supplements of soyabean meal and

Table 1.5 Effect of concentrate level on peak milk yield (kg/cow/day)

Reference	Concentrate feeding level	
	Low	High
MAFF/ADAS (1975)	25.7	26.9
Ekern (1970)	30.2	29.9

groundnut cake were added to the ration. Retter (1978) concluded from his experiments that long hay, regardless of its D-value, was of little value as a silage supplement. In contrast, other studies have shown that an increase in hay consumption has not decreased the silage intake to a large extent (McCullough, 1961; Murdock and Hodgson, 1967). In these studies, feeding of 1 kg of hay DM decreased the daily intake of silage DM by only 0.3 to 0.7 kg.

Effectsof supplements on milk yield and composition

A study by Thomas (1980) of sixteen feeding trials involving lactating dairy cows examined the effect of the level of concentrate input on milk yield when the cows were offered silage *ad libitum*. The data showed that the average response to the concentrate input was + 0.79 ± 0.09 kg milk per kg concentrate DM, and that there was no indication that the response was greater in the higher yielding groups of animals than in the lower yielding groups. Similarly, Østergaard (1979) did not detect any effect of level of milk yield on the response in milk output to concentrate input. The response to the ME intake estimated from the data of Thomas (1980) was calculated to be 0.10 ± 0.01 kg milk per megajoule (MJ), with a trend for the higher yielding groups to have a higher response than the lower yielding groups with values of 0.12 ± 0.02 and 0.08 ± 0.01 kg milk per MJ, respectively. The influence of level of concentrate feeding on milk yield during the period of early lactation up to peak yield can be relatively small when silage is offered *ad libitum* (Table 1.5) MAFF/ADAS, 1975; Ekern, 1970); this may be due to the high substitution rate in early lactation (Table 1.4). Feeding systems which allocate relatively more concentrate in early lactation may have little influence on total lactation yield when forage is offered *ad libitum*. For example, in the feeding experiments of Østergaard (1979) and Steen and Gordon (1980a,b) in which silage was given *ad libitum*, the pattern of concentrate feeding had either little or no effect on the total lactation yield. These results were in contrast with those in the trial of Johnson (1977) where restricted quantities of forage were given to the cows.

There are large differences, however, between supplements and their level of feeding on the milk yield. For example, Castle and Watson (1975; 1976) obtained poor responses with supplements of barley, with daily milk yields ranging from 15.7 to 17.0 kg per cow compared with a mean daily milk yield of 14.4 kg on silage alone. These studies revealed that the supplementation of barley not only reduced silage intake, but also reduced the efficiency of use of energy in terms of milk production. It was calculated by Thomas and Castle (1978) that the efficiency of utilization of ME for lactation was only 39% for barley plus grass silage compared with a value of 46% for silage alone. Similarly, a poor response to barley was seen in a large scale feeding trial (Ettala and Lampila, 1978) when a milk yield of 15.9 kg per cow/day was obtained when barley contributed 15.4% of the total daily dry matter and consumption.

Recent research has included the use of dried grass as a supplement to other conserved forages, in particular, silage and the effect of processing the dried material on its rôle as a replacement for dairy concentrates (Thomas, 1980). Dried grass has a smaller effect than barley in reducing the voluntary intake of silage (Castle and Watson, 1975), and thus higher milk yields were obtained on dried grass than on barley supplements with a high digestibility grass silage. The efficiency of utilization of ME averaged 62% with supplements of dried grass compared with only 46% with supplements of barley (Thomas and Castle, 1978). There was no significant effect on the milk yield when dried grass comprising up to 50% of the concentrate mixture was offered with medium-quality grass silage (McIlmoyle et al, 1975). Similarly, Tayler and Aston (1973) compared concentrates containing 0, 33, 66 and 100% dried grass and found no effect on milk yield. Both McIlmoyle et al (1975) and Tayler and Aston (1973) reported marked increases in the silage DM intake when dried grass was included in the concentrate which was cereal-based. All these workers suggested that the increase in silage intake compensated for the fact that the dried grass was lower in nutritive value than the cereal-based concentrate, and thus gave similar levels of milk production. Gordon (1975) included dried grass in the concentrate at different levels with a diet of silage ad libitum and detected no decreasing trend in milk output. It was suggested by Gordon (1975) that the intakes of the total diets were either equal in nutritive value or that the overall feeding levels were too high to allow animal responses to be measured. In another experiment with dairy cows in which a basal diet of silage was offered ad libitum (Tayler and Aston, 1976a) a supplement of dried grass pellets with a D-value of 65.7 resulted in a greater intake of silage compared to a supplement of barley plus groundnut; both treatments gave similar milk yields. In a further feeding experiment, Tayler and Aston (1976a) showed that cows given dried grass in the form of pellets consumed 11% more silage DM and produced 19% more milk than cows given the same grass as wafers. In Northern Ireland, Gordon and Kormos (1973) found that milk yield increased as the level of dried grass (DM digestibility 70%) was increased from 0.28 kg to 0.61 kg per kg milk. These workers concluded that dried grass offered as a supplement at a rate of 0.42 kg per kg of milk would give an equivalent milk production to that of conventional concentrates offered at 0.39 kg per kg milk. A series of feeding experiments conducted by Gordon and McIlmoyle (1973) also showed that good-quality dried grass could be used successfully as a complete replacement for conventional concentrates in the rations for dairy cows. However, when a supplement of 100% dried grass was used with forages which were high in protein, the maximum benefit was not achieved from the relatively high protein content of the dried grass. It was therefore suggested that this type of supplement was likely to be of the greatest advantage when used with low protein forages such as hay, whole-crop cereal silages and maize silage. Recently Mo (1980) estimated maximum milk production in the lactation of approximately 6000 kg FCM on a ration of silage supplemented with grass pellets. The replacement of the cereal-based concentrate portion of the diet by an equal intake of kale on an ad libitum silage diet had no effect on milk yield (Gordon, 1976).

Hay offered as a supplement on a diet of silage ad libitum had generally no significant effect on milk yield (Retter, 1978). This was rather surprising since the voluntary intake of hay was normally greater than that of silage when the two crops were made from the same herbage (Murdoch and Rook, 1963; Campling, 1966). It was also shown by Retter (1978) that hay caused a greater reduction in voluntary silage intake (Table 1.3) than any of the other supplements. However, in one experiment where the silage had a low intake, a supplement of hay with a D-value of 65 gave a marked increase in the milk yield, although with silages of high quality and high intake characteristics this effect on milk yield was generally non-significant. Recently, it was estimated by Helminen (1979) that a supplement of 2 kg hay and a good-quality AIV silage offered ad libitum to dairy cows can meet the maintenance requirements and produce 10 kg milk per cow/day.

A considerable proportion of dairy cows in large herds within the UK now receive winter diets based on grass silage. Improving the quality of this forage mainly through conservation of the grass crop at a more leafy and digestible stage of growth has been a major aim during the past decade. The resulting high-digestible silage normally also has a high crude protein (CP) content (Wilson and McCarrick, 1966; Castle, 1975; Castle et al, 1977a; Castle et al, 1980) which in theory gives adequate intakes of protein and thus the use of low protein supplements. There are, however, indications (Butler, 1973; Butler and Gleeson, 1973; Cuthbert et al, 1973; Gordon, 1979) that with silage-based diets, the response to additional protein may not decline even above the point where theoretically adequate amounts of protein are being supplied. There are still many uncertainties (Castle and Watson, 1969) regarding the value of non-protein-nitrogen (NPN) in the silage. For example, in one study of Castle and Watson (1975) a ration of silage and 3 kg barley was calculated to give a daily milk yield of 22.0 kg compared with a recorded yield of 16.6 kg per cow/day. The major factor limiting milk yield was apparently a deficiency of protein. The uncertain value of the nitrogen in the silage has been shown in two other experiments by Castle and Watson (1969, 1974) where substantial increases in milk yield were obtained when groundnut cake was included in the rations of cows on high-protein silage and barley. Marked increases in milk yield were obtained by Murdoch (1962) when concentrates contained 16% and 25% groundnut cake compared with barley only; theoretically, there appeared to be sufficient protein in the

Table 1.6 Effect of protein level in concentrate supplement on daily milk yield

Reference	Crude protein in supplement (g/kg^{-1})	Rate of feeding	Milk yield (kg/cow)
		kg/kg milk	
Adamson *et al* (1979)	130	0.35	18.5
	180	0.36	19.4
Castle *et al* (1977)	119	0.40	18.9
	335	0.15	19.4
		kg/cow/day	
Gordon (1979)	95	8 - 10	18.0
	137	8 - 10	19.4
	174	8 - 10	20.4
	209	8 - 10	21.7
Gordon and McMurray (1979)	103	8	17.4
	136	8	18.3
	173	8	20.1
	211	8	20.9
	252	8	21.5
	303	8	20.3
		kg/kg milk	
Laird *et al* (1978)	180	0.30	17.1
	360	0.15	15.6
Laird *et al* (1979)	140	0.40	17.4
	180	0.40	19.5
		kg/cow/day	
Thomas *et al* (1978)	104	6.6	14.8
	254	6.9	15.2
Gordon (1980a)	172	7.0	24.8
	234	7.0	25.6

silage plus barley ration to support high milk yields.

The effects of different levels of crude protein in the concentrate supplement on the daily milk yield are given in Table 1.6. In all the experiments (Table 1.6), concentrate supplements were offered with diets of silage *ad libitum*. Generally, as the protein content increased, so did the daily yield of milk. In the large scale experiment (Laird *et al*, 1979) concentrates containing 140 g and 180 g CP per kg (g kg^{-1}) were compared on a ration of medium D-value silage; the 10% increase in the milk yield on the treatment containing the high protein concentrate was associated with a 10% increase in silage consumption. Thus, both the energy and protein intake of the cows was increased. In another feeding trial involving cows with access to 67 D-value silage given *ad libitum*, higher milk yields were obtained with a concentrate containing 209 g CP kg^{-1} than a concentrate containing 95 g CP kg^{-1} (Gordon, 1979). In this experiment (Gordon, 1979), the level of CP did not affect the silage intake significantly but the overall digestibility of the ration was increased slightly, which in turn increased the daily intake of ME on the higher protein treatment. The increase in the ME intake was only marginal on the high protein treatment and it was therefore suggested that the major part of the response in milk yield was due to the increased protein *per se*. Gordon (1979) indicated that the protein was not utilized efficiently, although in theory the supply of protein was far above the requirements of the animals. In another experiment, Gordon and McMurray (1979) showed no trend towards a decline in the milk yield response to some extremely high protein levels in the concentrates. In this experiment, the cows were given 61 D-value silage *ad libitum* with concentrates containing 103, 136, 173, 211, 252 and 303 g CP kg^{-1}. From the results it was calculated that the maximum daily milk yield would be obtained with a concentrate containing 244 g CP kg^{-1}. These workers (Gordon and McMurray, 1979) concluded that if the protein content of the concentrate supplement had no effect on the intake of silage, then the maximum returns from milk production would be achieved with a concentrate supplement containing 222 g CP kg^{-1}. On the other hand, Gordon (1980a)obtained only a small increase in milk yield when a concentrate containing 234 g rather than 172 g CP kg^{-1} was offered with a 76.9 D-value grass silage. Under commercial conditions, Castle _et al_ (1977) reported higher milk yields with a supplement of groundnut cubes containing 335 g CP kg^{-1} given at a low rate than with a mixture of barley and groundnut having 119 g CP kg^{-1} given at a high rate with 67 D-value silage _ad libitum_. In another experiment, a concentrate containing 360 g CP kg^{-1} given at a rate of 1.5 kg per 10 kg milk gave a lower milk yield than a cube containing 180 g CP kg^{-1} given at 3.5 kg per 10 kg milk (Laird _et al_, 1978). Although the high protein concentrate increased the silage intake, this increase did not compensate for the reduced intake of energy from the lower intake of concentrates. Adamson _et al_ (1979) obtained about 5% higher milk yields with a supplement of barley plus groundnut than with barley only when offered with a 66 D-value grass silage. An increase of 11.5% in milk yield was recorded by Thomas _et al_ (1978) from cows given pellets consisting of ground maize and soyabean meal compared with pellets of groundmaize only on silage diets. In the experiment of Butler (1973), there was a marked increase in milk production as a result of increasing the CP content of the supplementary concentrate from 93 to 163 g kg^{-1} on a silage diet. The response per unit increase in protein percentage was 0.27 kg milk per day. The responses of 0.16 (Butler and Gleeson, 1973) and 0.14 kg

Table 1.7 Effect of protein concentrates on silage intake and daily milk yield

Reference	Type of concentrate	Level of concentrate DM (kg/cow/day)	Silage DM intake (kg/cow/day)	Milk yield (kg/cow)
Castle *et al* (1977a)	Groundnut cake	-	11.3	14.8
		1.2	11.4	16.5
		2.3	11.6	18.2
		3.4	11.2	18.4
Castle and Watson (1976)	Groundnut cake	-	10.8	15.2
		1.5	11.1	17.7
Retter (1978)	Soyabean meal	-	11.7	13.9
		1.8	11.8	14.8
Castle and Watson (1979)	Soya	3.92	8.38	16.2
	"Pruteen"	3.87	7.94	16.2
	Groundnut	3.99	7.49	15.2

milk/day (Cuthbert et al, 1973) per unit increase in the protein percentage of the supplement were obtained on silage-based diets. In the feeding trial by Castle and Watson (1976), the inclusion of a protein supplement in the diet of cows given ad libitum grass silage increased the voluntary intake and the response to the extra protein intake was 0.49 kg milk per 0.1 kg of additional digestible crude protein (DCP). More recently, a response of 0.31 kg milk/day per unit increase in the protein percentage of the concentrate supplement was obtained (Gordon, 1979).

The inclusion of groundnut cake in the diet has increased both silage intake and milk production (Table 1.7). In an experiment of Castle et al (1977a), the daily milk yield was increased from 14.8 kg per cow on a 68 D-value silage to 18.2 kg per cow when 2.3 kg of groundnut cake was offered. There was an increase in both ME and DCP intake on the groundnut cake treatment compared with the silage only treatment. Soyabean meal had a similar effect to groundnut cake and also increased the milk yield (Table 1.7). Castle and Watson (1979) showed that the supplementation of a medium D-value silage with soyabean meal increased the silage intake and supplied extra ME and DCP and produced 7% higher milk yields compared with a supplement of groundnut cake.

Concentrate feeds for ruminants contain limited amounts of supplementary oils and fats, the main function of which is to aid pelleting and to improve palatability. Recently there has been increased interest in feeding higher levels of fat in order to increase the energy concentration in the concentrate and hence the energy intake of high-yielding dairy cows in particular during the peak period of lactation (Murphy and Gleeson, 1978). A study was conducted to evaluate the feeding of added tallow to the diet of early-lactation cows offered silage _ad libitum_ (Murphy and Gleeson, 1979). A concentrate containing 8.75% tallow was given at the rates of either 7.25 or 6.60 kg per day and was compared with a concentrate containing 2% added tallow given at 7.25 kg per day. Animals receiving 7.25 kg of the high-tallow concentrate gave higher milk yields than those receiving 6.60 kg, but they did not differ significantly in yield from those on the low fat treatment. The results of this experiment indicated that the inclusion levels of unprotected tallow (up to 8.75%) did not improve the cow performance. The effect of including protected fat (megalac 95) in the ration of dairy cows in early lactation has been reported by Rath and Nunes (1979). In this experiment, daily milk yields were 17.5 and 17.8 kg on the standard ration and the ration containing 7.5% protected fat respectively, when given _ad libitum_ with good-quality silage. In another study Clapperton (private communication 1981), investigated the effects of giving various amounts of protected fat to cows eating 8 kg DM of grass silage per cow/day. The concentrates supplied 0, 180, 360 and 540 g protected fat per day and the milk yields on the four feeding treatments were 15.2, 15.3, 14.7 and 16.7 kg per cow/day, respectively. In a further experiment this worker obtained daily milk yields of 13.7, 14.9 and 13.9 kg per cow when concentrates containing high fat (1000 g per day), medium fat (500 g per day) and no fat were offered to the cows to supply the same amount of energy with silage _ad libitum_. The concentrates containing the high fat caused the largest depression in the silage DM intake and hence in the total food intake.

Many factors can affect the chemical composition of milk. The most important non-nutritional factors are milk yield, breed of cow,

Table 1.8 The effect of supplementary concentrates on the fat, solids-not-fat (SNF) and crude protein content of milk

Reference	Type of supplement	Milk composition ($g\ kg^{-1}$)		
		Fat	SNF	CP*
Castle and Watson (1975)	Nil	43.4	82.0	29.9
	Barley	46.8	84.4	31.1
	Dried grass	42.0	85.0	32.3
Castle and Watson (1976)	Nil	41.9	83.7	29.0
	Barley	45.0	84.3	30.1
	Barley + groundnut cake	42.3	85.3	31.0
McIlmoyle *et al* (1975)	Dried grass (0) + conc (4)	38.5	84.2	29.7
	Dried grass (1) + conc (3)	36.3	86.6	28.7
	Dried grass (2) + conc (2)	37.7	83.6	29.1
Tayler and Aston (1973)	Dried grass pellets	39.0	85.0	-
	Dried grass pellets (1) + barley mix (3)	38.0	84.0	-
	Dried grass pellets (3) + barley mix (1)	39.0	86.0	-
Tayler and Aston (1976a)	Dried grass pellets	38.2	84.7	29.9
	Dried grass pellets (2) + barley (1)	39.6	85.2	31.0
	Barley + groundnut cake	36.2	83.9	29.3
	Barley + groundnut cake	41.7	87.3	32.9
Gordon and Kormos (1973)	Dried grass	32.8	82.5	29.8
	Dried grass	36.6	83.5	31.1
	Dried grass	37.8	85.2	31.6
	Dried grass	37.5	86.3	32.7
Tayler and Aston (1976a)	Dried grass wafers	37.1	84.9	-
	Dried grass cobs	38.7	85.9	-
	Dried grass pellets	38.2	86.1	-
Castle *et al* (1977a)	Nil	40.2	84.0	30.3
	Groundnut cake	38.0	85.4	30.8
Retter (1978)	Nil	41.6	85.0	32.4
	Soya bean meal	36.3	87.1	33.6

*N x 6.38

individuals within a breed and stage of lactation (Oldham and Sutton, 1979). Other factors include disease (Newbould, 1974; Anderson and Andrews, 1977), day to day variation (Syrstad, 1977) and age of cow (Rook, 1961). However, nutritional factors can also have an important effect on the composition of milk. For example, a diet either lacking the physical property of fibrousness or containing a high proportion of soluble carbohydrates can lead to reduced milk fat levels, and milling and pelleting can further accentuate this effect (Balch, 1972; Rook, 1973; Rook, 1976). An increase in the plane of energy nutrition generally increases the protein and SNF content of the milk but there is frequently a decrease in the fat content (Rook, 1973; Rook, 1976). The lactose content of milk is also sensitive to the level of dietary energy and protein, with maximum values occurring at the time of the peak yield and then declining throughout the rest of lactation (Rook, 1976). The effect of different supplements given with diets based on silage on the fat, SNF and the CP of the milk is summarized in Tables 1.8 and 1.9.

Diets of silage alone have produced milk with lower SNF and CP contents than diets of silage supplemented with either barley or dried grass (Castle and Watson, 1975), a mixture of barley and groundnut (Castle and Watson, 1976), groundnut cake (Castle et al, 1977a), and soyabean meal (Retter, 1978). In a comparison between supplements of barley and dried grass, Castle and Watson (1975) obtained a higher milk fat content with barley than with dried grass, but the SNF and the CP contents of the milk were higher on the dried grass treatments. Similarly, in another experiment, Castle and Watson (1976) reported the highest milk fat content on the barley treatment, whereas the SNF and CP were highest with a supplement of barley plus groundnut.

In contrast, Tayler and Aston (1973) reported a decline in the butterfat content of the milk when increasing proportions of barley were mixed with a supplement of dried grass in the diet of cows in early lactation. There was also a tendency for the fat and SNF content of the milk to increase as the level of dried grass in the concentrate mixture was increased. In another feeding experiment, Tayler and Aston (1976a) obtained a significantly lower milk fat content with a supplement containing mixtures of barley and groundnut cake compared to either dried grass or a mixture of dried grass and barley. However, the mixture of barley and groundnut cake at a high rate of feeding produced milk with a higher fat, SNF and CP content than at a low rate of feeding, or even compared with dried grass or a mixture of dried grass and barley. These researchers suggested that an inadequate intake of fibre in a diet of silage, and a low rate of concentrate feeding could probably account for the low milk fat content. In a further experiment, Tayler and Aston (1976a) reported no significant differences in the fat and SNF contents of milk when dried grass was offered to dairy cows in the form of wafers, cobs and pellets. There was no significant change in the milk composition when McIlmoyle et al (1975) included dried grass up to 50% of the concentrate mixture, although a supplement containing 25% dried grass gave milk with a slightly lower fat and higher SNF content. The level of dried grass feeding has an important effect on the chemical composition of milk (Gordon and Kormos, 1973). For example, a high level of dried grass intake produced milk with a higher SNF and CP content than a low level of intake (Gordon and Kormos, 1973). These workers reported that the fat content of the milk on the treatment with the lowest level of dried grass intake (Table 1.8) was significantly lower than that on the

Table 1.9 The effect of level of crude protein in the supplementary concentrate on fat, solids-not-fat (SNF) and crude protein content of milk

Reference	Level of crude protein supplement ($g\ kg^{-1}$)	Milk composition ($g\ kg^{-1}$)		
		Fat	SNF	CP*
Gordon (1979)	95	39.9	86.9	30.2
	137	38.6	88.0	31.1
	174	37.7	88.5	31.7
Gordon and McMurray (1979)	103	38.4	87.1	28.4
	136	37.5	88.0	29.3
	173	37.0	88.9	30.4
	211	37.8	90.0	31.5
Adamson *et al* (1979)	130	40.3	88.3	33.3
	180	39.3	87.7	32.4
Gordon (1980a)	172	37.9	87.5	33.4
	234	37.0	88.5	34.3

*N x 6.38

Table 1.10 The effects of the frequency of feeding of food to dairy cows

Reference	Number of feeds per 24 hours	Feed intake (kg/cow/day)	Milk yield (kg/cow/day)	Milk composition (g/kg^{-1})		
				Fat	Protein	Lactose
Mochrie et al (1956)	2 Alfalfa hay and concs	16.0	13.4	-	-	-
	4 Alfalfa hay and concs	16.2	13.4	-	-	-
	8 Alfalfa hay and concs	16.2	13.4	-	-	-
Campbell and Merilan (1961)	2 Alfalfa hay, beet pulp and concs	17.7	15.7	41.0	-	-
	4 Alfalfa hay, beet pulp and concs	19.2	17.1	44.0	-	-
	7 Alfalfa hay, beet pulp and concs	19.0	16.8	46.0	-	-
Burton and Dunton (1967)	4 Silage, hay and concs	-	10.5	40.3	31.9	46.3
	10 Silage, hay and concs	-	10.7	40.1	32.0	47.0
Kaufmann (1973)	2 Roughage and concs	16.7	23.4	36.9	-	-
	7 Roughage and concs	16.9	23.6	40.0	-	-
Thomas and Kelly (1976)	*2 Hay, sugarbeet pulp and concs	-	12.3	45.5	33.0	44.8
	*4 Hay, sugarbeet pulp and concs (24)	-	12.3	43.6	34.1	45.5
	†2 Hay, sugarbeet pulp and concs	-	9.2	46.7	34.6	42.0
	†4 Hay, sugarbeet pulp and concs (24)	-	9.0	47.0	38.3	42.9
Smith et al (1978)	1 Forage and concs	18.9	15.2	36.5	-	-
	2 Forage and concs	18.7	15.2	36.9	-	-
Frobish et al (1978)	Electronic feeding	25.9	16.9	36.2	-	-
	Feed in parlour	26.9	16.7	37.7	-	-
Linder et al (1979)	2 Forage and 2 concs	18.1	22.2	38.3	-	-
	2 Forage and 6 concs	18.4	22.9	39.2	-	-
	6 Forage and 6 concs	19.2	22.4	38.0	-	-

*Feeding to requirement
†Restricted feeding

treatment with the highest intake of dried grass.

An increase in the level of CP in the concentrate supplement generally increases the CP and SNF content of milk (Table 1.9). Gordon (1979) reported an increase in the SNF and CP concentration of the milk when the level of protein in the concentrate supplement was increased from 95 to 179 g kg^{-1}. Similarly, Gordon and McMurray (1979) obtained higher SNF and CP contents in the milk when the level of CP in the supplementary concentrate was increased from 103 to 211 g kg^{-1}. These workers concluded that the maximum milk protein could be achieved when the supplementary concentrate contained 239 g CP kg^{-1}. To summarize, it would seem that diets of silage only will produce milk with low contents of SNF and CP, and that most supplements will raise these values. Barley as a supplement will consistently increase the fat content of milk, whereas an increase in the protein content of the supplement will lower the fat content.

Effect of frequency of feeding on food intake, milk yield and composition

Many experiments have been conducted to investigate the effect of the frequency of feeding on feed intake, milk yield and the milk composition. The main results of these various studies (Mochrie *et al*, 1956; Campbell and Merilan, 1961; Burt and Dunton, 1967; Kaufmann, 1973; Thomas and Kelly, 1976; Smith *et al*, 1978; Frobish *et al*, 1978 and Linder *et al*, 1979) are reported in Table 1.10. Several workers noted an increase in the feed intake, milk yield and the milk fat content as a result of more frequent feeding. For example, Campbell and Merilan (1961) obtained a marked increase in the feed intake, milk yield and milk fat content when dairy cows were offered their daily feed in either four or seven separate meals per 24 hours (hrs) instead of twice daily. Similarly, Meinhold *et al* (1976) reported a substantial increase in the yield of FCM as a result of both feeding and milking cows four times rather than twice daily. In this study, it was not possible to separate the effects of feeding and milking, but it would appear that each factor had an effect in increasing milk output. More recently, Linder *et al* (1979) showed that the feeding of forage and concentrate six times daily had little effect on milk yield and the milk fat content, but increased the feed intake markedly when compared to twice daily feeding. In the study of Kaufmann (1973), an increase in feeding frequency increased the forage intake and milk fat content, but had little effect on milk yield. In some recent studies, Sutton *et al* (1978) and Johnson (1979) reported increases in milk fat content when concentrates were given in five instead of two feeds daily. Several studies reviewed by Kaufmann (1976) indicated that, with high yielding cows, a higher frequency of feeding can allow a higher intake of concentrates per 24 hrs without the same drop in rumen pH value as on less frequent feeding. The more frequent feeding tended to maintain the ratio of acetic to propionic acid near 3:1 and therefore prevented any fall in milk fat content. The higher pH also tended to favour cellulolytic activity and this could account for the higher roughage intake which was associated with the increased frequency of feeding. Rumen acidosis (Dirksen, 1970) can occur in ruminants which are given large amounts of food containing a high level of readily digestible carbohydrate. This results in an unfavourable proportion of crude fibre to readily digestible carobydrate in the diet and can cause either a loss of appetite or irregular appetite among animals. Increasing the frequency of feeding of the foods containing high levels of readily digestible carbohydrate can help to avoid rumen acidosis.

The findings of Tremere *et al* (1968) also suggested that cows on a high level of feeding, and which are liable to refuse feed, can benefit from more frequent feeding.

However, there are numerous other studies which have reported either little or no response in feed intake, milk yield and milk fat content due to an increase in the frequency of feeding. For example, Frobish *et al* (1978) obtained similar FCM yields and milk fat contents and a small decrease in feed intake by offering concentrates using electronic feeders which dispensed concentrates at any hour of the day and night, instead of the parlour feeding. In the study of Smith *et al* (1978), there was little difference in the feed intake, milk yield and the milk fat content as a result of feeding forage and concentrates either once or twice per 24 hrs. In the experiments of Mochrie *et al* (1956) and Thomas and Kelly (1976) no response in milk yield was obtained by increasing the frequency of feeding when the same weight of feed nutrients were given on the different frequency treatments. Burt and Dunton (1967) also found no benefit by increasing the frequency of feeding of forage and concentrates to dairy cows. These workers pointed out the difficulty of this type of experimentation when the cows on different feeding frequencies are in the same building and may influence each other's behaviour.

Effect of frequency of feeding on food utilization

Several workers have reported that increasing the frequency of feeding can increase the efficiency of feed utilization. The DM digestibility of the ration may be increased (Moir and Somers, 1957; Campbell and Merilan, 1961), but in other experiments it was not altered (Blaxter *et al*, 1956; Satter and Baumgardt, 1962;

Broster et al, 1979) due to the more frequent feeding. It has been reported that an increase in the frequency of feeding reduces the fluctuations in the ruminal ammonia concentrations because of absorption at peak levels (Moir and Somers, 1957; Gordon and Tribe, 1952; Rakes et al, 1961; Satter and Baumgardt, 1962) and also helps in the conversion of nitrogen to microbial protein by increasing the numbers of rumen protozoa (Moir and Somers, 1957; Putman et al, 1961). In numerous studies there have been efforts to relate the frequency of feeding to the rate of flow of digesta from the rumen. Sutherland et al (1963) found that continuous feeding reduced the volume of rumen contents, the quantity of DM in the rumen and increased the fractional hourly clearance of rumen contents. More recently, Kaufmann (1976) reported that an increase in the frequency of feeding could increase the rate of passage of the feed and thus give a higher intake of roughage. However, Blaxter et al (1956) and Rakes et al (1957) found no difference in the overall rate of passage on rations which were given at different feeding frequencies.

It is concluded that the experimental evidence on the subject of feeding frequency is far from clear cut, and at times almost contradictory. As stated earlier, the effect of animals on one treatment may affect the behaviour of animals on another treatment and this may complicate the results of an apparently simple comparison, and clearly far more work on this topic is required.

The feeding behaviour of ruminants

The feeding behaviour of ruminants can be one of the many factors that can affect the voluntary intake of feed, in particular, of forages. Intake is determined mainly by the rate of disappearance of the digesta from the reticulo-rumen (Campling, 1966; 1970; Deswysen, 1980; Osbourn, 1980) and a study of eating and ruminating behaviour could possibly help in explaining the results of many feeding experiments. Rumination plays a particularly important role in reducing the particle size of the reticulo-rumen contents to allow their passage from the rumen and thus make room for ingesting more forage (Pearce and Moir, 1964; Gordon, 1968; Okamoto, 1979). The prevention of rumination by muzzling can reduce the physical breakdown of forages and this in turn can depress intake (Osbourn, 1980). Several experiments have been conducted to study the factors that could influence the feeding behaviour of ruminants on diets including silage and other forages. Dulphy et al, 1975, Deswysen et al, 1978 and Deswysen, 1980 all reported that the main reason for the low voluntary intake of coarsely-chopped silage by sheep was the difficulty in the regurgitation of long silage particles present in the rumen. This rumination problem in sheep (Deswysen et al, 1978 and Deswysen, 1980) and heifers (Michalet, 1975) was further characterized by a longer latency time (i.e. the time from the end of the main meal and to the beginning of rumination) on the long compared to the short silage, and a greater percentage of abnormal boli (pseudo-rumination). In the experiments of Deswysen and Vanbelle (1976) with heifers, and of Retter (1978) with dairy cows, there were no reports of abnormal boli, although in the latter experiment the latency time was longer on the long silage compared with the short silage. More recently, Deswysen (1980) suggested that the physiological reason for pseudo-rumination could be the absence of sufficient small particles of silage in the reticulum for regurgitation, and thus a delay in rumination activity.

Chewing time (i.e. eating plus ruminating) for a specific ration has been used as an index to describe how the diet possesses the physical property of fibrousness (Balch, 1971). Numerous feeding-behaviour studies have recorded the chewing times when animals were offered different types of diets. In the experiment of Campling (1966), a comparison was made between silage and hay, when the two forages were offered ad libitum in a single meal for either 5 or 24 hrs. Chewing times were 92.9 and 117.7 minutes (mins) per kg DM intake for the hay and silage, respectively. The eating time and the voluntary intake of hay and silage were increased when access to the food was for 24 hrs rather than 5 hrs. The cows offered hay ate at a faster rate per minute than those offered silage, and the rumination time per kg DM eaten was also shorter. This researcher (Campling, 1966) suggested that the longer time of retention of the silage residues in the digestive tract, and the longer time spent chewing, may in part have been responsible for the lower intake of silage. In the behaviour study of Duckworth and Shirlaw (1958), cows spent 185 and 200 mins per day eating chopped and unchopped wet silage, respectively. The rate of eating the two silages was 8.9 mins per kg, and the ruminating times were 515 and 533 mins per day on the chopped and unchopped silages respectively. Ruminating time per kg of wet silage was similar on both silages. More recently, Castle et al (1979) recorded the feeding behaviour of dairy cows offered silages of long, medium and short chop lengths and also unchopped hay. Chewing times were 117, 106, 91 and 95 mins per kg DM intake on the long, medium and short silage and unchopped hay, respectively. The chewing times per bolus were substantially higher on the short compared with the long silage. In the experiment conducted by Thomas and Campling (1977), chewing time per kg of food intake was 6 - 19 times longer with sheep than with non-lactating dairy cows. Other workers (Welch and Smith, 1970), have suggested that as cattle have a larger reticulo-omasal orifice than sheep, they do not have to chew the feed so finely to allow it to pass through the orifice. Cattle also have a larger tooth area than sheep and therefore can chew more efficiently, i.e. the weight of DM chewed per unit of time. Numerous other studies have also shown that a reduction in the chop length of silage increased the voluntary intake of DM and decreased the chewing time per kg of silage DM (Dulphy and Demarquilly, 1973; Michalet, 1975; Deswysen and Vanbelle, 1976; Deswysen, 1980; Castle et al, 1979). The decrease in chewing time in these experiments was due mainly to a faster rate of eating the short silage, but, in addition, these workers (Michalet, 1975; Castle et al, 1979; Deswysen, 1980) reported that less time was spent ruminating per kg silage DM on short than on long silage.

The feeding behaviour of cattle offered silage ad libitum in stalls (Wilson and Flynn, 1974), troughs (Wilson and Flynn, 1975; 1976b) and under self-feeding systems (Wilson and Flynn, 1976a) has been recorded. The type of silage, i.e. single chop, precision chop and wilted (Wilson and Flynn, 1974), the method of feeding (Wilson and Flynn, 1975; 1976a) and the stage of maturity had only a small effect on the eating behaviour (Wilson and Flynn, 1976b), but barley supplementation reduced the eating and ruminating times by 54 mins and 48 mins per 24 hrs, respectively. Wilson and Flynn (1974) reported that beef cattle offered grass silage ad libitum spent on average 6.2, 7.9 and 9.9 hrs daily eating, ruminating and resting, respectively. These workers also suggested that beef cattle offered silage ad libitum would have ample time to reach their maximum voluntary intake in 12 hrs. In another experiment (Wilson and Flynn, 1976a), cattle given continuous access to silage spent 4.5, 6.8 and 12.7 hrs per day eating ruminating and resting, respectively.

Many researchers have reported the diurnal variation in the time spent eating, ruminating and resting when beef cattle have 24 hrs access to silage. Under a self-feeding system there was only a mild diurnal pattern with 50% of the total eating time during daylight (Wilson and Flynn, 1976a). In contrast, with trough-fed (Wilson and Flynn, 1975, 1976b) and grazing cattle (Donnell and Walton, 1969) about 70% of the eating was during the period 06.00 - 18.00 hrs. This difference in behaviour under self-feeding, grazing and trough feeding conditions (Ewbank, 1969) may be due to the inability of the entire group of self-feeding cattle to feed simultaneously. The poor performance of some cattle on _ad libitum_ silage during the winter in comparison to summer grazing may be partly due to the animals having a restricted nutrient intake because of a limited period of active eating in the winter daylight hours. The cattle may spend 50% of the daylight hours resting and hence not eating in the winter (Wilson and Flynn, 1975). However, more recently, Wilson and Flynn (1979) conducted a feeding-behaviour study with cattle offered silage in troughs with either 9 or 16 hrs of daylight per 24 hrs. The total time spent eating and the liveweight gain were not influenced by the two treatments as the animals on the 9 hr treatment compensated by eating more actively during daylight and by eating again about midnight (Wilson and Flynn, 1979).

In general, there is a lack of recent information of the behaviour of dairy cows, especially concerning the effect of frequency of feeding. Further experiments on this topic are required, and thus a behaviour study was made as a part of the experimental work in this thesis.

C H A P T E R 2

MATERIALS AND METHODS

Table 2.1 Details of the silage production

	Experiment number							
	3.1	3.2	3.3				3.4, 3.5 and 3.6	3.7
Variety of grass	S24	S24	S24	S23	S24	S24	S23	S23 + S24
Date cut	22-30 May 1978	30 Aug 1978	3 June 1980	21 May 1980	7 June 1980	15 May 1980	12-18 June 1979	6 Sept 1979
Harvest number in season	1	3	1	1	1	1	1	2
Yield (kg/DM/ha)	4100	2700	6300	3400	6500	5300	5400	4000
Fertilizer (kg/ha) in season N	315	243	315	315	315	315	315	243
P_2O_5	-	40	-	-	-	-	-	40
K_2O	-	152	-	-	-	-	-	152
Time of wilt (hrs)	24-48	48	48	48	48	48	48	48
Approx chop length (mm)	12	12	12	12	12	12	12	12
Rate of additive (ℓ/tonne)	2.3	2.1	2.0	2.0	2.3	2.2	1.9	3.5
Silo capacity (t)	350	40	40	40	350	40	350	40
DM as ensiled (%)	23.4	22.8	19.0	19.2	22.3	27.7	20.0	24.7
Weather:								
Rain (mm/day)	none	3	4	none	3	none	1	3
Sun (hrs/day)	5	3	2	9	4	12	4	4

PRODUCTION OF SILAGE AND HAY

The silage used in all the experiments was made from herbage from leys of either S23 or S24 perennial rye grass (Lolium perenne) without any clover. The crops were cut with a disc mower, wilted for 24 to 48 hrs, harvested with a precision-chop forage harvester (Claas Jaguar 60E) and chopped to a median length of approximately 12 mm. An additive containing 85% formic acid ("Add-F", B.P. Nutrition Limited) was applied as the crop was chopped. The grass was transported from the field using tractors and trailers and was then ensiled in concrete clamp silos with a roof. After consolidating the material with tractors, it was then immediately covered with either two or three black polythene sheets which were weighted down using old rubber tyres. Some details of each silage are given in Table 2.1. When the feeding experiments were in progress, the silage was taken from the various silos either two or three times per week with a tractor foreloader and placed on a concrete floor in a weighing area adjacent to the cow shed. The silages were then weighed accurately into individual plastic boxes on a tared Avery scale (Birmingham, England).

The herbage for the hay in Expt 3.1 was cut with a disc mower from a ley of S24 perennial ryegrass. After tedding, the hay was baled at a DM content of 77% and was put on an indoor tray drier (ICI Ltd, Mk II) where further drying was done with both hot and cold air.

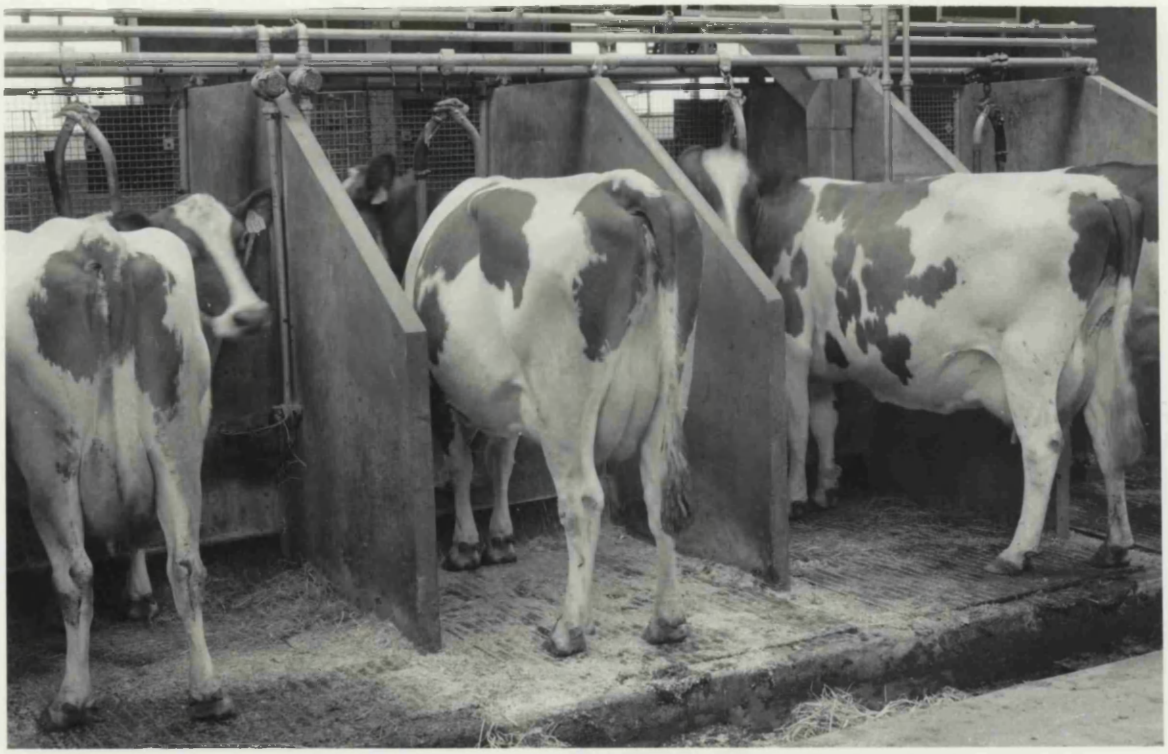
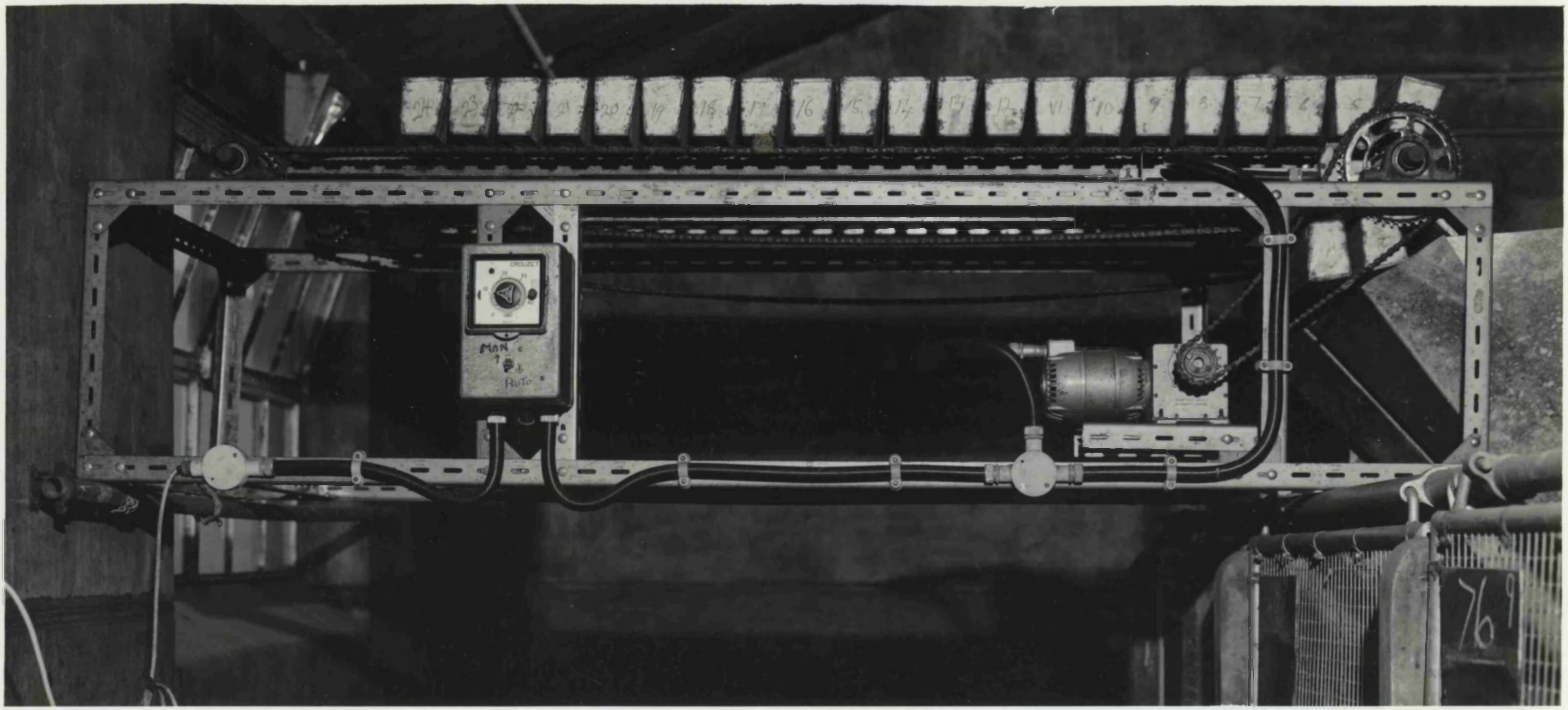


Fig. 2.1 Cows on feeding experiments fastened in the individual stalls fitted with water bowls

Fig. 2.2 An automatic concentrate feeder with 24 individual troughs, synchronous timer and drive motor



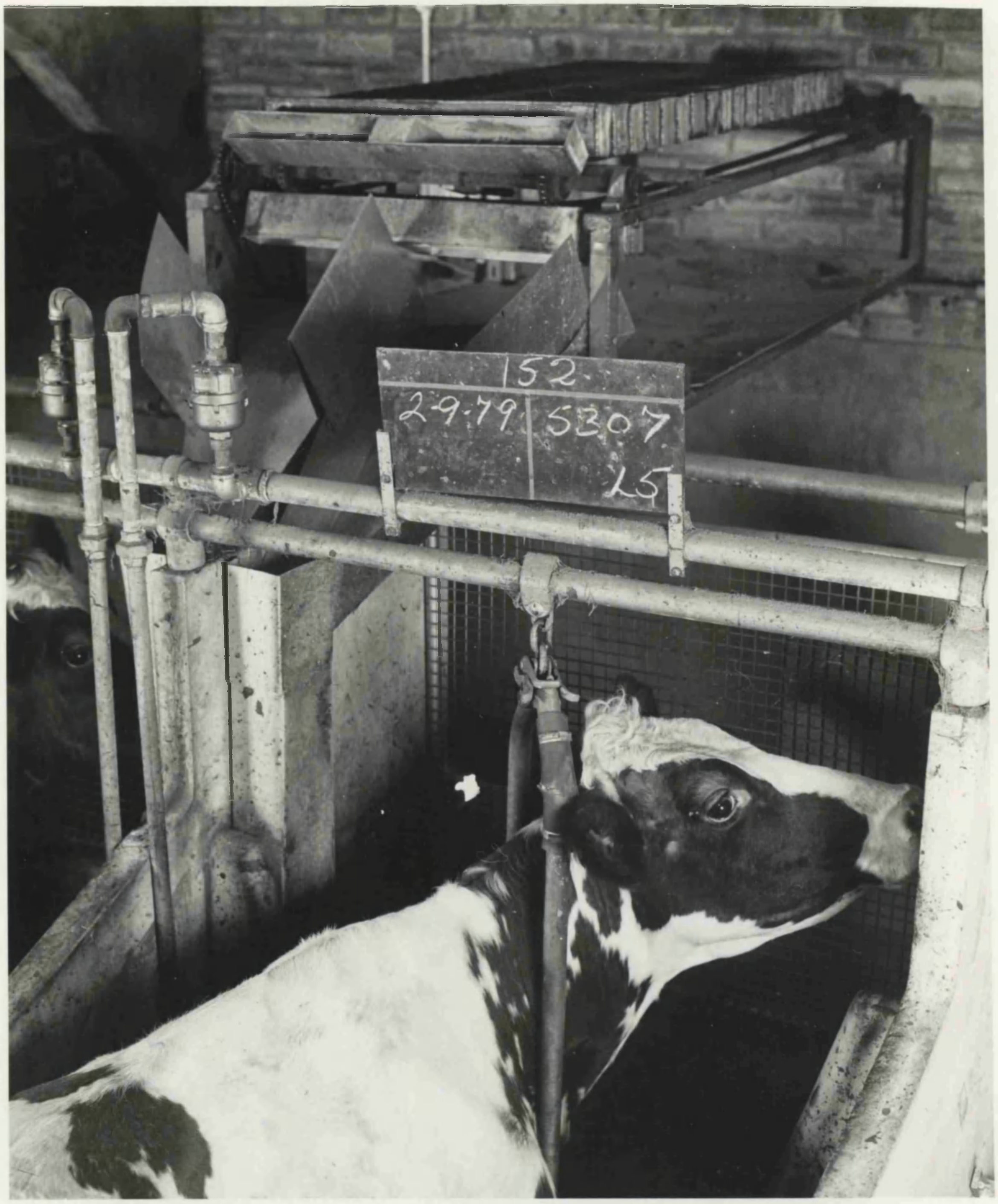


Fig. 2.3 An automatic feeder giving concentrates to two cows at the same time. Note the water meter.

ANIMAL HOUSING AND FEEDING

All the experiments were conducted with Ayrshire cows fastened by yokes in individual stalls in experimental byres (Fig. 2.1) to allow the accurate measurement of feed intake. The cows were kept in their stalls for the entire 24 hr period except for milking at 06.00 and 15.00 hrs in a 8:16 herringbone parlour (Gascoigne, Reading, England), and the yields were recorded at each milking. The cows were weighed two days each week before the afternoon milking on an electronic weighbridge (Avery, Birmingham, England). Records of water intake were taken from individual water meters (Kent Meters Ltd, Luton, England) fitted to the drinking bowls in each stall (Fig. 2.1).

In all the experiments the cows were offered silage *ad libitum*, and it was made sure that at least 10% of the original weight of silage was available for weighing as a refusal before the next silage feed. The feeds of silage were weighed for seven days per week but the refusals were collected and weighed only for five days. The number of the silage feeds per 24 hrs and the exact times of feeding are described later in the individual experiments.

The amount of concentrates offered per cow and the exact times of feeding are also described later. However, when two, three and four feeds of concentrates were offered per 24 hrs, these were given manually from buckets, whereas when 22 feeds were offered, an automatic feeder designed by Clapperton *et al* (1974) was used (Fig. 2.2). Each automatic feeder was fitted with a synchronous timer, and the two rows of 24 troughs supplied two adjacent cows at the same time (Fig. 2.3). The clock on the feeder was set to deliver the concentrate feeds to each trough every hour but avoiding 06.00 and 15.00 hrs, i.e. the times of milking.

In experiments 3.2, 3.3 and 3.7 a mineral/vitamin mixture (Pegasus RR, Upjohn Limited, Crawley, England) was used to supplement the silage diets. The composition of the mixture was: calcium 9.5%, phosphorus 14.7%, sodium 5.2%, chlorine 8.0%, magnesium 2.5%, iron 1.0%, magnese 0.40%, zinc 0.10%, copper 600 mg/kg, cobalt 130 mg/kg, iodine 420 mg/kg, vitamin D_3 110,000 iu per kg. Each cow received 150 g per day, and it was spread on the silage. In other experiments (3.1 and 3.4), the minerals were included in the concentrate cubes and are reported in the experiments.

SAMPLING

Feeds

In all the experiments, a sample of each silage was taken on five days per week, and, after thorough mixing, duplicate 200 g samples were used for the determination of the DM content. The dried samples were ground through a 1 mm sieve using a Christy and Norris laboratory mill (Christy & Norris Ltd, Chelmsford, England) and sub-sampled to form a weekly bulk sample. The hays and the concentrate feeds were sampled and processed in a similar way on two days per week. At the end of each experiment the weekly batches of dried ground samples were bulked into a single sample for each four-week period and analysed for total nitrogen, crude protein, true protein, crude fibre, ether extract and ash. On one day every week a wet sample of silage was minced for a pH determination. The same minced sample of silage was used also for the determination of a DM content by a toluene distillation method. From this value, and the one obtained from the silage dried in the oven, a "volatile" correction value was obtained. This correction value was added to the daily DM values determined from the oven-dried samples of silage. A non-minced sample of silage was bulked daily in polythene bags for the determination of the *in vitro* digestibility.

Milk

Milk samples were collected on two consecutive milkings in the third and fourth week of each experimental period. The samples of milk were delivered from the collection jars into small bottles, each containing 210 mg of potassium dichromate as a preservative and stored in a cold room at 5°C. During the bulking process the milk samples were warmed to 40^{o}C in a water bath and the bottles were inverted at regular intervals to disperse the fat globules. A bulked sample from each cow was prepared according to the milk yield at each milking and analysed for fat, lactose, crude protein, total solids and ash.

CHEMICAL ANALYSIS

Feeds

Dry matter. The DM determination of the silage, hay and concentrates was done in a forced-draught oven ("Unitherm", Russell and Lindsey Engineering Limited, Birmingham, England) by drying for 22 hrs at 100°C.

The DM content of the silage was also determined every fourth week in each period by the toluene distillation method (Dewar and McDonald, 1961). This method is fully described in Appendix 1.

Total nitrogen. Total nitrogen determinations of the feeds were made on dried ground samples using the macro-Kjeldahl technique (Fertilizer and Feedingstuff regulations, 1960). The results were expressed as crude protein (total N x 6.25). This technique, and the analytical methods for all the following fractions are also fully described in Appendix 1.

True protein and NPN. The estimation of the true protein was made using the tannic acid method of Van Roth (1939). The non-protein-nitrogen (NPN) content was determined by subtracting the true protein content from the crude protein content.

Ether extract. The ether extract was determined by Soxhlet extraction with ethyl ether (Whitehouse, et al, 1945).

Crude fibre. Crude fibre was determined by refluxing the defatted sample after determination of ether extract with acids (Whitehouse *et al*, 1945).

Ash. Ash was determined by igniting 2.5 g dried ground sample at 550°C for 16 hrs (Fertilizer and Feedingstuff regulations, 1960). The results were expressed as a percentage of the dry weight.

pH. The pH values of the silages were determined with a Beckmanglass rode pH meter (Beckman, USA) on an extract obtained by soaking 20 g of minced silage in 100 ml of distilled water. The pH meter was calibrated using a standard buffer solution of pH 4.0.

In vitro digestibility. The *in vitro* digestibility of the silages, hays and the concentrate feeds was determined according to the method of Alexander and McGowan (1966, 1969).

Milk

Total solids. The total solids content was determined by drying 2.5 g of milk on a briskly boiling water bath for 30 mins and then heating at 100°C in a fan-ventillated oven for 3 hrs to complete dryness (British Standard (BS): 1963). The results were calculated as follows:-

$$\text{Total solids} = \frac{\text{Wt of solids}}{\text{Wt of milk}} \times 100$$

Fat. Milk fat was determined according to BS 696 (1969). This is a "Gerber" method which separates fat from milk using sulphuric acid, amyl alcohol and a centrifuging system.

Milk protein. The determination of the milk protein was made using the same method as described for the feeds. The total nitrogen obtained in milk was multiplied by 6.38 to obtain the crude protein content.

Lactose. The lactose in the milk was determined using a polarimetric lactose method (Grimbleby, 1956).

Solids-not-fat. The solids-not-fat (SNF) content of the milk was calculated by subtracting the fat from the total solids.

The methods used for the determination of fat and lactose are fully described in Appendix 1.

CALCULATION OF ME, DCP AND DEGRADABILITY OF FOODS

The ME content of the grass silages was determined by the equation of Alexander and McGowan (personal communication) —

Silage ME (MJ/kg DM) = 0.249 x *in vitro* DOMD% - 0.00716 x DM g/kg - 4.211

where DOMD is the digestible organic matter in the DM.

The ME content of the hays in Expt 3.1 was calculated from the *in vitro* DOMD values and the following equation (Alexander and McGowan, personal communication) —

Hay ME (MJ/kg DM) = 0.235 x *in vitro* DOMD% - 4.45

The ME content of the concentrates used in Expt 3.1 was obtained from equation 2 in Bulletin 33 (MAFF, 1975) —

ME (MJ/kg DM) = 0.0152 DCP + 0.0342 DEE + 0.0128 DCF + 0.0159 DNFE

where DCP is the digestible crude protein

DEE is the digestible ether extract

DCF is the digestible crude fibre

DNFE is the digestible nitrogen free extract

The ME of the concentrates used in Expts 3.3 and 3.4 was calculated from equation 58 in Bulletin 33 (MAFF, 1975) —

ME (MJ/kg DM) = 0.16 x *in vitro* DOMD%

where DOMD is the digestible organic matter in the DM.

The ME content of the barley, sugarbeet pulp and the soyabean meal was obtained from the tables in Bulletin 33 (MAFF, 1975).

The DCP content of the silage and hays in Expt 3.1 was determined by the equation of Watson and Nash (1960) —

Silage and Hay DCP (g/kg DM) = 0.9115 x CP g/kg DM - 36.7

In Expts 3.4 and 3.7 the DCP content of silage was calculated using the equation of Watson (1939) —

Silage DCP (g/kg DM) = 0.8179 x CP g/kg DM - 24.154

The DCP content of the concentrate feeds was obtained using Bulletin 33 (MAFF, 1975).

The degradability coefficients of silages in Expts 3.2 and 3.3 were calculated from the equation of Wilson and Strachan (1981). The degradability coefficients of the concentrate feeds in Expts 3.2 and 3.3 were obtained from ARC bulletin (1980).

CALCULATION OF ME, DCP, TP, TMP, RDP AND UDP REQUIREMENTS

The ME required for maintenance, per kg of liveweight change and to produce 1 kg of milk of varying composition was calculated from Bulletin 33 (MAFF, 1975).

The energy allowances to allow for liveweight change were calculated from the following values:-

1 kg liveweight loss = 28 MJ of dietary ME

1 kg liveweight gain = 34 MJ of dietary ME

The DCP requirements for maintenance and to produce 1 kg of milk were calculated from Advisory Paper No. 11 (ADAS, 1971).

The TP required for maintenance, liveweight change and milk production in Expts 3.2 and 3.3 were obtained from ARC Bulletin (1980) —

1 kg liveweight gain = 150 g protein

1 kg liveweight loss = 112 g protein

Milk protein production = milk yield (kg/day) x protein concentration ($g\ kg^{-1}$ milk)

TMP, RDP and UDP in Expts 3.2 and 3.3 were obtained also from the equations in ARC Bulletin (1980) —

TMP (g/day) = 3.3 x ME intake (MJ/day)

where TMP = TP supplied from microbial protein synthesis alone

RDP (g/day) = 7.8 x ME intake (MJ/day)

UDP (g/day) = (1.91 x TP) - (6.25 x ME intake (MJ/day))

CALCULATION OF WATER INTAKE

The water intake (kg/kg DM intake) was calculated according to the ARC (1980) method —

$$\text{Water intake kg/kg DM consumed} = \frac{\text{Water in feed + water drunk - water in milk}}{\text{Feed DM intake}}$$

THE EFFICIENCY OF UTILIZATION OF ME FOR LACTATION

The efficiency of utilization of ME for lactation was calculated according to the method of Thomas and Castle (1978) —

$$k_{\ell o} = \frac{\text{Energy secreted in milk (MJ/day)}}{\text{ME used for lactation (MJ/day)}} \times 100$$

The energy secreted in the milk was calculated from the milk yield and the energy value (EV) of milk (MAFF *et al*, 1975). The EV of milk was obtained from the following equation:-

$$EV = 0.0386\ BF + 0.0205\ SNF - 0.236$$

where BF = butterfat content (g/kg)

SNF = solids-not-fat content (g/kg)

ME used for lactation (ME_{ℓ}) was calculated from —

ME = ME intake - ME maintenance - ME for body weight gain or loss

ME for maintenance was obtained from equation 20 (MAFF *et al*, 1975).

ME for weight gain or loss was assumed to be —

34 MJ/kg body weight gain and

- 28 MJ/kg body weight loss (MAFF *et al*, 1975).

Fig. 2.4 A cow in a stall and fitted with a halter and a jaw-movement sensor and rubber tubing

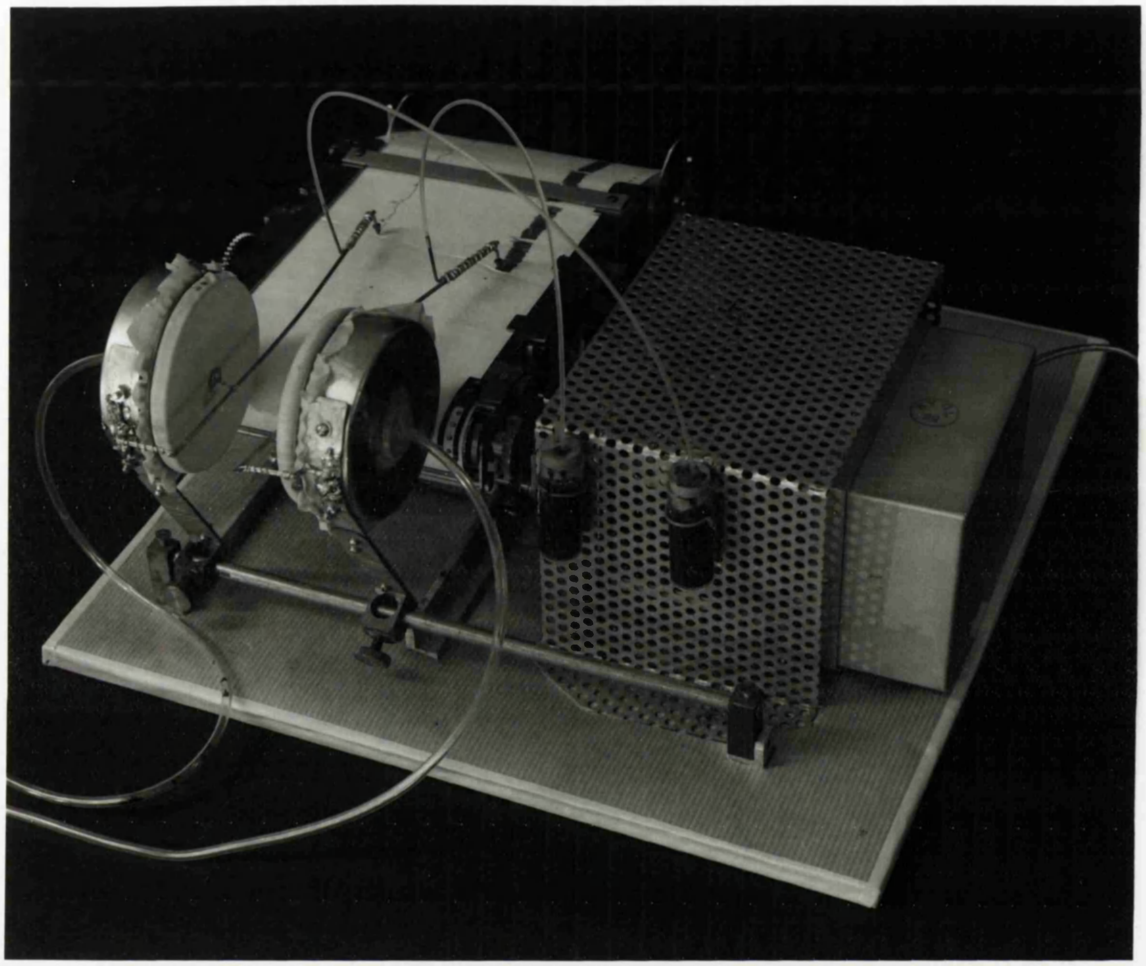


Fig. 2.5 The apparatus for recording feeding behaviour with an enclosed electric motor, two tambours, pens and moving chart

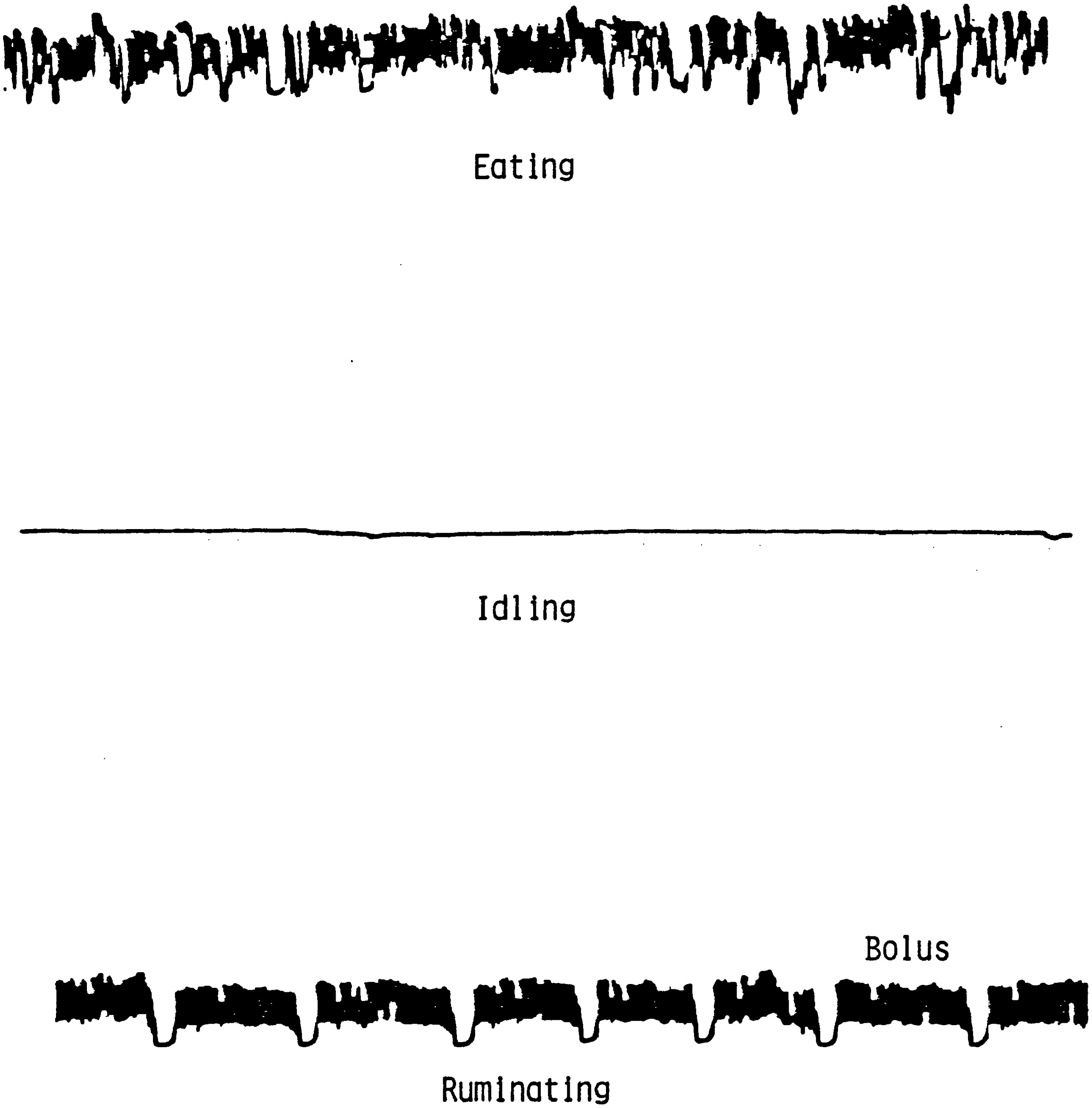


Fig. 2.6 Typical recordings on the chart of jaw movements of the cows indicating the eating, idling and the ruminating patterns

BEHAVIOUR RECORDING

The study of feeding behaviour (Expt 3.6) was conducted using non-lactating cows retained by yokes in individual stalls. The recording apparatus was the same as that used by Retter (1978). and also described by Castle et al (1979).

In this experiment, a head halter fitted with a jaw-movement sensor was fastened on each cow at the start of the third week of each period (Fig. 2.4) and a 48 hrs recording of jaw movements was taken. The jaw movement sensor consisted of a rubber pneumograph tube, blocked at one end, which was placed under the lower jaw. Inserted at the other end of this sensor was a hard but flexible plastic tube (inside diameter 2 mm) which was connected to a small plastic tube on a tambour mounted on the recorder. The plastic tube was given a U-shaped loop to allow for the free movement of the cow and was also placed inside a rubber pressure tube to protect it from damage. During the recording period care was taken to ensure that the connections between the jaw movement sensor, the plastic tubing and the tambour were airtight. The fulcrum of the recording arm was attached to the centre of the tambour and an inked nib at the end of the recording arm made a tracing on a paper chart moved by an electric motor (Fig. 2.5). The jaw movements of the cows resulted in different types of tracings on a moving chart paper. Examples of each type of tracing are shown in Fig. 2.6. The tracings from the recording sheets were then identified and measured.

Two tambours were mounted on the two recording machines and thus four cows were recorded at the same time.

TEST FOR KETOSIS

In the first month of Expt 3.3 a test for signs of ketosis in the milk was performed regularly on all animals using the method described by Dumm and Shipley (1946). A sample of milk was drawn daily from each cow into small vials containing 5 g of Rotheras' powder (20 g sodium nitroprusside + 400 g ammonium sulphate + 400 g anhydrous sodium carbonate). The vials were left undisturbed and after 5 minutes any changes in the colour of the powder were recorded. A change in colour from whitish-yellow to dark purple indicated a positive sign of ketosis.

STATISTICAL ANALYSIS

In Expts 3.1, 3.3 and 3.4 the design of the experiments was a six treatment cyclic-changeover, with four periods and twelve cows in two blocks (Design No. 6, Davis & Hall, 1969). The statistical analysis of the results was done on EMAS (Edinburgh Multi-Access System) via a remote terminal using the EDEX program (Hunter et al, 1973). The results from the three-treatment extra-period changeover design in Expt 3.2 and 4 x 4 balanced Latin Square in Expt 3.7 were analysed on the LSI 11/02 computer using programs written by Reid (Private communication). In Expt 3.5, the results of the crossover or reversal design were analysed on a desk calculator (Hitachi KK 562A) by the method developed by Brandt (1938). The statistical analysis of the results obtained in the balanced changeover design in Expt 3.6 was analysed on a Wang 720 programmable calculator using a program written by Reid (Private communication). An example of the analysis of variance for each type of design is given in Appendix 2.

C H A P T E R 3

EFFECTS OF SUPPLEMENTARY FOODS ON FEED INTAKE, MILK YIELD AND MILK COMPOSITION

EXPERIMENT 3.1

Introduction

In a series of feeding experiments with dairy cows at this Institute, supplements of barley and dried grass (Castle and Watson, 1975), high-protein concentrates (Castle and Watson, 1976; 1977a, b; 1979) and hay (Retter, 1978), have been offered with grass silages *ad libitum*. The dried grass and high-protein concentrates were particularly useful in allowing a high voluntary intake of silage whereas long hay as a supplement to silage was of little value, regardless of its D-value (Retter, 1978), and clearly reduced the intake of silage. The difference between the supplements of hay and dried grass could be due to the physical form of crop as the hay was long and the dried grass was ground. The present experiment was planned therefore to investigate the effect of different physical forms of forage supplements. A high-digestibility silage was supplemented with long, short and ground and cubed hay with either a low or a high rate of concentrate feeding. The effect of the treatments on DM intake, milk yield, milk composition and liveweight was recorded.

Experimental feeding and design

There were six feeding treatments as follows:-

Hay form	Concentrates (kg per 10 kg milk)
Long	2
Short	2
Ground	2
Long	4
Short	4
Ground	4

The basal ration was grass silage offered ad libitum to all cows, plus hay in the long, chopped and ground form with either a low (2 kg/10 kg milk) or a high (4 kg/10 kg milk) rate of concentrate feeding. The silage was offered at 09.30 and 16.00 hrs in sufficient quantities to ensure that at least a 10% refusal was available for weighing before the next silage feed. All the cows had access to silage for about 15 h per 24 h. The hay, 3 kg/cow/day, was given in equal amounts at 07.00 and 12.00 hrs daily, and the concentrates were given in equal parts at 06.00 and 15.00 hrs, approximately.

The hay in the long treatment was given in its normal form straight from the bale, whereas the short hay was chopped by the same precision-chop forage harvester as used for the silage, and at the same chop-length setting. The hay for the ground treatment was ground in a hammer mill, mixed with 4% molasses and cubed into cylindrical pellets of 10 mm diameter. The concentrate was cubed also, and contained as parts by weight, barley 15.0, maize 30.0, fat premix 12.5, soyabean meal 10.0, groundnut meal 10.0, maize gluten 10.0, wheat feed 10.0,

Table 3.1 Experiment 3.1 The composition of the silage, hay and the concentrate

	DM ($g\ kg^{-1}$)	Crude protein	True protein	Crude fibre	Ether extract	Ash	D-value
			(g/kg DM)				
Silage	262*	176	69	278	61	71	69.8
Long hay	833	145	113	291	20	70	59.7
Short hay	823	149	121	300	22	73	59.4
Ground and cubed hay	916	140	108	263	24	79	61.9
Concentrate	867	203	174	79	43	83	ND

*Determined by the toluene distillation method (Dewar and McDonald, 1961)

ND = not determined

dried distillers maize grains 4.5, maize germ meal 2.5, molasses 5.0 and a vitamin-mineral supplement 3.2. The weight of concentrate cubes offered to the cows on the low and high concentrate treatments was based on rates of 2 and 4 kg per 10 kg milk respectively, using the milk yields in the previous period and the equalized principle of Lucas (1943). The amount given daily was kept constant throughout each period.

Twelve Ayrshire cows, which had calved on average 6 weeks (range 4 - 8 weeks) before the start of the experiment, were divided into two groups of six similar animals. Within each group, the cows were allotted at random to the treatment sequences in a cyclic change-over design with four periods (Davis and Hall, 1969). The experiment lasted from 23 October 1978 to 14 February 1979 with periods of 4 weeks each but the results from weeks 3 and 4 in each period were used.

The water intake of each cow was measured daily in weeks 3 and 4 of each period, and cows were weighed every Wednesday and Thursday.

Results

Composition of the feeds

The D-value of the silage (Table 3.1), determined by the *in vitro* technique of Alexander and McGowan (1969), was 69.8. The mean pH of the silage was 3.78 ± 0.13, with concentrations of NPN and ammonia-N in the total N of 608 and 106 g kg^{-1}, respectively. The long and short hays were similar in analysis, whereas the ground and cubed hay had a higher concentration of DM and a higher D-value, but lower crude protein and crude fibre concentrations.

Samples of the silage and chopped hay were sorted into chop

Table 3.2 Experiment 3.1 The daily feed and water intakes on the six feeding treatments

Treatment		DM (kg/cow)					Daily forage DM intake as % of liveweight	Daily total DM intake as % of liveweight	Drinking water (kg/cow)	kg water per kg DM consumed*
Hay form	Concentrates (kg/10 kg milk)	Silage	Hay	Forage	Concen-trates	Total				
Long	2	7.94	1.83	9.77	3.48	13.25	2.04	2.77	39.3	3.42
Short	2	8.56	1.33	9.89	3.30	13.19	2.07	2.79	37.8	3.52
Ground	2	8.23	2.51	10.74	3.50	14.24	2.23	2.97	43.8	3.54
Long	4	6.36	1.74	8.10	6.80	14.90	1.68	3.07	49.1	3.47
Short	4	6.93	1.12	8.05	6.84	14.89	1.68	3.04	49.1	3.58
Ground	4	7.63	1.62	9.25	6.73	15.98	1.86	3.25	51.6	3.59
s.e. difference between two means		0.30	0.21	0.33	0.26	0.34	0.04	0.06	1.78	0.16

*Allowance made for the water content of the milk (ARC, 1980)

length groups on an automatic machine at the National Institute of Agricultural Engineering (G. E. Gale, personal communication) and gave median chop lengths of 12.4 and 12.1 mm, respectively. The concentrate contained 203 g CP per kg DM (Table 3.1), i.e. 176 g/kg^{-1} as offered to the cows. Particle size distribution in the ground and cubed hay was determined by a dry-sieving technique (Tetlow and Wilkins, 1978) and the modulus of fineness was 0.80, and modulus of uniformity was 0:5:5.

Feed and nutrient intake

The mean weights of DM consumed daily on each treatment are given in Table 3.2. The intake of short hay was significantly ($P<0.05$) lower than that of long hay at both rates of concentrate intake, and the highest intake of hay was in the ground form at the low rate of concentrate feeding. Within the low rate of concentrate feeding, the form of hay had no significant ($P>0.05$) effect on silage intake, but within the high rate of concentrate feeding, the intake of silage DM was significantly higher ($P<0.01$) when ground rather than long hay was given. As expected, the silage DM intake and total forage DM intake expressed as either kg per cow or as a percentage of liveweight were significantly ($P<0.001$) lower on the high compared with the low rate of concentrate feeding. Within both the low and high rate of concentrate feeding, the intake of forage expressed as either kg per cow or as a percentage of liveweight was significantly ($P<0.05$) higher on the ground hay treatments than on the other two treatments. The total intakes of DM expressed as either kg per cow or as a percentage of liveweight were significantly ($P<0.001$) higher on the high compared with the low rate of concentrate feeding. Within the two concentrate

Table 3.3 Experiment 3.1 The daily intake of metabolizable energy and digestible crude protein

Treatment		ME intake		DCP intake	
Hay form	Concentrates (kg/10 kg milk)	MJ per cow	% of requirement	g per cow	% of requirement
Long	2	153	105	1780	146
Short	2	153	99	1780	143
Ground	2	164	102	1870	140
Long	4	177	105	2160	163
Short	4	178	113	2190	166
Ground	4	190	113	2290	165
s.e. difference between two means		4.0	4.6	48	4.5

feeding treatments, the intake of total DM was highest on the two ground hay treatments, with only small and non-significant (P>0.05) differences between the long and short hay treatments. As expected, the intake of drinking water per cow was significantly (P<0.001) higher on the high compared with the low concentrate treatments. The intakes of drinking water expressed as kg per cow, and total water intake as kg per unit of DM consumed were higher on the ground hay treatments (Table 3.2) than on the other treatments, but there were no significant (P>0.05) differences between the long and short hay treatments.

The daily intakes of ME (Table 3.3) were calculated from the DM intakes in Table 3.2 and values of 11.4, 12.9, 9.60, 9.50 and 10.1 MJ/kg DM for silage, concentrate, long, short and ground hays, respectively. Total ME intakes were significantly higher (P<0.001) on the high compared with the low rate of concentrate feeding, but the differences in ME intake expressed as a percentage of requirement were not significant. Within the two rates of concentrate feeding, the intake of ME was significantly (P<0.05) higher on the ground compared with the long and short hay treatments.

The intakes of DCP were calculated from values of 124, 178, 95, 99 and 91 g DCP/kg DM for the silage, concentrate, long, short and ground hays, respectively. Total DCP intake (Table 3.3) and the intake expressed as a percentage of requirement was significantly (P<0.001) higher on the high compared with the low rate of concentrate feeding. The hay treatments within either of the concentrate levels had no significant effect on total DCP intake and on intake expressed as a percentage of requirement.

Table 3.4 Experiment 3.1 The mean daily milk yield, composition of the milk and liveweight of the cows

Treatment		Milk yield (kg/cow)		Milk composition (g kg^{-1})					Mean liveweight	
Hay form	Concentrates (kg/10 kg milk)	Un-corrected	Corrected to 4% fat	Fat	SNF	Total solids	Crude* protein	Lactose	(kg)	Daily change (kg/cow)
Long	2	17.6	16.4	38.2	89.7	127.9	32.8	49.5	476	+ 0.12
Short	2	18.0	17.2	38.8	88.8	127.6	32.2	49.1	471	+ 0.27
Ground	2	19.4	18.6	39.1	88.9	128.0	32.4	49.2	479	+ 0.32
Long	4	19.4	18.1	38.6	90.6	129.2	34.0	49.0	483	+ 0.51
Short	4	19.1	17.6	38.0	90.4	128.4	33.8	49.4	487	+ 0.18
Ground	4	19.7	19.3	39.8	90.7	130.5	34.2	48.9	488	+ 0.38
s.e. difference between two means		0.59	0.78	1.3	0.4	1.3	0.4	0.5	4.0	0.17

*N x 6.38

Milk yield, composition and liveweight

The mean daily milk yields per cow on each treatment are given in Table 3.4. On average, the uncorrected yields were significantly higher ($P<0.05$) on the high compared with the low concentrate feeding treatments, but when the yields were corrected to a standard 4% fat content they were not significantly different. On the high rate of concentrate feeding, the yields of milk on the three hay treatments were not significantly ($P>0.05$) different, whereas on the low rate of concentrate feeding the milk yield on the ground hay was significantly ($P<0.05$) higher than on the long hay treatment with the yield on the short hay in an intermediate position.

There were no significant differences in the fat and lactose concentrations of the milk on the six treatments, but the CP and SNF values were significantly ($P<0.01$) higher on the high than on the low rate of concentrate feeding treatments. The form of the hay within the two concentrate treatments had no significant effects on the CP and SNF concentrations of the milk which were all at a satisfactory level.

The mean liveweight of the cows was signficantly ($P<0.01$) higher on the high compared with the low rate of concentrate feeding, but there were no significant differences due to the hay treatments. On all the six treatments, the cows increased in liveweight by 0.30 kg per cow/day but the differences between treatments were not significant.

Discussion

In a series of recent feeding experiments Retter (1978) investigated the use of hay as a supplement to grass silages offered *ad libitum* to dairy cows. In these studies, the supplementary hay

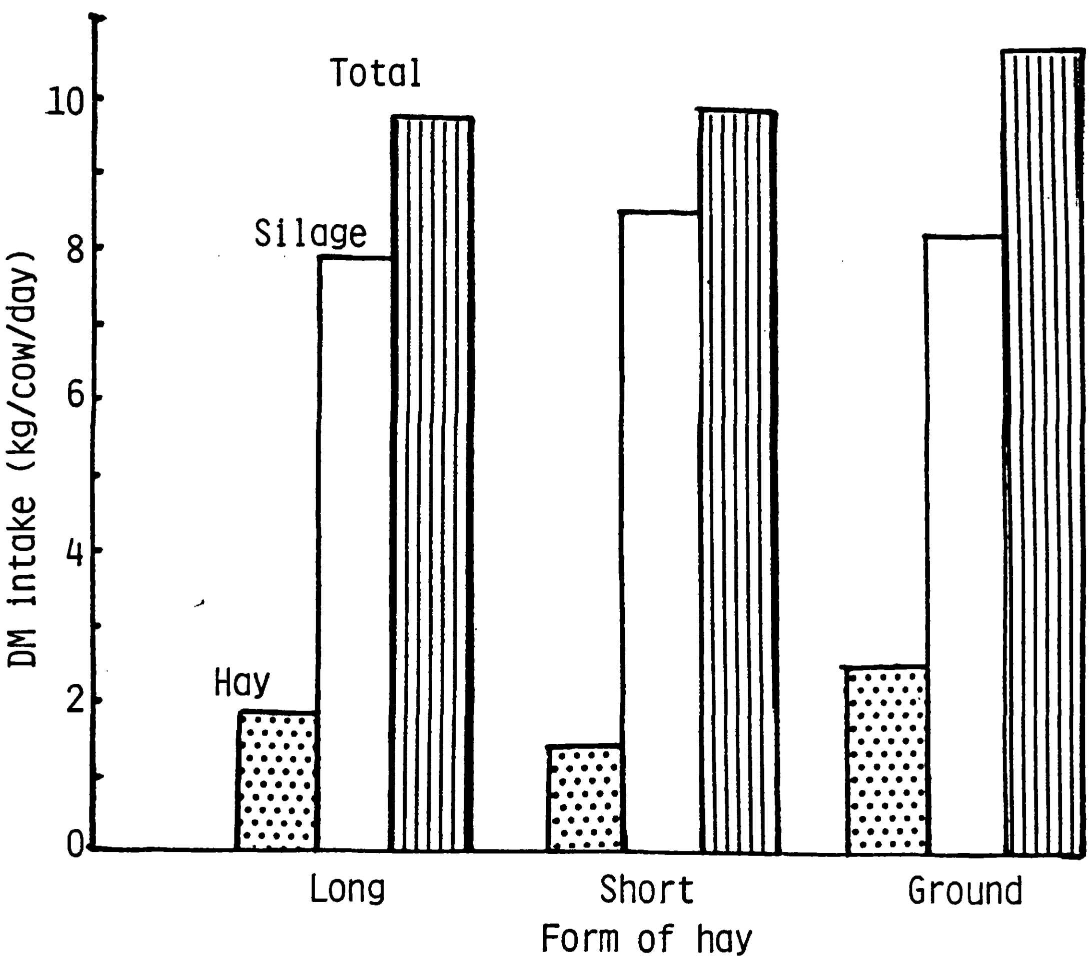


Fig. 3.1 Forage intake with low rate of concentrate feeding

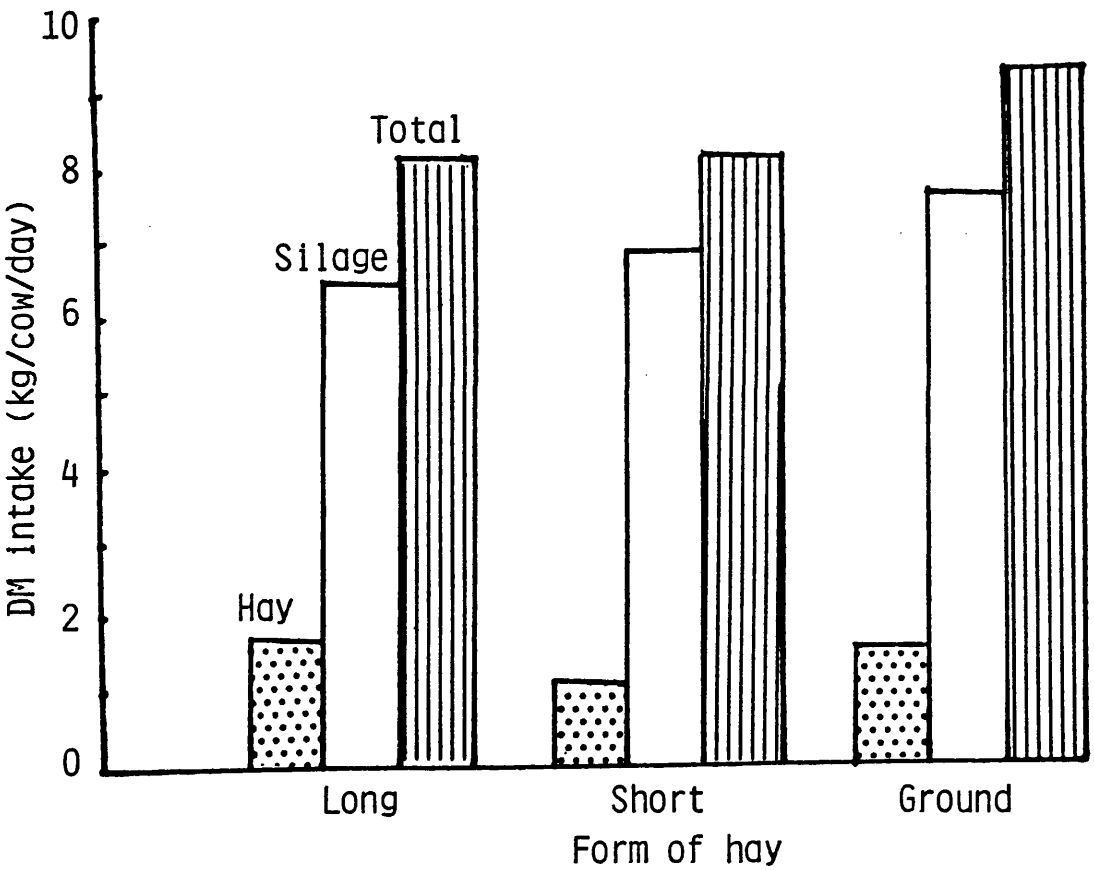


Fig. 3.2 Forage intake with high rate of concentrate feeding

which was in the long form was not especially useful in increasing either the total intake of forage DM or the milk yield, and therefore this treatment of long hay was used as a control treatment in the present experiment. The treatment of hay in the short form was included because of an increase in the intake of silage obtained when feeding short rather than long-chopped silages (Castle et al, 1979). In particular, a treatment of hay in the ground and cubed form was included because of the excellent results obtained with dried grass cubes (Castle and Watson, 1975) and dried grass pellets (Tayler and Aston, 1976a) as a silage supplement. The feeding of concentrates on all treatments was considered to be important as the cows were in the early to middle stage of lactation and the concentrate supplementation would allow liveweight loss to be avoided and fairly high milk yields and satisfactory SNF contents in the milk to be obtained. When planning this experiment, the aim was to obtain results which could be applied in a commercial farming situation. The time of access to the hay supplement had to be restricted so that the silage could contribute a major portion of total forage intake. On average, the time allowed to eat the hay was about 5 h compared to about 15 h per 24 h for silage, and each cow was offered only 3 kg of hay daily.

Within both concentrate feeding treatments, the intake of short hay was lower than the intake of long and ground hays (Figs 3.1 and 3.2). The highest intake of hay occurred with the ground hay on the low rate of concentrate feeding (Fig. 3.1). It was observed that the cows had difficulty in grasping and eating the short hay. This was probably due to the thorny particles of short hay which might have caused irritation to the animal's tongue. In contrast, the hay cubes which contained molasses were likely to be more palatable. These cubes were relatively dense and therefore were much easier to grasp and swallow. It has been reported that the addition of molasses (Porter et al, 1953) and pelleting (Weir et al, 1959) of ground feeds can reduce dustiness and increase the feed intake. When the cows were on the high rate of concentrate feeding, the differences between the intakes of hay in the different forms were reduced compared with the differences on the low rate of concentrate feeding, and there was no real advantage in feeding ground and cubed hay (Fig. 3.2). It has been reported previously that the intake of silage increases as the chop length of silage is decreased (Castle et al, 1979; Deswysen, 1980) but this effect was not seen when comparing the long and short hays in the present experiment. In the present study, it was not possible to calculate the exact substitution rate between hay and silage because there were no treatments of silage and concentrates alone. However, within the low concentrate treatments, the total intake of forage increased on the ground hay treatment and this was mainly attributed to the higher intake of ground and cubed hay compared to the long and short hays (Fig. 3.1). On the high concentrate treatments, the total intake of forage was also higher on the ground hay treatment and this was mainly due to a reduced depression of silage intake on the ground compared to the long and short hays (Fig. 3.2). Other workers (Tayler and Aston, 1976a) reported that reducing the modulus of fineness of dried grass caused less depression on silage intake. In the four experiments of Retter (1978), supplements of long hay decreased the intake of silage DM by an average of 0.84 kg per kg hay DM. In the present experiment, the increase in the rate of concentrate feeding from 2 to 4 kg per 10 kg milk reduced the intake of both hays and silage and on average the decrease in the forage DM was 0.50 kg per kg concentrate DM. This value is similar to the mean value calculated from sixteen feeding trials in which cows were given silage *ad libitum* (Thomas, 1980).

As expected, the total DM (Table 3.2), ME and DCP intakes (Table 3.3) were higher on the high compared with the low rate of concentrate feeding, and thus the uncorrected yields of milk were 6.01% higher on the high compared with the low rate of concentrate feeding. In the present experiment, the grinding and cubing of the hay also played a vital role in increasing the forage intake and milk yield. Within both the low and high rate of concentrate feeding, milk yields were higher on the ground hay treatments than on the long and short hay treatments (Table 3.4). However, this response in milk yield to the higher intakes of ME on the ground hay treatments (Table 3.3) were not clear. On both concentrate treatments, the intake of ME was significantly higher on the ground than on the long and short hay treatments, but the increase in milk yield on the ground hay treatment was only significant on the low rate of concentrate feeding (Table 3.4).

It is concluded that there seems to be little advantage in supplementing grass silage with ground hay if the rate of concentrate feeding is high. However, if the rate of concentrate feeding is low, the total intake of feed and milk yield can be significantly increased by offering hay in a ground and cubed form. The additional costs of processing the hay and adding the molasses should be considered, but nonetheless this relatively simple technique would appear to be worthy of much further study.

EXPERIMENT 3.2

Introduction

In previous silage feeding experiments at this Institute, supplements of barley and dried grass (Castle and Watson, 1975), hay (Retter, 1978) and some high-protein foods (Castle and Watson, 1976; Castle *et al*, 1977a, b; Retter, 1978; Castle and Watson, 1979) have been used with silage diets. The supplements of barley and hay reduced silage intake whereas the high-protein concentrates increased the intake of silage.

Root crops have the potential to produce higher outputs of nutrients per hectare than the cereals (Kay, 1974; Nix, 1980) and can also offer the possibility of being used as supplements to silage. An important root by-product is sugarbeet pulp which is fairly widely used as a silage supplement, but there is only limited information on the change in silage dry matter intake caused by this feed. In one experiment, Castle *et al* (1966) showed that the inclusion of sugarbeet pulp in the diet decreased silage intake, but ultimately increased the total intake of dry matter. In this study, the D-value of the silage was not determined, and on all the treatments a concentrate mixture containing 70% barley was given.

The present experiment was conducted to compare bruised barley and shredded molassed sugarbeet pulp offered as supplements with a low D-value silage. The effect of these two feeds on the intake of silage, milk yield, milk composition and liveweight was also investigated.

Experimental feeding and design

There were three feeding treatments as follows:-

Treatment	Concentrate supplement
1	Soyabean meal only
2	Bruised barley + soyabean meal
3	Shredded sugarbeet pulp + soyabean meal

In addition, a basal ration of grass silage was offered *ad libitum* on all three treatments. The silage was offered at 06.30, 10.30 and 16.30 hrs in sufficient quantities to ensure that a 10% refusal was available for weighing before the next feed of silage. All the animals received 150 g per day of a mineral mixture (Pegasus RR) on top of the silage and were given access to the silage for about 21 h per 24 h. The soyabean meal, the mixture of soyabean meal and barley, and the mixture of soyabean meal and sugarbeet pulp were offered in equal portions twice daily at 05.35 and 14.30 hrs. The barley and the sugarbeet pulp were given at a rate of approximately 3.5 kg per 10 kg milk to supply exactly the same weight of concentrates on a dry matter basis. The soyabean meal was offered alone on treatment 1, and the amount was 20% of the total weight of either the barley or the sugarbeet pulp mixture. The weight of concentrates offered to the cows was kept constant throughout each period, and the amount was calculated from the individual milk yields of the cows in the previous period and the equalized principle of Lucas (1943), using the mean decline of all the animals.

Table 3.5 Experiment 3.2 The composition of the silage, soyabean meal, barley and the sugarbeet pulp

	DM ($g\ kg^{-1}$)	Crude protein	True protein	Crude fibre (g/kg DM)	Ether extract	Ash	D-value
Silage	250*	201	95	260	76	142	61.6
Soyabean meal	856	513	487	95	24	64	ND
Bruised barley	799	128	122	72	26	24	ND
Sugarbeet pulp	858	106	71	184	9	53	ND

*Determined by the toluene distillation method (Dewar and McDonald, 1961)

ND = not determined

Table 3.6 Experiment 3.2 The daily feed and water intakes on the three feeding treatments

Concentrate treatment	DM (kg/cow)					Daily DM intake as % of liveweight	Drinking water (kg/cow)	kg water per kg DM consumed*
	Silage	Soya	Barley	Sugarbeet-pulp	Total			
Soyabean meal	11.26	1.33	-	-	12.59	2.66	36.4	4.34
Bruised barley + soyabean meal	9.18	1.30	4.87	-	15.35	3.16	45.7	3.71
Sugarbeet pulp + soyabean meal	9.48	1.33	-	5.06	15.87	3.22	48.7	3.77
s.e. difference between two means	0.24				0.35	0.05	2.2	0.16

*Allowance made for the water content of the milk (ARC, 1980)

Six Ayrshire cows which had calved on average 6 weeks before the start of the experiment were divided into two groups of three animals. Within each group the cows were allotted at random to the treatment sequences in a 3 x 3 Latin Square plus a fourth period. The experiment lasted from 16 April 1979 to 9 July 1979 with four periods of 3 weeks each, and the data from week 3 in each period were used to calculate the results. The water intake of every cow was measured daily in week 3 of each period and the cows were weighed each Wednesday and Thursday at 15.00 hrs.

Results

Composition of the feeds

The D-value of the silage (Table 3.5), determined by the *in vitro* technique of Alexander and McGowan (1969), was 61.6. The mean pH of the silage was 4.16 ± 0.18, with concentrations of NPN and ammonia-N in the total N of 527 and 140 g kg^{-1} respectively. The concentrations of crude protein, true protein and ether extract were higher in the barley than in the sugarbeet pulp (Table 3.5). The crude fibre concentration in the beet pulp was 184 g per kg DM, and more than twice the concentration in the barley (Table 3.5).

Feed and nutrient intake

The mean weights of DM consumed daily on the three feeding treatments, and these intakes expressed as a percentage of liveweight, are given in Table 3.6. The intake of silage DM was significantly ($P<0.001$) higher on the soya-only treatment compared to the barley and

Table 3.7 Experiment 3.2 The daily intakes of ME, RDP and UDP

Concentrate treatment	ME intake		RDP (g per cow)		UDP (g per cow)	
	MJ per cow	% of requirement	Intake	Requirement	Intake	Requirement
Soyabean meal	125	95	2752	971	509	400
Bruised barley + soyabean meal	173	99	2805	1346	583	541
Sugarbeet pulp + soyabean meal	169	100	2770	1320	574	546
S.E. difference between two means	5.0	7.8	82	39	12	120

sugarbeet pulp treatments. The silage DM intake was higher on the sugarbeet pulp treatment than on the barley treatment but the difference was not significant ($P>0.05$). The total DM intakes expressed as a percentage of liveweight were significantly ($P<0.001$) higher on both the barley and sugarbeet pulp treatments than on the soya treatment but the small differences between the barley and sugarbeet pulp were not signficant ($P>0.05$). The intakes of drinking water expressed as kg per cow, and total water intake expressed as kg per kg of DM eaten were not significantly ($P>0.05$) different between the barley and sugarbeet pulp treatments (Table 3.6). However, the drinking water intake expressed as kg per cow increased significantly ($P<0.001$) on both barley and sugarbeet pulp, whereas the total water consumed per kg DM eaten was significantly ($P<0.01$) higher on the soya treatment compared with both barley and sugarbeet pulp treatments.

The daily intakes of ME (Table 3.7) were calculated from the DM intakes in Table 3.6, and ME values of 9.6, 12.3, 13.7 and 12.2 MJ/kg DM for silage, soya, barley and the sugarbeet pulp, respectively. Intakes of ME were significantly ($P<0.001$) higher on the barley and sugarbeet pulp than on soya, and the small differences in intakes of ME expressed as a percentage of requirement were not significant between the three treatments.

The daily intakes of RDP (Table 3.7) were calculated from the DM intakes in Table 3.6, and values of 208, 308, 102 and 84.8 g/kg DM for silage, soya, barley and sugarbeet pulp, respectively. There were no significant ($P>0.05$) differences in the RDP intakes between the three treatments, and the intakes of RDP were in excess of the requirements on all treatments.

Table 3.8 Experiment 3.2 The mean daily milk yield, composition of the milk and the liveweight of the cows

Concentrate treatment	Milk yield (kg/cow)	Milk composition ($g\ kg^{-1}$)					Mean liveweight	
		Fat	SNF	Total solids	Crude protein*	Lactose	(kg)	Daily change (kg/cow)
Soyabean meal	18.0	33.6	84.9	119	29.9	47.7	472	- 0.11
Bruised barley + soyabean meal	20.5	33.2	87.9	121	31.6	48.9	486	+ 0.86
Sugarbeet pulp + soyabean meal	20.8	36.4	87.3	124	31.8	48.0	494	+ 0.67
s.e. difference between two means	0.60	2.30	0.40	2.10	0.50	0.40	6.5	0.40

*N x 6.38

The daily intakes of UDP (Table 3.7) were calculated from the DM intakes in Table 3.6, and values of 20.6, 205, 25.6 and 21.2 g/kg DM for silage, soya, barley and sugarbeet pulp, respectively. The total intakes of UDP were not significantly (P>0.05) different between the barley and the sugarbeet pulp treatments, but both were significantly higher (P<0.001) than the intake on the soya treatment. On all treatments, the intakes of UDP were in excess of the requirements.

Milk yield, composition and liveweight

The mean daily milk yields, the composition of the milk and the liveweight of the cows on the three feeding treatments are given in Table 3.8. The milk yields were significantly higher (P<0.001) on the barley and the sugarbeet pulp than on soya only, but the small difference of 0.3 kg/cow/day between the barley and sugarbeet pulp was not significant (P>0.05).

There were no significant differences (P>0.05) between the fat concentrations of milk on the three feeding treatments. The CP and SNF concentrations of milk were both significantly (P<0.01) higher on the barley and sugarbeet pulp than on the soya. There was also a significantly (P<0.05) higher lactose and total solids concentration in the milk on the barley and sugarbeet pulp treatments compared with the soya treatment. The barley treatment gave a significantly higher (P<0.05) lactose concentration in the milk than the sugarbeet pulp treatment but the fat, SNF, total solids and CP concentrations of the milk were not significantly different (P>0.05).

The mean liveweights of the cows (Table 3.8) were not significantly ($P>0.05$) different between the barley and sugarbeet pulp treatments, but both were significantly ($P<0.05$) higher than the weight on the soya treatment. There were no significant differences in the liveweight changes on the three treatments, but the cows lost a little weight on the soya treatment and increased in liveweight on both the barley and sugarbeet pulp treatments (Table 3.8).

Discussion

Before the start of this experiment it was planned to supply exactly the same weight of barley and sugarbeet pulp on a DM basis. However, two cows refused small amounts of barley, and thus the mean DM intake (Table 3.6) was slightly higher on the sugarbeet pulp than on the barley treatment. In addition, the difference in the DM contents of the barley and beet pulp (Table 3.5) was greater than in the pre-experimental period, and this fact altered the intakes of concentrate DM. However, the difference between the intakes of barley and beet pulp DM was not large and probably had no major effect on the ultimate results in this study.

In the present experiment the ration of grass silage plus soyabean meal was the control treatment, and this treatment enabled a calculation of the depression in the silage DM intake as a result of giving supplements of either barley or sugarbeet pulp in the other two feeding treatments. Soyabean meal as a basic supplementary feed was offered in equal amounts on all the three treatments, and this was done to ensure an adequate supply of protein to the animals and hence

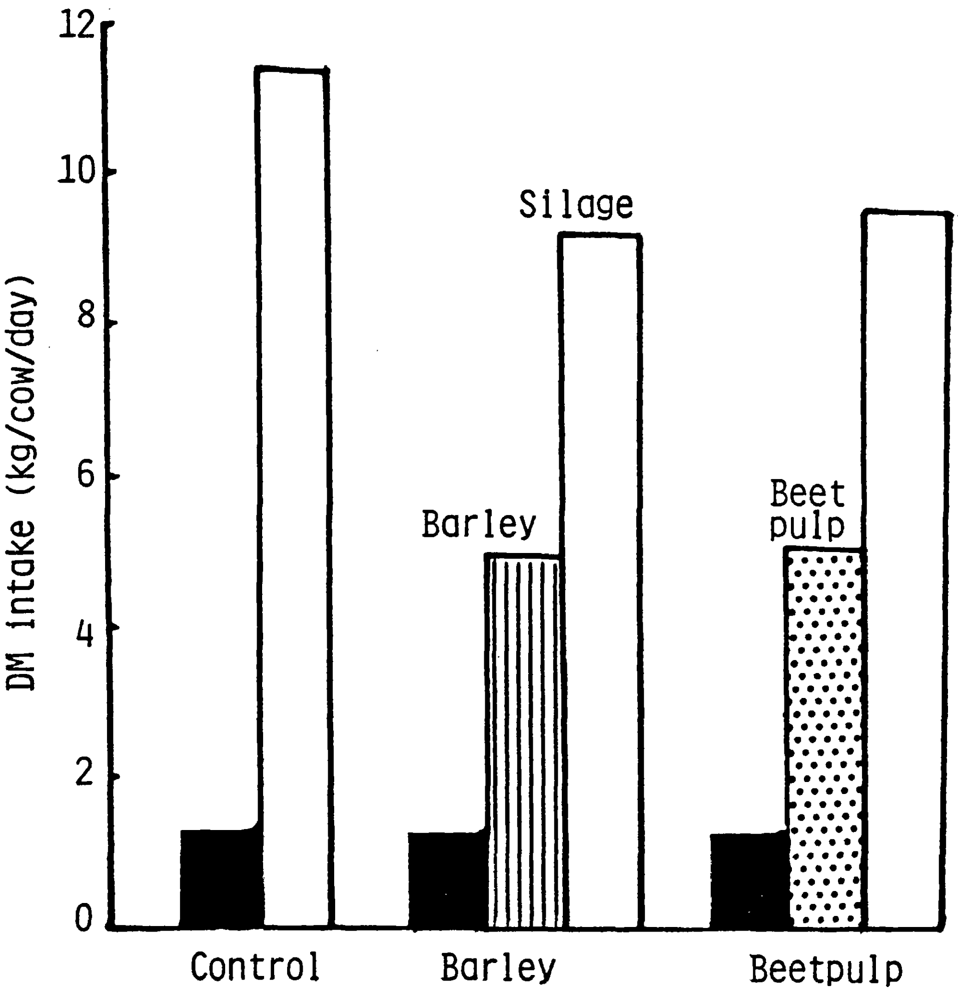


Fig. 3.3 Feed intake with supplements of barley and sugarbeet pulp

a satisfactory yield of milk on the control treatment. It was thought important to give adequate protein in the present comparative experiment as previous studies with dairy cows had shown the uncertainty regarding the value of N in silage (Castle and Watson, 1969, 1974; Gordon, 1979). In these experiments (Castle and Watson, 1969, 1974) significant increases in milk yield were obtained when groundnut cake was included in the ration of cows given high-protein silage and barley. The cows in these experiments were apparently overfed with protein but nonetheless the extra protein from the groundnut cake increased the voluntary intake of silage DM, the intakes of ME and N, and the milk yield.

The silage used in the present experiment had a high ash content, 142 g per kg DM, and this contributed to the low D-value of 61.6 (Table 3.5). The highest silage DM intake of 11.3 kg/cow (Fig. 3.3) occurred on the soya-only treatment. This value was only slightly lower than the mean DM intake of 11.8 kg obtained with high digestibility grass silage plus soya (Retter, 1978). There was only a small difference in the intake of silage DM on the treatments with supplements of barley and sugarbeet pulp (Fig. 3.3). On average, for each kg of barley and sugarbeet pulp DM consumed, the reduction in the intake of silage DM was 0.44 and 0.36 kg, respectively. A similar result was noted in another experiment (Krohn and Andersen, 1979) where the depression in the silage DM intake was 0.4 to 0.5 kg per kg of barley and fodder sugarbeet eaten. Castle and Watson (1975) reported a reduction of 0.52 kg silage DM per kg of barley consumed with a high digestibility grass silage. Although the silage used in the present experiment had a low digestibility, it appeared that the addition of a small amount of soya to the barley had partially offset the effect on silage intake compared to feeding of barley alone (Castle and Watson, 1975). When high-protein concentrates are given in small amounts with supplements of hay and barley there can be a decreased effect on silage intake. For example, Retter (1978) reported reductions in the intake of silage DM of 0.87 and 0.61 kg per kg of hay or hay plus soyabean meal consumed. In the experiment of Castle and Watson (1976), the depressions in the intake of silage DM were 0.47 and 0.32 kg per kg of barley or barley plus groundnut, respectively.

The lowest intake of total DM (Table 3.6), ME and protein (Table 3.7) occurred on the soyabean meal treatment and this resulted in a substantially lower milk yield compared to the barley and sugarbeet pulp treatments (Table 3.8). A small and non-significant increase in the feed intake on the sugarbeet pulp treatment compared with the barley treatment (Fig. 3.3) probably did not have any major effect on the milk yields. Although the ME value of barley is stated to be 1.50 MJ/kg DM higher than that of molassed beet pulp (MAFF et al, 1975), the similar milk yields and milk composition on the barley treatment and on the sugarbeet pulp treatment indicated that the two feeds are fairly similar in feeding value on a DM basis. The results of the present experiment agree with previous experiments in which barley and sugarbeet pulp were offered with a basal diet of hay (Castle, 1972). In contrast, Krohn and Andersen (1979) reported a small increase in both feed consumption and milk yield when barley rather than fodder sugarbeet was offered with grass silage ad libitum. The difference between the results of the present experiment and those reported by Krohn and Andersen (1979) can be due to a number of causes. In the present experiment, silage of low D-value was used with a small number of animals, and the feed consumption (Table 3.7) and milk yield results

(Table 3.8) were the mean of 5 days in the last week of each period. In the other study (Krohn and Andersen, 1979), silage of high digestibility was used with a large number of animals, and the data on feed intake and milk yield were presented from an average of 84 days. However, the differences between the barley and the sugarbeet pulp were not significant in the present study.

An increase in the level of energy intake generally increases the protein and the SNF content of milk (Rook, 1973, 1976; Castle and Watson, 1975, 1976; Retter, 1978). In the present study, the higher intake of total DM and hence the energy intake increased the CP and SNF contents of the milk on both the barley and the sugarbeet pulp treatments compared with the soya alone (Table 3.8). The milk fat content was lower on the barley treatment than on the sugarbeet pulp treatment. This result is similar to that in the experiment of Krohn and Andersen (1979) where there was a marked fall in the milk fat content with barley compared to fodder sugarbeet and this was reported to be due to the high starch content of the barley.

It is concluded that the difference between the feeding values of bruised barley and shredded sugarbeet pulp were small when used as supplements to grass silage, and for most feeding purposes these two feeds are interchangeable on an equal weight basis. This conclusion is in full agreement with that of Castle (1972) who obtained similar results with barley and sugarbeet pulp when hay was used as the basic forage in the ration.

EXPERIMENT 3.3

Introduction

As stated previously, the feeding of silage as the sole food to dairy cows is normally considered inadequate to obtain high milk yields. In order to achieve higher milk yields, silage is usually given with supplements, and feeds with a high protein content have been particularly useful as a supplement for high digestibility grass silage (Castle and Watson, 1976; Castle *et al*, 1977a; Retter, 1978). This type of supplement did not reduce the voluntary intake of silage DM, and the milk yields were increased compared to a ration of silage alone. However, if a high-protein concentrate is to be used with success as a silage supplement, it is important to determine the optimum rate of feeding with silages of different D-values. The present experiment investigates various rates of feeding of a high-protein concentrate with both low-D and high-D silages. The intake of silage, milk yield and composition were recorded as in the other experiments.

Table 3.9 Experiment 3.3 The composition of the silages and the supplementary concentrate

Feed	DM (g kg^{-1})	Crude protein	True protein	Crude fibre	Ether extract	Ash	D-value
		(g kg^{-1} DM)					
A. Low-D silage	225*	143	63	323	52	62	62.6
B. Low-D silage	223	145	56	309	45	72	65.5
C. High-D silage	224	194	85	269	65	66	69.7
D. High-D silage	277	157	69	264	46	79	68.6
Concentrate	852	362	350	94	29	99	-

*Determined by the toluene distillation method (Dewar and McDonald, 1961)

Experimental feeding and design

There were six feeding treatments as follows:-

Treatment	
Silage D-value	Rate of concentrate feeding
Low	Low
Low	Medium
Low	High
High	Low
High	Medium
High	High

The basal ration of grass silage was offered ad libitum to the cows at 06.30, 10.30 and 16.30 hrs in sufficient quantities to ensure that a 10% refusal was available for weighing before the next silage feed. Thus, all the cows had access to silage for about 20 h per day. Two low-D and two high-D silages were used in the experiment. The low-D (A) and high-D (C) were given in periods 1, 2 and 3 and the low-D (B) and high-D (D) in period 4 (Table 3.9). The concentrates were given in equal amounts twice daily at 05.35 and 14.30 hrs. The concentrate contained 10% barley, 77% soyabean meal, 4.5% molasses, 1.5% dicalcium phosphate, 1.0% salt, 0.5% vitamin supplement, 2% binder and 3.5% BP fat by weight. The concentrate was given at a flat rate of 1.5, 3.0 and 4.5 kg per cow/day on the low, medium and high rates, respectively. This amount was kept constant for all the cows throughout the 4-week experimental period.

Twelve Ayrshire cows, which had calved on average 5 weeks (range 4 - 6 weeks) before the start of the experiment, were divided into two groups of six similar animals on the basis of daily milk yield and date of calving. Within each group, the cows were allotted at random to a treatment sequence in a cyclic changeover design (Davis and Hall, 1969) with four periods of 4 weeks each. The experiment lasted for 16 weeks from 29 September 1980 to 19 January 1981, and the results from weeks 3 and 4 in each period were used. The water intake of each cow was recorded daily in weeks 3 and 4 of each period, and the cows were weighed every Wednesday and Thursday at 15.00 hrs.

Results

Composition of the feeds

The D-values of the four silages (Table 3.9) were determined by the *in vitro* technique of Alexander and McGowan (1969). On average, the D-value was 5 units higher on the high-D than on the low-D silages. The mean pH values were 3.83 ± 0.02 and 3.87 ± 0.04 for the low-D silages, and 3.83 ± 0.03 and 3.88 ± 0.04 for the high-D silages. The concentrations of ammonia-N in total N were 81 and 82 for the low-D silages, and 98 and 92 g kg^{-1} for the high-D silages. The concentration of crude protein, true protein, ether extract and ash were higher on the high-D silages compared to the low-D silages (Table 3.9), whereas, as anticipated, the crude fibre was higher on the low-D than on the high-D silages. The two low-D silages had similar dry matter concentrations (Table 3.9) but there was a difference of 53 g kg^{-1} between the two high-D silages.

The health of the animals was good throughout the experiment. The two cows showing slight signs of ketosis in period 1 were on the

Table 3.10 Experiment 3.3 The daily feed and water intake on the six feeding treatments

Treatment		DM (kg/cow)			Daily silage DM intake as % of liveweight	Daily total DM intake as % of liveweight	Drinking water (kg/cow)	kg water per kg DM consumed*
Silage D-value	Rate of concentrate feeding	Silage	Concen-trates	Total				
Low	Low	10.92	1.28	12.20	2.11	2.36	23.1	3.79
Low	Medium	11.38	2.56	13.94	2.18	2.67	31.3	3.88
Low	High	10.93	3.84	14.77	2.09	2.82	35.8	3.87
High	Low	12.59	1.28	13.87	2.42	2.66	30.6	3.90
High	Medium	12.65	2.56	15.21	2.43	2.93	32.9	3.66
High	High	12.59	3.83	16.42	2.37	3.09	40.8	3.78
S.E. difference between two means		0.42	-	0.42	0.07	0.07	1.83	0.11

*Allowance made for water content of milk (ARC, 1980).

low-D silage and low rate of concentrate intake.

Feed and nutrient intake

The mean weights of DM consumed daily on each treatment are given in Table 3.10. On average, the intake of silage DM and the intake of total DM expressed as either kg per cow or as a percentage of liveweight were significantly ($P<0.001$) higher on the high-D than on the low-D silage treatments. Within both the low-D and high-D silage treatments, the rate of concentrate feeding treatments had no significant ($P>0.05$) effect on the silage DM intake expressed as either kg per cow or as a percentage of liveweight. On both the low-D and the high-D silage treatments the intake of total DM expressed as either kg per cow or as a percentage of liveweight were significantly ($P<0.001$) higher on the medium rates and high rates than on the low rates of concentrate feeding. The total DM intake was significantly ($P<0.01$) higher on the high compared to the medium rate of concentrate feeding, when offered with the high-D silage. Within the low-D silage treatments, the small difference in the total DM intake between the medium and high rates of concentrate feeding was not significant ($P>0.05$). On average, the intake of drinking water was significantly ($P<0.001$) lower on the low-D than on the high-D silage treatments (Table 3.10). Within both the low-D and the high-D silage treatments, the water intake was signficantly higher ($P<0.01$) on the medium and high rate treatments compared with the low rate of concentrate feeding. On the high-D silages, water intake was significantly ($P<0.01$) higher on the high than on the medium rate of concentrate feeding. Similarly, a significant ($P<0.05$) increase in water intake occurred on the high compared to the medium rate of concentrate feeding, when both were offered with

Table 3.11 Experiment 3.3 The daily intake of ME, RDP and UDP on the six treatments

Treatment		ME intake		RDP (g per cow)		UDP (g per cow)	
Silage D-value	Rate of concentrate feeding	MJ per cow	% of requirement	Intake	Requirement	Intake	Requirement
Low	Low	126	93	1581	984	408	283
Low	Medium	146	89	1895	1135	594	412
Low	High	159	89	2200	1238	759	481
High	Low	159	102	2293	1239	426	298
High	Medium	177	101	2632	1377	602	404
High	High	191	96	2902	1488	777	486
S.E. difference between two means		4.4	7.0	70	34	9.4	62

low-D silages. The intake of water expressed as kg per kg DM consumed was not significantly different on the six feeding treatments (Table 3.10).

The daily intakes of ME (Table 3.11) were calculated from the DM intakes in Table 3.10, and ME values of 9.90 and 10.6 for the two low-D silages, 11.5 and 11.2 for the two high-D silages, and 12.3 MJ/kg DM for the concentrate. The total daily ME intakes and the intakes expressed as a percentage of requirement were all signficantly (P<0.01) higher on the high-D compared to the low-D silage treatments. Within both the low-D and high-D silage treatments, ME intakes were significantly (P<0.001) lower on the low than on the medium and high rates of concentrate feeding. Similarly, within both silages, there was a significantly (P<0.01) higher ME intake on the high compared to the medium rate of concentrate feeding.

The daily intakes of RDP (Table 3.11) were calculated from the DM intakes in Table 3.10 and values of 120 and 113 for the low-D silages, 174 and 129 for the high-D silages, and 225 g/kg DM for the concentrate. The total daily intakes and the requirements of RDP were significantly (P<0.001) lower on the low-D than on the high-D silage treatments. Within both the low-D and the high-D silage treatments, RDP intakes and requirements were significantly (P<0.001) higher on medium and high rates than on the low rate of concentrate feeding. On all treatments, the intakes of RDP were in excess of the requirements.

The daily intakes of UDP (Table 3.11) were calculated from the DM intakes in Table 3.10 and values of 21.1 and 21.6 for the low-D silages, 19.3 and 21.0 for the high-D silages, and 138 g/kg DM for the concentrate. The intakes of UDP were significantly (P<0.01) lower on the low- than on the high-D silage treatments. Within the two silage treatments, UDP intakes were significantly (P<0.001) higher

Table 3.12 Experiment 3.3 The mean daily milk yield, composition of the milk and liveweight of the cows

Treatment		Milk yield (kg/cow)		Milk composition ($g\ kg^{-1}$)					Mean liveweight	
Silage D-value	Rate of concentrate feeding	Un-corrected	Corrected to 4% fat	Fat	SNF	Total solids	Crude protein*	Lactose	(kg)	Daily change (kg/cow)
Low	Low	17.1	18.0	42.3	85.3	127.6	30.2	47.0	514	- 0.25
Low	Medium	18.6	18.5	40.2	86.2	126.4	30.8	47.1	523	+ 0.34
Low	High	21.0	21.3	40.4	87.6	128.0	31.7	47.9	526	+ 0.32
High	Low	19.6	19.8	40.4	86.3	126.7	30.8	47.2	522	- 0.02
High	Medium	21.2	21.2	39.9	87.3	127.2	31.9	47.4	522	+ 0.30
High	High	22.8	23.6	41.8	88.0	129.8	32.5	47.7	531	+ 0.59
S.E. difference between two means		0.59	0.88	1.4	0.5	1.5	0.5	0.4	4.5	0.20

*N x 6.38

on the medium and high rates compared to the low rate of concentrate feeding. Similarly, within both silage treatments, there was a significantly (P<0.001) higher UDP intake on the high compared with the medium rate of concentrate feeding. On all treatments, UDP intakes were in excess of the requirements.

Milk yield, composition and liveweight

The mean daily milk yields per cow on each treatment are given in Table 3.12. The uncorrected yields and the yields corrected to 4% fat content (FCM) were both significantly (P<0.001) higher on the high-D than on the low-D silage treatments. Within both the low-D and high-D silage treatments, the uncorrected yields were significantly (P<0.001) lower on the low rate than on the medium and high rates of concentrate feeding. On the low-D silage treatments, the uncorrected yields were significantly (P<0.001) lower on the medium rate than on the high rate of concentrate feeding. Similarly, on the high-D silage treatments, the uncorrected yields were significantly (P<0.01) lower on the medium rate than on the high rate of concentrate feeding. Within the low-D silages, FCM was signficantly (P<0.05) higher on the medium and high rates compared to the low rate of concentrate feeding. There was also a significant (P<0.001) increase in FCM on the high rate compared to the medium rate of concentrate feeding. On the high-D silage treatments, the FCM was significantly (P<0.01) higher on the medium and high rates than on the low rate of feeding; this difference in FCM was also significant (P<0.01) between the high and the medium rates of concentrate feeding.

The milk fat, total solids and the lactose concentrations were not significantly different on the six feeding treatments (Table 3.12), but the crude protein and SNF concentrations were both significantly ($P<0.05$) higher on the high-D than on the low-D silage treatments (Table 3.12). Within both the low-D and high-D silage treatments, the crude protein values were significantly ($P<0.05$) higher on the medium and high rates than on the low rate of concentrate feeding, but there were no significant differences between the medium and high rates of concentrate feeding. On both the low- and high-D silage treatments, the SNF values were significantly ($P<0.01$) lower on the low rate than on the medium and high rates of concentrate feeding. On the low-D silages, the SNF concentration was significantly ($P<0.05$) lower on the medium than on the high rate of concentrate feeding, whereas with the high-D silages, the small differences between the medium and high rates of concentrate feeding were not significant.

The mean liveweight and the liveweight changes per cow showed no significant differences between the low-D and high-D silage treatments (Table 3.12). On both the low-D and high-D silage treatments, the liveweight was not significantly different on the three rates of concentrate feeding. Within the low- and high-D silage treatments, there were no significant differences in liveweight change between medium and high rates of concentrate feeding. However, on the low-D silage treatments, the increase in liveweight was significantly ($P<0.01$) higher on the medium and high rates than on the low rate of concentrate feeding. Similarly, within the high-D silage treatment, a significant ($P<0.05$) increase in liveweight occurred on the medium and high rates compared with the low rate of concentrate feeding.

Discussion

In the present experiment to compare three rates of feeding of a high-protein concentrate, the aim was to make and to feed silages of low- and high-D value. The grass for the low-D silages was cut at a fairly mature stage of growth with seed heads visible, whereas the high-D silages were made by cutting grass at a leafy stage of growth and no seed heads were present. The four silages all had good fermentation qualities with low pH values, low ammonia-N in total N, and mean D-values of 64.0 and 69.2 on the low- and high-D value silages, respectively. The two silages used in periods 1, 2 and 3 had high intake characteristics but the amount of these silages (A and C, Table 3.9) was insufficient to complete period 4, and two other silages which had a similar chemical composition were used in the fourth period of the experiment. This change of silages had not been planned but fortunately silages B and D were available, and proved to be highly suitable for this particular experiment.

Effect of rate of concentrate feeding on feed intake

The important characteristic of the high-protein concentrate was the lack of any significant depression in the voluntary intake of silage DM when increasing amounts of concentrate were eaten with either the low-D or the high-D silage. The mean silage DM intakes were high and on the low-D and high-D silage treatments averaged 11.1 and 12.6 kg per cow/day, respectively. These values are close to the mean intake of 11.3 kg DM calculated from six feeding trials (Castle and Watson, 1975, 1976, 1977a,b; Castle *et al*, 1980; Retter, 1978) in which the dairy cows were offered silage with a mean D-value of 70 as the sole constituent of

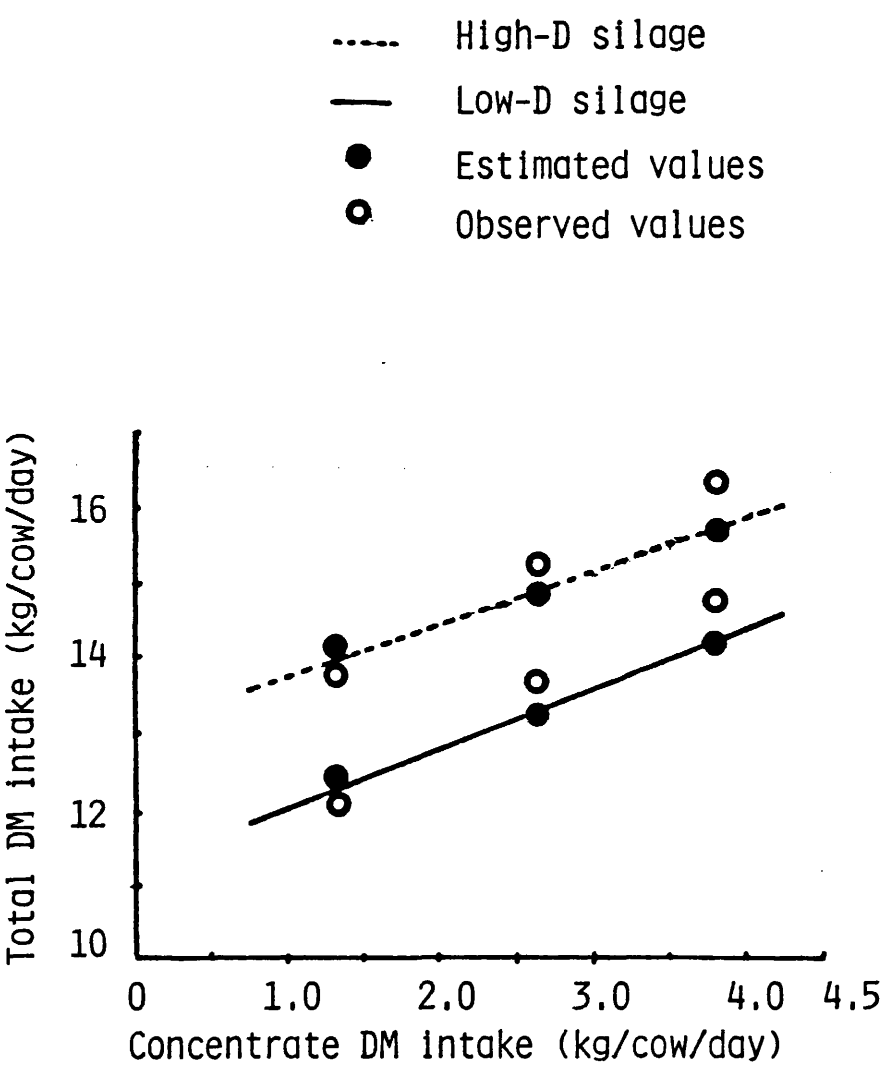


Fig. 3.4 Relationship between concentrate intake and the total DM intake

the diet. The high-protein concentrate did not reduce silage intake which contrasts with the effect of supplements such as barley, dried grass, concentrates and hay (Castle and Watson, 1975, 1976; Castle et al, 1980; Retter, 1978). In the present experiment, the high-protein concentrate was particularly valuable in increasing the total DM intake rather than causing a depression, and this increase occurred with both the low- and high-D-value silages (Table 3.10). The relationship between the rate of concentrate feeding and the total DM intake (Fig. 3.4) was highly significant ($P<0.001$) and was described by the following regression equations:-

low-D silage : $y = 11.70 + 0.64x$ SE = ± 0.105

high-D silage: $y = 13.26 + 0.64x$ SE = ± 0.109

where y is the total DM intake (kg/cow/day)

and x is the concentrate DM intake (kg/cow/day)

It is worthy of note that b values were 0.64 in both equations although the qualities of silage as measured by D-value were different. Silage intakes as stated previously were higher on the high-D-value silage than on the low-D-value silage but the effect of concentrate supplements was exactly the same. It will be seen from Fig. 3.4 that the linear regressions fitted the observed values for both the high-D value and low-D-value silages.

Effect of rate of concentrate feeding on milk yield and composition

The importance of the high-protein concentrate was not only in its effect on silage intake, but, as the concentrate intake increased, so too did the ME, RDP and UDP intake (Table 3.11), and this in turn led to increases in the milk yields (Table 3.12). The relationship

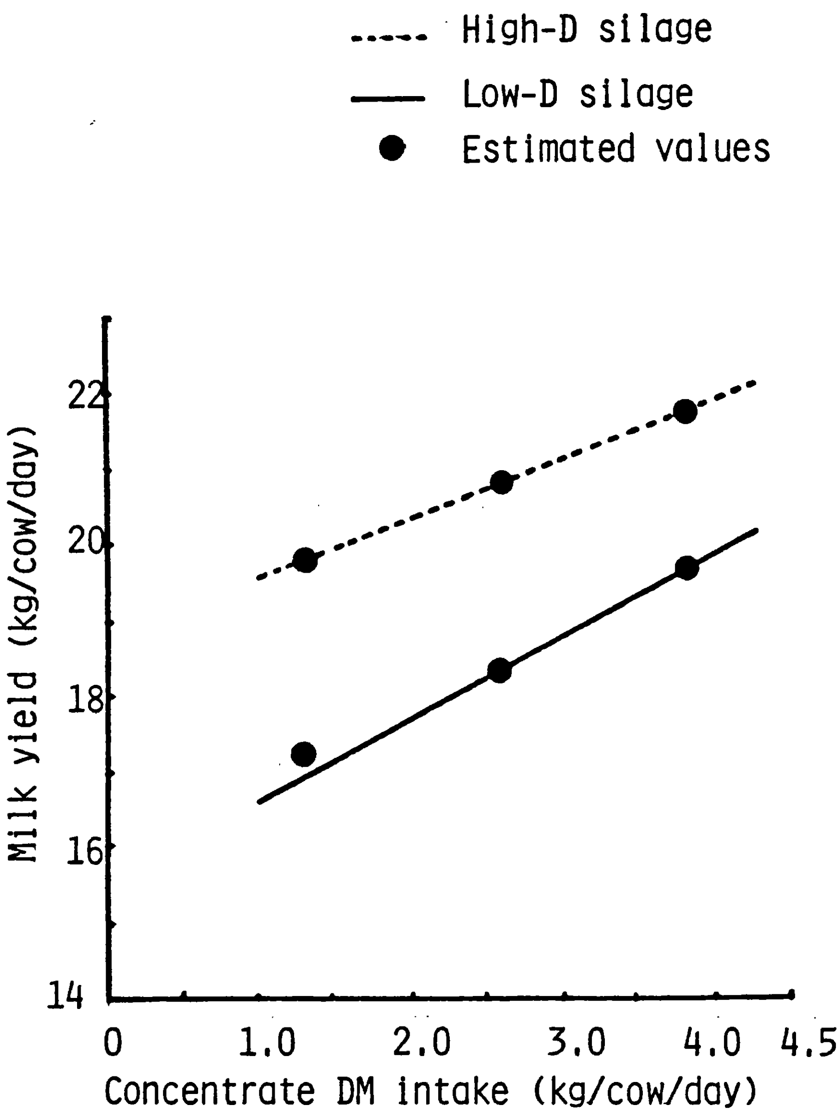


Fig. 3.5 Relationship between concentrate intake and the milk yield

between the level of concentrate feeding and the milk yield (Fig. 3.5) was highly significant ($P<0.001$) and was described by the equations:-

<u>low-D silage</u> : $y = 15.94 + 0.98x$ $SE = \pm 0.13$

<u>high-D silage</u>: $y = 18.77 + 0.80x$ $SE = \pm 0.15$

where y is the milk yield (kg/cow/day)

and x is the concentrate DM intake (kg/cow/day)

In Fig. 3.5 only estimated values have been inserted as observed values were so similar to the estimated ones.

It will be noted that the b value with the low-D silage at 0.98 is greater than that with the high-D silage at 0.80, which is probably a reflection of a diminishing response at the higher level of energy intake occurring with the silage of higher D-value.

The response in milk yield to the level of concentrate offered with silage diets <u>ad libitum</u> has been variable in different experiments. For example, Castle <u>et al</u> (1977a) obtained a response of 1.7 kg milk per kg concentrate when DM intakes of high-protein concentrates were 1.2 to 2.3 kg per cow/day. Retter (1978) reported a similar value of 1.7 kg milk per kg of soya DM intake. The data from silage experiments in Northern Ireland also showed a relationship between level of supplementation and milk yield (Gordon, 1981). These responses in milk yield were 1.8, 1.1 and 0.8 kg per kg concentrates when intakes of concentrates were 3, 4 and 5 kg per day, respectively. The results of the present experiment, within the low D-silage treatments, showed a response of 1.2 and 1.9 kg milk/kg concentrate on the medium and high rates of concentrate treatments. On the high-D silage treatments response was 1.2 kg milk/kg concentrate on both medium and high concentrate treatments. It is again stressed that the response of milk yield per kg concentrate was lower with the high-D than with the low-D

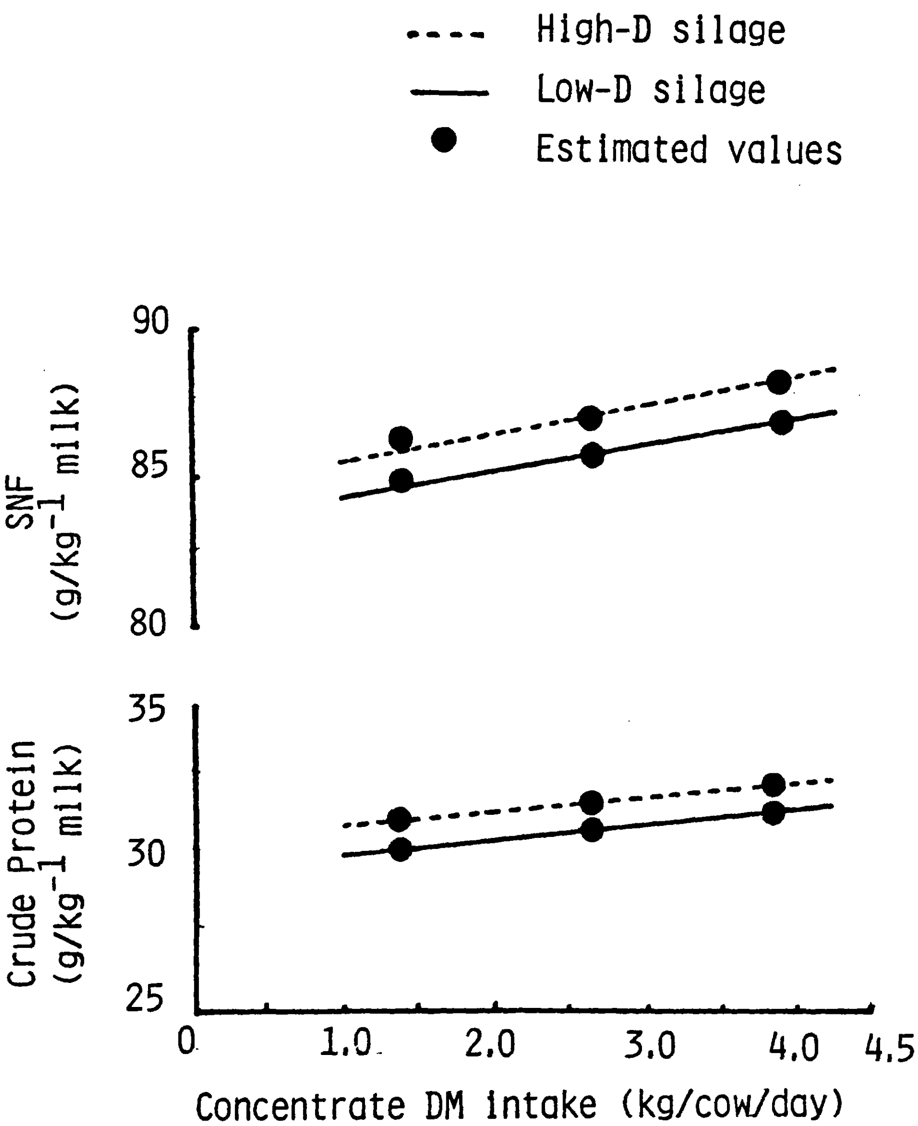


Fig. 3.6 Relationship between concentrate DM intake and crude protein and SNF

silage. This reduction in response with the high-D silage was due presumably to a higher plane of nutrition on the high-D-value silages. In other experiments, high levels of concentrate supplementation also showed small responses in milk yield with high D-value silages (Parker, 1976; Steen and Gordon, 1980b). It is suggested, therefore, that the variation in the response in milk yield in relation to the level of concentrate feeding in the present feeding experiment was mainly due to the differences in quality of the silage.

The CP and SNF contents of the milk increased (Table 3.12) as the energy and protein intakes increased (Table 3.11) due to the higher rates of concentrate feeding. The positive and significant relationship between concentrate intake and CP and SNF (Fig. 3.6) was described by the following regression equations:-

Crude protein

low-D silages : $y = 2.98 + 0.038x$ SE = ± 0.014

high-D silages: $y = 3.04 + 0.043x$ SE = ± 0.014

where y = percent crude protein or 10 g/kg milk

and x = concentrate DM intake (kg/cow/day)

SNF

low-D silages : $y = 8.46 + 0.058x$ SE = ± 0.013

high-D silages: $y = 8.58 + 0.048x$ SE = ± 0.013

where y = percent SNF or 10 g/kg milk

and x = concentrate DM intake (kg/cow/day)

The effects of the increased supply of energy and protein cannot be separated in this experiment but it is clear that both the CP and SNF concentrations were extremely sensitive to changes in concentrate level but with the silage quality also having a marked influence. All the values were high, and indicate that a diet with a high content of silage can produce milk of a satisfactory composition.

Effect of silage quality on feed intake

Several workers have noted increases in silage DM intake when the digestibility of the silage was increased. The data from the experiments reviewed by Thomas (1980) showed an increase in silage DM intake of 0.15 kg per unit increase in D-value. This was less than the value of 0.23 kg calculated from another two experiments (Gordon, 1980c; Steen and Gordon, 1980b). A similar increase of 0.24 kg per unit increase in D-value was reported by Castle et al (1980). In the present feeding experiment, an increase of 0.22 kg silage DM per unit D-value was obtained when comparing the low- and the high-D silages used in the first three periods of the experiment. The fermentation quality of silage can also have an important influence on silage intake regardless of its D-value. A negative response in silage intake to an increase in D-value was attributed to the low DM and high lactic acid contents of a high digestibility silage (Tayler and Aston, 1976b).

Effect of silage quality on milk yield and composition

Many experimental results have shown increases in milk yield when the digestibility of the silage offered to the cows was increased. The average response in terms of milk yield in the experiments reported by Thomas (1980) was calculated to be 0.29 kg milk per unit increase in D-value. This value is higher than the response of 0.23 kg milk calculated from 15 silages used in studies at the Hannah Research Institute (Castle, 1975). A response of 0.28 kg milk per unit D-value was obtained in another recent experiment (Gordon, 1980b). A value of 0.32 kg milk/unit D-value was calculated from the results of the low- and the high-D silages used in the first three periods of the present experiment. The digestibility of silage can influence also the response in milk yield to extra concentrate supplementation. At low levels of concentrate feeding the response can be increased, i.e. the milk yield per kg of concentrate, if the diet contains high digestibility silage (Gleeson, 1970). However, with high levels of concentrate feeding, the response in milk yield per kg concentrate eaten decreases even with high digestibility silage (Parker, 1976; Steen and Gordon, 1980b).

The results in the present feeding experiment showed that there was no significant depression in silage intake when increasing amounts of high-protein concentrate were consumed, and the response in milk yield per kg of the concentrate did not decline. It is therefore concluded that up to 4.5 kg of a high-protein concentrate can be given to dairy cows with either low- or high-D silages with no decline in response to the increasing amounts of concentrates.

EXPERIMENT 3.4

Introduction

There is some limited experimental evidence which indicates that if dairy cows are given frequent meals throughout the 24 hours, there will be an increase in feed intake, in milk yield and in the milk fat content. For example, Campbell and Merilan (1961) obtained higher yields of milk, fat and solids-not-fat (SNF) when the frequency of feeding was increased from 2 to either 4 or 7 times per 24 hours. In the study of Kaufmann (1973) milk fat content was increased significantly when the roughage and concentrates were given more frequently. More recently there have been reports of an increase in roughage intake by feeding the concentrates and roughage more than twice daily (Kaufmann, 1976; Linder *et al*, 1979). A preliminary unpublished study by Castle and Watson at the Hannah Institute showed that silage intake was substantially increased when supplements of bruised barley were given in 22 rather than in 2 meals per 24 hours. In the UK, the frequent feeding of concentrates with a diet of silage given *ad libitum* is now practised on an increasing number of dairy farms. However, there is little information in the literature concerning the response from the frequent feeding of concentrates on the intake of silage, milk yield and milk composition. Three experiments were conducted therefore to investigate the effect of the frequent feeding of concentrates with *ad libitum* silage.

In the first experiment, the effect of giving high- and low-protein concentrates 2, 4 and 22 times per 24 hours with *ad libitum* silage was investigated. The silage intake, milk yield, milk composition and liveweight were measured.

Experimental feeding and design

There were six feeding treatments as follows:-

Treatment	
Level of crude protein in concentrate	Number of concentrate feeds per 24 hours
High	2
High	4
High	22
Low	2
Low	4
Low	22

In addition, a basal ration of grass silage was offered *ad libitum*. The silage was offered to the cows at 06.30, 10.30 and 16.30 hrs in sufficient quantities to ensure that a 10% refusal was available for weighing before the next silage feed. All the cows had access to the silage for about 20 h per 24 h. The concentrates were given in equal portions, twice daily at 05.35 and 14.30 hrs, 4 times daily at 05.35, 10.30, 14.30 and 22.00 hrs and 22 times daily via automatic feeders every hour, except at 06.00 and 15.00 hrs when the cows were being milked. The high-protein concentrate contained 63% barley, 27% soya-bean meal, 5% molasses, 3% vitamins-minerals supplement and 2% binder by weight, whereas the low-protein concentrate contained 90% barley, 5% molasses, 3% vitamins-minerals supplement and 2% binder by weight.

Table 3.13 Experiment 3.4 The composition of the silage and the high- and low-protein concentrates

	DM ($g\ kg^{-1}$)	Crude protein	True protein	Crude fibre (g/kg DM)	Ether extract	Ash	D-value
Silage	218*	141	65	329	50	75	65.5
High-protein concentrate	849	202	190	68	22	92	-
Low-protein concentrate	847	128	119	63	21	85	-

*Determined by the toluene distillation method (Dewar and McDonald, 1961)

The weight of the concentrates offered was based on a rate of 4 kg per 10 kg milk yield and the daily amount was constant throughout each period. The exact weight was calculated from the individual milk yields in the previous period and the equalized principle of Lucas (1943).

Twelve Ayrshire cows, which had calved on average 8 weeks (range 6 - 10 weeks) before the start of the experiment, were divided into two groups of six similar animals on the basis of daily milk yield. Within each group, the cows were allotted at random to the treatment sequences in a cyclic changeover design (Davis and Hall, 1969) with four periods of 4 weeks each. The experiment lasted for 16 weeks from 22 October 1979 to 10 February 1980, and the results from weeks 3 and 4 in each period were used. The water intake of each cow was recorded daily in weeks 3 and 4 of each period, and the cows were weighed every Wednesday and Thursday at 15.00 hrs.

Results

Composition of the feeds

The D-value of the silage (Table 3.13), determined by the *in vitro* technique of Alexander and McGowan (1969), was 65.5. The mean pH of the silage was 4.08 ± 0.22, with concentrations of NPN and ammonia-N in the total N of 536 and 126 g kg^{-1}, respectively. The high- and low-protein concentrates contained 202 and 128 g CP per kg DM (Table 3.13), i.e. 171 and 108 g kg^{-1} as offered to the cows. The concentration of DM, crude fibre and ash were slightly higher in the high-protein concentrate compared to the low-protein concentrate (Table 3.13).

Table 3.14 Experiment 3.4 The daily intake of feed and drinking water on the six feeding treatments

Treatment		DM (kg/cow)			Daily DM intake as % of liveweight	Drinking water (kg/cow)	kg water per kg DM consumed*
Concentrate	Number of concentrate feeds per 24 hours	Silage	Concen-trates	Total			
High-protein	2	8.38	6.06	14.44	2.79	33.8	3.44
High-protein	4	8.49	6.09	14.58	2.84	36.3	3.58
High-protein	22	8.52	6.05	14.57	2.80	34.7	3.55
Low-protein	2	7.93	5.99	13.92	2.76	33.3	3.55
Low-protein	4	8.20	5.94	14.14	2.77	34.0	3.69
Low-protein	22	7.95	6.08	14.03	2.73	37.6	3.80
S.E. difference between two means		0.32	0.06	0.31	0.04	3.14	0.23

*Allowance made for the water content of the milk (ARC, 1980)

Table 3.15 Experiment 3.4 The daily intake of metabolizable energy and digestible crude protein

Treatment		ME intake		DCP intake	
Concentrate	Number of concentrate feeds per 24 hours	MJ per cow	% of requirement	g per cow	% of requirement
High-protein	2	166	111	1982	157
High-protein	4	167	109	1991	153
High-protein	22	167	107	1953	152
Low-protein	2	160	118	1355	113
Low-protein	4	162	112	1390	116
Low-protein	22	160	107	1371	110
S.E. difference between two means		3.4	5.7	52	8.3

Feed and nutrient intake

The mean weights of DM consumed daily on each treatment are given in Table 3.14. On both the high- and low-protein concentrate treatments, the 2, 4 and 22 feeds daily had no significant effects (P>0.05) on the intake of silage DM and the total daily intake of DM expressed as either kg per cow or as a percentage of liveweight. The intakes of silage DM and the total DM intakes expressed as a percentage of liveweight were all higher on the high- compared with the low-protein concentrate treatments (Table 3.14), but the differences were again not significant (P>0.05). The intakes of drinking water expressed as either kg per cow or as kg per unit of DM (Table 3.14) were also unaffected by the treatments.

The daily intakes of ME (Table 3.15) were calculated from the DM intakes in Table 3.14 and values of 10.6 and 12.6 MJ/kg DM for the silage, and the high- and low-protein concentrates, respectively. The total daily ME intakes, and the intakes expressed as a percentage of requirement on the six treatments (Table 3.15) were not significantly (P>0.05) different.

The daily intakes and the requirements of DCP are given also in Table 3.15. The intakes of DCP were calculated from values of 95, 193 and 101 g DCP/kg DM for the silage, the high-protein and the low-protein concentrates, respectively. The DCP intakes and the intakes expressed as a percentage of requirement were significantly (P<0.01) higher on the high- compared with the low-protein concentrate treatments, but there were no significant differences (P>0.05) within the two concentrate treatments as a result of the frequency of treatments.

Table 3.16 Experiment 3.4 The mean daily milk yield, composition of the milk and the liveweight of the cows

Treatment		Milk yield (kg/cow)		Milk composition (g kg^{-1})					Mean liveweight	
Concentrate	Number of concentrate feeds per 24 hours	Un-corrected	Corrected to 4% fat	Fat	SNF	Total solids	Crude protein*	Lactose	(kg)	Daily change (kg/cow)
High-protein	2	17.3	18.8	43.1	88.0	131.1	33.5	46.7	519	+ 0.07
High-protein	4	17.7	19.4	43.6	88.4	132.0	33.2	47.4	513	+ 0.10
High-protein	22	17.2	19.4	45.8	89.1	134.9	33.3	47.8	522	+ 0.14
Low-protein	2	15.3	17.3	45.3	87.7	133.0	31.8	48.5	502	- 0.22
Low-protein	4	15.2	17.6	45.9	88.1	134.0	32.8	47.5	511	+ 0.15
Low-protein	22	15.9	19.1	48.3	88.5	136.7	33.2	47.4	516	+ 0.14
S.E. difference between two means		0.77	1.2	2.4	0.68	2.6	0.81	0.68	6	0.17

*N x 6.38

Milk yield, composition and liveweight

The mean daily milk yields per cow on each treatment are given in Table 3.16. The uncorrected yields were significantly ($P<0.05$) higher on the high- compared to the low-protein concentrate treatments, but there were no significant differences ($P>0.05$) within either the high- or the low-protein concentrate treatments (Table 3.16). When the milk yields were corrected to a standard 4% fat content, the yields on the six treatments were not significantly different ($P>0.05$). The fat, SNF, total solids, crude protein and lactose concentrations of the milk on the six treatments were not significantly different ($P>0.05$) and were all at a satisfactory level. The mean liveweight of the cows and the daily changes in weight on the various treatments (Table 3.16) were not significantly different ($P>0.05$).

Discussion

There have been few studies on the effects of the frequency of feeding concentrates on the total intake of feed, milk yield and the composition of milk. In the few reported investigations, the levels of feeding were not controlled and thus the effects of feeding frequencies were confounded by differences in feed intake. For example, Campbell and Merilan (1961) found that an increase in the frequency of feeding led to an increase in the yields of milk, fat and total solids with parallel changes in food intake. An increase in roughage consumption was noted also in the experiment of Kaufmann (1973) where the increase in the frequency of meal feeding had no apparent effect on milk yield but there was an increase in the content of milk fat. In a more recent study, Meinhold *et al* (1976) also reported

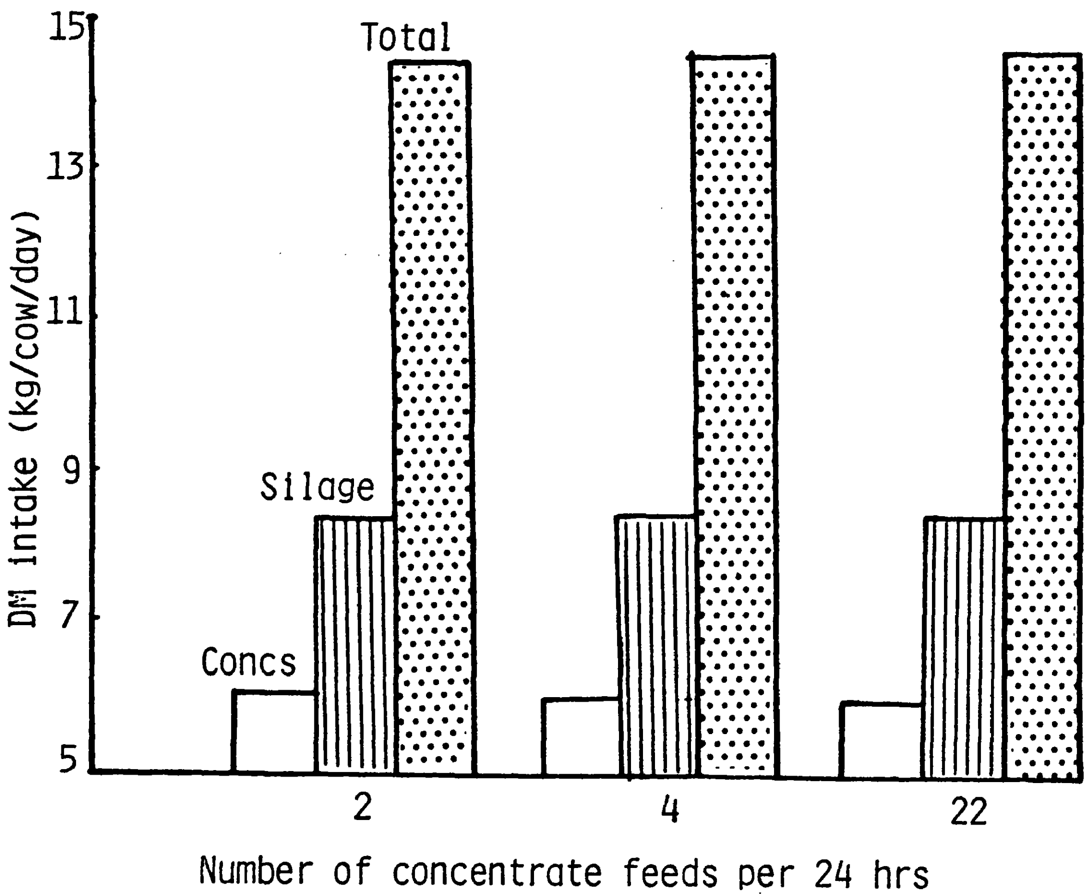


Fig. 3.7 Feed intake with high-protein (202 g CP/kg DM) concentrate

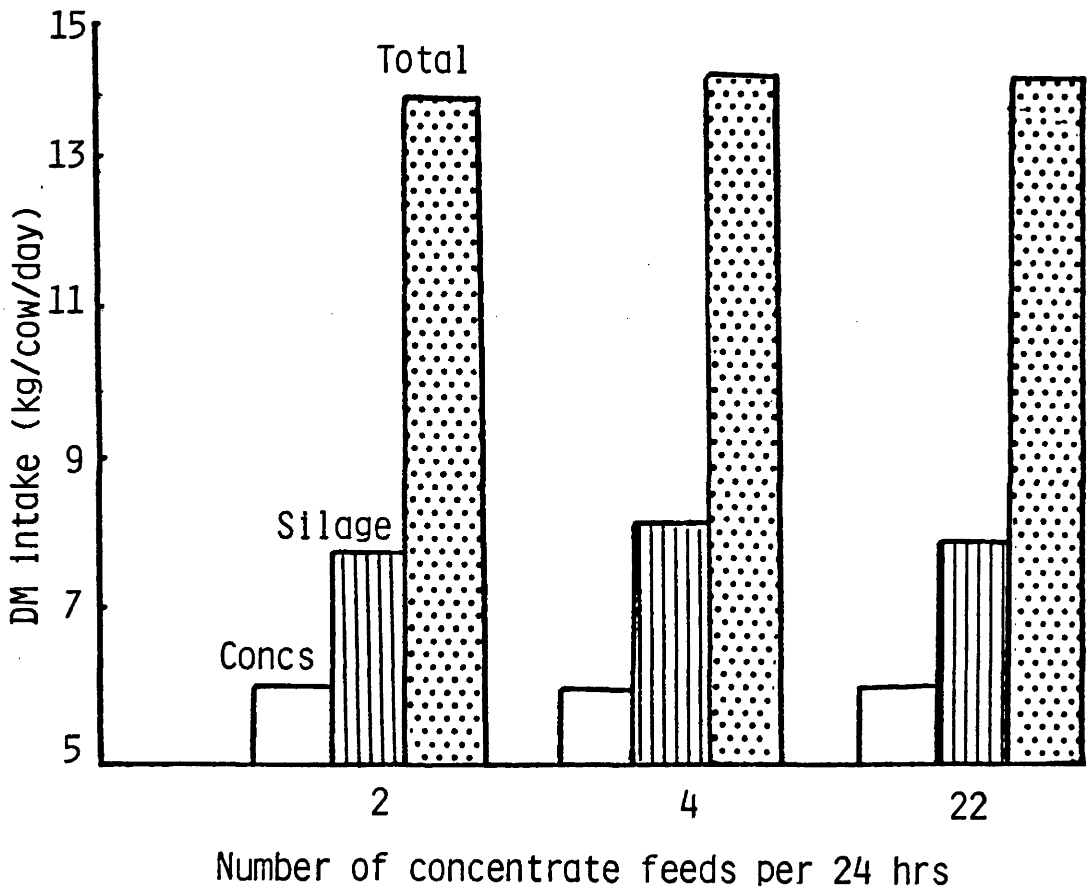


Fig. 3.8 Feed intake with low-protein (128 g CP/kg DM) concentrate

marked increases in the feed intake and in the yield of the fat-corrected milk when the cows were offered food four times instead of twice daily but milking was also increased from twice to four times per day. In contrast, two other recent studies showed no response to an increased frequency of feeding. For example, Smith et al (1978) found no apparent differences in DM intake, milk yields and the milk fat content when the diets of silage and concentrates were offered either once or twice daily. In the study of Linder et al (1979) the feeding of concentrates either twice or 6 times per day had little effect on forage intake, milk yields and the content of fat. The results of the present feeding experiment in which silage was offered ad libitum on all six treatments support the general findings of Smith et al (1978) and Linder et al (1979). The same weight of concentrates was consumed on all treatments (Table 3.14) but it was clear that a change in the frequency of feeding from 2 to 4 or 22 feeds per 24 hours had no major effect on silage intake, and hence on total DM intake (Figs 3.7 and 3.8). Thus, as a result, there were no significant effects on milk yield, milk composition and liveweight. The mean daily intake of concentrates on all the treatments was approximately 6.0 kg DM/cow which at the present moment is a fairly typical value for cows on good-quality grass silage, but it is possible that the results would have been somewhat different if much larger amounts of concentrates had been used.

Although there was no significant difference in the silage DM intake between the two concentrate treatments, the intake of silage DM was on average 5.4% higher on the high-compared with the low-protein concentrate treatments. Similarly, Gordon (1979) showed a 4.6% increase in the intake of silage DM when concentrates containing 174 rather than 137 g CP/kg DM were given to dairy cows.

In the present feeding experiment, higher ME and the DCP intakes on the high-protein treatments (Tabel 3.15) led to an average increase in the milk yields of 12.5%. This response to extra protein intake in the present trial agrees with other recent findings with silage diets. For example, a marked increase in milk yield was found by Gordon (1979) when the crude protein concentration of the concentrate supplement was increased from 95 to 209 g/kg fresh weight. In another study, Gordon and McMurray (1979) reported significant increases in milk yield when the crude protein in the concentrates was increased from 103 to 252 g/kg fresh weight. These responses in milk yield to increased protein intakes in the present experiment can be due to either an increase in the total feed intake (Gordon and McMurray, 1979; Castle and Watson, 1979) or an increase in the ration digestibility (Gordon, 1979). The small and non-significant increases in the CP and SNF contents of the milk on the high-protein concentrate treatments in the present experiment are in close agreement with the results of Gordon (1979).

A high protein content in the feeds can increase the demand for water (Agricultural Research Council, 1980) but in the present experiment there was no difference in the water drunk on the high- and low-protein concentrate treatments (Table 3.14). The average weight of water consumed on the six treatments was 3.60 kg per kg DM and this value is well within the range found in a survey of water intake on commercial farms (Castle and Thomas, 1975).

It is concluded that offering concentrates more than twice daily did not significantly affect (P>0.05) the silage intake, milk yield, milk composition and the liveweight. However, it must be emphasised that the daily milk yield of the cows averaged 16.4 kg per cow with a mean intake of concentrates of approximately 6.0 kg DM per day.

In addition, the silage was offered *ad libitum* with no competition between the cows. In these circumstances there was no justification for giving the daily ration of concentrates in more than two separate feeds per 24 hours.

EXPERIMENT 3.5

Introduction

In the previous experiment it was noticed that when cows were on treatments in which concentrates were dispersed automatically on top of the silage that some silage was accidentally eaten with the concentrates. This was to be expected as the cows could not grasp the concentrates without also eating some of the silage. The concentrates and silage were not thoroughly mixed but nevertheless the two foods were consumed together in one trough. Because of this observation it was thought worthwhile to conduct a further experiment in which concentrates were given either with silage or quite separately from the silage, and to record intake. This subsidiary experiment could also give a little information on the subject of complete diets for cows although it is appreciated that the foods given in the present experiment were not blended in a mixer wagon.

Blended complete diets are becoming more common especially in large dairy herds because of the ease of feeding (Holter et al, 1977). This method of feeding also reduces the large variation in the composition of the diet that may occur among cows which are free to select feed components offered separately (Coppock et al, 1974). In the studies of Wiktorsson and Bengtsson (1973), Marshall and Voigt (1975) and Holter et al (1977) there were no significant differences in the feed intake, milk yield and milk fat percentage when silages and concentrate were given either separately or blended. Baxter et al (1972) recorded similar DM intakes, but higher milk yields when silage and concentrate were given separately rather than blended. In the experiment of Palmquist *et al* (1964) the intake of hay was increased significantly when it was given separately from the concentrates. In The Netherlands, Rossing (1979) reported only small differences in milk yield, but a higher intake of roughage as a result of feeding concentrate mixed with roughage compared with the supply of concentrate through a programmed concentrate dispenser. More recently, Krohn and Andersen (1979) indicated that the feeding of barley, barley and fodder sugarbeet pulp, and fodder sugarbeet pulp mixed with silage all increased the feed consumption compared to the traditional method of feeding the individual feedstuffs separately.

The aim in the present experiment was to study the effect of feeding concentrates either separately from the silage or with the silage. The intake of silage, the liveweight of the cows and the water intake were recorded.

Experimental feeding and design

Four non-lactating Ayrshire cows which were on average 19 weeks pregnant (range 17 - 21 weeks) were used during a 9-week experimental period from 12 November 1979 to 13 January 1980. There were two treatments as follows:-

Treatment A: High-protein concentrate given separately from silage

Treatment B: High-protein concentrate given with silage

The grass silage was offered *ad libitum* to all the cows at 05.45, 10.30 and 16.30 hrs in sufficient quantities to ensure 10% refusal was available before the next feed. All the cows had access to the silage for about 21 h daily. On treatment A the three separate feeds of concentrate were given 15 minutes before the three meals of silage,

Table 3.17 Experiment 3.5 The daily intake of feed, the liveweight of the cows and the water drunk on the two treatments

kg per cow	Treatment		S.E. difference between two means
	Concentrate given separately from silage	Concentrate given with silage	
Silage DM intake	8.50	8.80	0.30
Concentrate DM intake	4.26	4.26	-
Total DM intake	12.76	13.06	0.29
DM intake as % of liveweight	2.14	2.23	0.06
Water drunk	17.6	19.5	3.1
Total water intake	47.8	50.9	3.0
Liveweight	598	585	2.6

whereas on treatment B the concentrates were tipped on top of the silage after the silage had been placed in the trough. The concentrate was given at the rate of 5 kg per cow/day, and this amount was kept constant for all the cows throughout the experimental period. A crossover design was used with 3 periods of 3 weeks each. Water intakes were recorded weekly for the first 2 weeks and daily during the last week of each period. The cows were weighed once per week.

Results and Discussion

The chemical composition of the silage and the high-protein concentrate were exactly the same as in the previous experiment except that the DM concentrations were 222 and 852 g per kg DM for the silage and the high-protein concentrate, respectively.

The mean intakes of DM, the liveweights and the water intakes on the two treatments are given in Table 3.17. The silage DM intake and the total DM intake were not significantly different ($P>0.05$) on the two treatments although there was a 3.5% increase in the silage DM intake and hence in the total DM intake as a result of feeding the concentrate with the silage. This result agrees broadly with those of other workers (Wiktorsson and Bengtsson, 1973; Holter et al, 1977) who reported small and non-significant increases in feed consumption when giving silages and concentrate blended rather than separately. In the work of Rossing (1979), the intake of roughage was somewhat higher when the concentrates were mixed with the roughage but this result was partly due to the higher intake of concentrates on the other diet when cows were given the roughage separately from the concentrates. The feeding of barley, barley and fodder sugarbeet pulp and fodder sugarbeet pulp mixed with silage increased the feed intake (Krohn and Andersen, 1979) by only 1 - 5% compared to separate feeding.

There were no significant differences ($P>0.05$) between the two treatments in the DM intake expressed as a percentage of liveweight, the mean liveweight and the water intake. A marked increase in the liveweight of cows given concentrates separately from silage could have been due to gut fill at the time of weighing.

Thus, from the results of the above experiment and from a study of the relevant literature it is clear that silage intake is not affected to any large extent by the system of feeding of the concentrates. The silage which is inadvertantly eaten with the concentrates is possibly not a large amount and does not have any marked effect on total silage intake. The practice of dispensing concentrates on top of the silage in the trough did not appear to introduce any bias into the experimental results. It could also be a little further evidence indicating that any merits of complete diets are not due to an increase in silage intake. However, this suggestion requires much further detailed investigation.

EXPERIMENT 3.6

Introduction

In the previous experiment (Expt 3.4) the effects of the frequencies of feeding on milk production in lactating cows was recorded, but no records were kept of the behaviour of the animals. To extend the overall investigation, a behaviour study with dry cows was therefore conducted. The aim of this experiment was to investigate the effect of the frequency of feeding treatments with the high-protein and the low-protein concentrates on the intake of silage, but primarily to record the eating and ruminating behaviour of the dairy cows.

Experimental feeding and design

Four non-lactating Ayrshire cows which were on average 19 weeks pregnant (range 17 - 22 weeks) were used during a 15-week experimental period from 12 November 1979 to 24 February 1980. There were four treatments as follows:-

Treatment	
Concentrate	Number of concentrate feeds per 24 hours
High-protein	2
High-protein	22
Low-protein	2
Low-protein	22

Grass silage was offered *ad libitum* to all the cows at 05.45, 10.30 and 16.30 hrs in sufficient quantities to ensure that 10% refusal was available for weighing before the next feed. The cows on all the treatments had access to the silage for about 21 h per day. The two feeds of concentrates were given in equal parts at 05.30 and 14.30 hrs whereas the 22 feeds of concentrates per 24 hours were given via the automatic feeder every hour except 06.00 and 15.00 hrs. The concentrates were offered at a flat rate of 5 kg per cow/day and this amount was kept constant throughout the entire experiment. The design of the experiment was a balanced 4 x 4 Latin Square with an extra fifth period. Each period was 3 weeks and during week 3 of each period a recording of the eating and ruminating behaviour was made using the same technique and equipment as in previous behaviour experiments at this Institute (Retter, 1978). Water intakes were recorded weekly during weeks 1 and 2 and daily during week 3 of each period. The cows were weighed once per week.

Results

Composition of the feeds

The chemical composition of the silage, the high-protein and the low-protein concentrates was the same as that in the previous experiment (Expt 3.4), except for small differences in DM concentrations which were 210, 850 and 847 g/kg DM for the silage, and the high- and low-protein concentrates, respectively.

Silage and concentrate intakes and eating behaviour

The average weights of DM consumed daily, and the eating

Table 3.18 Experiment 3.6 The daily intakes of DM and the eating behaviour on the four treatments

Treatment		DM intake during recording period (kg/cow)			Silage DM intake (kg/cow)	Total daily eating time* (min/cow)	Number of meals per day*	Mean length per meal (min)	Mean DM intake per meal (kg)
Concentrate	Number of concentrate feeds per 24 hours	Silage	Concen-trates	Total	mean of 5 days				
High-protein	2	6.62	4.25	10.87	6.64	206	15.7	13.1	0.69
High-protein	22	5.73	4.25	9.98	6.16	213	23.8	8.9	0.42
Low-protein	2	6.34	4.24	10.58	6.56	203	17.0	11.9	0.62
Low-protein	22	6.09	4.23	10.32	6.17	229	23.4	9.8	0.44
S.E. difference between two means		0.39	0.004	0.37	0.36	24.0	1.6	1.3	0.06

*Silage plus concentrates

Table 3.19 Experiment 3.6 The unitary eating, ruminating and chewing times

Treatment		Behaviour per kg DM intake			Total chewing time*		
Concentrate	Number of concentrate feeds per 24 hours	Eating (min)	Rumination (min)	No of boluses	min	Average chewing per bolus (sec)	min per kg DM intake
High-protein	2	18.9	36.6	41.6	603	52.7	55.5
High-protein	22	21.3	37.8	41.7	590	54.4	59.1
Low-protein	2	19.2	35.8	38.7	582	55.6	55.0
Low-protein	22	22.2	37.4	41.5	614	54.1	59.6
S.E. difference between two means		2.3	1.8	1.8	32	1.2	2.6

*Eating plus ruminating time

behaviour on the four treatments are given in Table 3.18. There were no significant differences (P>0.05) in the silage and the total DM intakes on the four treatments although the silage DM intake was highest when the concentrates were given in 2 instead of 22 feeds per 24 hours. The total eating time per day, the number of meals per 24 hours, the mean length of each meal and the DM intake per meal are given in Table 3.18. The total time spent eating, with an average value of 213 mins/24 hours and the mean length per meal were not significantly different (P>0.05) on the four treatments. As expected, the number of individual meals increased significantly (P<0.01) when the concentrates were given in 22 feeds rather than in 2 feeds per 24 hours. As a result of this increase in the number of meals the calculated DM intake per meal was significantly lower (P<0.05) on the 22 than on 2 feeds per 24 hours treatments.

Unitary eating, ruminating and chewing times

The various types of behaviour expressed as minutes per kg DM intake are shown in Table 3.19. There were no significant differences (P>0.05) between treatments in the time spent either eating or ruminating per kg of feed DM. Some aspects of the chewing time, i.e. the sum of the time spent eating and ruminating, are shown also in Table 3.19. The total chewing times were not significantly different (P>0.05) with an average value of 597 mins per 24 hours. As there were no significant differences between the intakes of DM on the four treatments (Table 3.18), the unitary chewing times did not vary significantly (P>0.05) and were on average 57.3 mins per kg DM. The number of boluses per kg DM intake and the average chewing time per bolus were also similar on the four treatments and were on average

Table 3.20 Experiment 3.6 The eating, idling and ruminating behaviour during the day (06.00 - 18.00 hrs), the water drunk and the liveweight of the cows

Treatment		Eating 06.00 - 18.00 hrs		Idling 06.00 - 18.00 hrs		Ruminating 06.00 - 18.00 hrs		Water drunk (kg/cow /day)	live-weight (kg)
Concentrate	Number of concentrate feeds per 24 hours	min per cow	as % of total eating time	min per cow	as % of total idling time	min per cow	as % of total ruminating time		
High-protein	2	145	70.5	434	51.8	146	36.7	17.9	592
High-protein	22	145	68.3	428	50.3	157	41.5	15.9	598
Low-protein	2	136	66.8	451	52.5	133	35.0	16.5	594
Low-protein	22	156	68.4	407	49.2	157	40.8	16.6	599
S.E. difference between two means		14	4.7	13	1.0	10	1.8	2.0	4.5

Table 3.21 Experiment 3.6 The behaviour after feeding, the idling time, the ruminating time and the number of boluses

Treatment		Length of meal after feeding (min)	Latency time (min)	Idling time		Ruminating time		Boluses per cow per day
Concentrate	Number of concentrate feeds per 24 hours			Total (min/day)	No of periods per day	Total (min/day)	No of periods per day	
High-protein	2	43.9	40.7	838	27.0	397	19.5	452
High-protein	22	39.8	34.5	851	32.0	377	19.6	416
Low-protein	2	42.3	42.9	858	29.8	379	18.6	409
Low-protein	22	40.1	37.5	826	31.0	386	19.8	428
S.E. difference between two means		3.0	7.7	33	1.4	24	1.1	30

41 per kg DM and 54 secs per bolus, respectively.

The time spent eating, idling and ruminating during the day, which is defined as the period between 06.00 and 18.00 hrs, and these times expressed as a percentage of total eating, idling and ruminating time per 24 hours are given in Table 3.20. The eating times and the times expressed as a percentage of total eating time were similar on each treatment and were not significantly different (P>0.05). On average the eating time between 06.00 and 18.00 hrs was 68.5% of the total eating time. Ruminating time during the day was also similar on all four treatments and again was not significant (P>0.05). However, when expressed as a percentage of total ruminating time it was significantly higher (P<0.01) on the treatments in which concentrates were given in 22 rather than in 2 feeds per 24 hours. There were no significant differences (P>0.05) in the idling times between the four treatments which averaged 430 mins per cow in the 12 hour period. On average, 51% of the total idling occurred during the day with no significant differences between treatments. The water drunk and the liveweights were not significantly different between the four treatments (Table 3.20).

Behaviour after feeding, and idling and ruminating times

The average length of the first meal after the silage was given to the cows (Table 3.21) was calculated from the three periods of eating on the three major meals each day. Latency time was defined as the time interval between the end of the three major meals of silage and the start of rumination, and the mean from the three values is given in Table 3.21. Both the length of the meal after feeding and the latency time increased when the concentrates were given in

2 rather than 22 feeds per 24 hours (Table 3.21), but the differences were not significant (P>0.05). There were also no significant differences (P>0.05) in idling times on the four treatments which, on average, was 843 mins per 24 hours. The average number of idling periods per 24 hours was 30.0 and were significantly (P<0.05) lower when concentrates were offered in 2 compared to 22 feeds per 24 hours. The daily time spent ruminating and the number of ruminating periods were similar on the four treatments, with overall averages of 385 mins and 19.4 periods per 24 hours, respectively. There were no significant differences (P>0.05) in the total number of boluses per day (Table 3.21) and the average was 426 per cow per day.

Discussion

This study was conducted to determine the effect of the frequency of feeding concentrates of either high- or low-protein content on feeding behaviour. When the concentrates were given twice daily rather than 22 times per 24 hours the silage DM intakes were increased slightly, but this was not associated with an increase in the total daily eating times (Table 3.18). The total eating times on the four treatments were similar and averaged 213 mins per 24 hours. This value agrees with the results of an experiment where a grass silage was given with high-protein cubes, and the total eating time was 263 mins per 24 hours (Retter, 1978). In the study of Wilson and Flynn (1976b), beef cattle spent 276 mins per 24 hours eating silage supplemented with barley. In contrast, it has been shown clearly that cows spent comparatively more time eating silage offered without any supplementary foods. For example, in a comparison of silages with chop lengths of 9 mm, 17 mm and 72 mm, the total daily eating times were 329, 395 and 368 mins, respectively (Retter, 1978). In another behaviour study, silages with chop lengths of 83 mm and 120 mm resulted in total eating times of 416 and 371 mins per 24 hours, respectively (Deswysen and Vanbelle, 1976). It has been proposed that the total time spent chewing (eating time plus ruminating time) per kg DM should be used as an index of the physical property of fibrousness (Balch, 1971). The unitary eating and ruminating times were therefore pooled (Table 3.19) to give the total chewing time per kg DM intake. As stated earlier, when concentrates were offered in 22 feeds rather than in 2 feeds per 24 hours the total DM intakes were decreased (Table 3.18) and thus the chewing time per kg DM was slightly higher on this treatment. The mean chewing time of 57.3 mins per kg DM on the four treatments (Table 3.19) was much lower than the values of 91.0 mins and 117.4 mins recorded for short chopped silages and long chopped silages (Castle et al, 1979). This large difference is attributed to the fact that concentrates contributed 41% of the total DM intake in the present experiment whereas in the experiment of Castle et al (1979) the cows were offered a ration of silage only. In general, this trend is in accord with the values for grass silage alone and hay plus concentrates given by Balch (1971).

The effects of the frequency of feeding on the ruminating behaviour of animals were reported in two previous studies. Rakes et al (1957) found that growing heifers offered alfalfa orchard grass hay 10 times daily had a markedly higher rumination time per 24 hours than those offered hay twice daily. In contrast, sheep spent a substantially shorter time ruminating when they were given hay and concentrates in eight feeds instead of two feeds per 24 hours (Gordon and Tribe, 1952). The average ruminating time in the present study of 385 mins per 24 hours was lower than the value of 512 mins recorded for the non-lactating cows given short chopped silage alone (Retter, 1978). This is again attributed to the relatively high proportion of concentrates in the total diet in the present behaviour study. In the studies of Balch (1971), ruminating times of 47 mins and 20 mins per kg DM intake were recorded when concentrates contributed 33% and 93% of the total diet of hay plus concentrates. The ruminating time during the "day" (06.00 - 18.00 hrs) expressed as a percentage of total ruminating time was significantly higher ($P<0.01$) when concentrates were given in 22 feeds rather than in 2 feeds per 24 hours, and may be due to the higher silage intakes during the day (06.00 - 18.00 hrs) on these treatments. It has been reported that the lag time between the end of a major meal of silage and the beginning of rumination, i.e. latency time, is greater for long-chopped silages than short-chopped silages (Deswysen et al, 1978; Retter, 1978; Deswysen, 1980). In the present experiment, a uniform silage with the same chop length was offered on all four treatments but there was a marked increase in the length of the meal time after feeding and also in the latency time (Table 3.21) as a result of feeding concentrates in 2 instead of 22 feeds per 24 hours. Similarly in another behaviour study where grass silage was offered with high-protein cubes (Retter, 1978), it was found that increases in the length of the meal after feeding were associated with higher latency times. In the present experiment, some of the apparent differences in silage DM intake, chewing time per kg DM intake and the latency time on the four treatments were not significant ($P>0.05$) due to the large error terms. This was due to a number of causes. Only four animals could be recorded at any one time because of the large amount of labour involved in the study, and this lack of replication increased the errors although a 4 x 4 Latin Square design plus a fifth period was used. Furthermore, there was a fairly large variation between the individual cows, and the differences between recordings from successive days with the same animals also affected the behaviour results derived from the same cows. As a result, in the present experiment, with the total DM intakes similar on the four treatments and the variability high with behaviour measurements, there were no significant effects with most of the feeding behaviour parameters. Although this experiment was conducted to investigate the eating behaviour of the cows on the four different feeding treatments, it is of interest to note also the effect of the different crude protein contents of concentrates on the intake of silage. In contrast to the results in the previous experiment, the intake of silage was not increased on the high-protein concentrate treatment. This lack of response to the high-protein concentrates is contrary to other recent experimental results (Laird et al, 1979; Gordon, 1979) and this may be due to the fact that non-lactating cows were used in the present experiment and these animals had a low DM intake equivalent to only 1.8% of liveweight. In other studies with a large number of lactating animals (Laird et al, 1979; Gordon, 1979) the intake of DM was equivalent to 3.3% of liveweight (Gordon, 1979).

Offering concentrates in 22 rather than 2 feeds per 24 hours decreased the silage DM intake by 7%. Kaufmann (1976) obtained a 4.3% increase in the roughage intake by giving roughage and concentrates in 7 rather than 2 feeds per day. More recently, Linder et al (1979) reported an increase of 9.5% in the forage DM intake when forage and concentrates were given in 6 feeds instead of 2 feeds per 24 hours.

However, in another comparison, (Linder et al, 1979) the feeding of concentrates in 6 rather than 2 feeds per 24 hours increased the forage DM intake by only 2.6% but this small increase was not signficant. In a preliminary study by Castle and Watson (Private communication) there were substantial increases in silage intake when barley was offered in 22 rather than 2 meals per 24 hours. More frequent feeding in the present experiment did not increase the silage intake which is in contrast to these other experiments (Kaufmann, 1976; Linder et al, 1979; Castle and Watson, Private communication).

EXPERIMENT 3.7

Introduction

In the previous experiments (Expts 3.4 and 3.6) there was no interaction between the frequency of feeding treatments and the two levels of crude protein in the concentrates which differed by 74 g per kg DM. This difference is similar to that likely to be found in concentrates used in commercial practice but a further experimental study with a wider difference in protein content was felt to be worthwhile.

In this experiment, the effects of giving supplements of either barley or soyabean meal in either 2 or 22 feeds per 24 hours on the intake of silage, milk yield, milk composition and liveweight were investigated.

Experimental feeding and design

There were four feeding treatments as follows:-

Treatment	
Type of supplement	Number of supplement feeds per 24 hours
Bruised barley	2
Bruised barley	22
Soyabean meal	2
Soyabean meal	22

Table 3.22 Experiment 3.7 The composition of the silage, barley and the soyabean meal

	DM (g/kg^{-1})	Crude protein	True protein	Crude fibre (g/kg DM)	Ether extract	Ash	D-value
Silage	262*	173	83	272	54	135	58.7
Barley	812	103	96	72	20	23	ND
Soyabean meal	861	510	483	85	21	67	ND

*Determined by the toluene distillation method (Dewar and McDonald, 1961)

ND = not determined

In addition, a basal ration of grass silage was offered *ad libitum*. The silage was offered to the cows at 06.30, 10.30 and 16.30 hrs in sufficient quantities to ensure that 10% refusal was available for weighing before the next silage feed. All the cows had access to the silage for about 20 h daily. The concentrate supplements on the two frequency of feeding treatments were given either in equal portions twice daily at 05.35 and 14.30 hrs or 22 times per 24 hours every hour except 06.00 and 15.00 hrs using automatic feeders. Both the barley and the soyabean meal were given at a flat rate of 5 kg per cow/day. This amount was kept constant for all the cows throughout the entire experimental period.

Four Ayrshire cows which had calved on average 26 weeks (range 24 - 27 weeks) before the start of the experiment and which had similar milk yields were allotted at random to the treatment sequences in a 4 x 4 balanced Latin Square design with four periods of 3 weeks each. The experiment lasted from 12 February 1980 to 12 May 1980 and the results from week 3 in each period were used. The water intake of each cow was recorded daily in week 3 of each period and the cows were weighed every Wednesday and Thursday at 15.00 hrs.

Results

Composition of the feeds

The D-value of the silage (Table 3.22), determined by the *in vitro* technique of Alexander and McGowan (1969), was 58.7. The mean pH of the silage was 4.16 ± 0.18, with concentrations of NPN and ammonia-N in the total N of 521 and 112 g kg^{-1}, respectively. The composition of the barley and the soyabean meal is given also in Table 3.22. The

Table 3.23 Experiment 3.7 The daily intake of feed and drinking water on the four feeding treatments

Treatment		DM (kg/cow)			Daily DM intake as % of liveweight	Drinking water (kg/cow)	kg water per kg DM consumed*
Supplement	Number of concentrate feeds per 24 hours	Silage	Concen-trate	Total			
Barley	2	8.52	4.06	12.58	2.37	31.7	3.77
Barley	22	7.70	4.06	11.76	2.26	31.0	3.89
Soyabean meal	2	8.06	4.30	12.36	2.34	46.0	4.74
Soyabean meal	22	8.74	4.30	13.04	2.47	43.2	4.61
S.E. difference between two means		0.65	0.03	0.66	0.11	3.4	0.36

*Allowance made for the water content of the milk (ARC, 1980)

Table 3.24 Experiment 3.7 The daily intake and requirements of metabolizable energy and digestible crude protein

Treatment		ME Intake		DCP intake	
Supplement	Number of concentrate feeds per 24 hours	MJ per cow	intake as % of requirement	g per cow	intake as % of requirement
Barley	2	130	114	1330	148
Barley	22	123	113	1233	150
Soyabean meal	2	123	84	2933	315
Soyabean meal	22	129	85	3014	323
S.E. difference between two means		5.8	15	81	10

dry matter content and the concentrations of crude protein, true protein, crude fibre and ash were all higher in the soyabean meal than in the barley.

Feed and nutrient intake

The mean weights of DM consumed daily on each feeding treatment, and the intakes expressed as a percentage of liveweight are given in Table 3.23. There were no significant differences ($P>0.05$) in the silage DM intake and the total DM intake between the four treatments. The total DM intake expressed as a percentage of liveweight was 2.47% on the soyabean meal and was higher than 2.26% on the barley when both were given 22 times per 24 hours but differences were again not significant ($P>0.05$). The DM intakes expressed as percentages of liveweight were also not significantly different ($P>0.05$) when either the barley or the soyabean meal were given in 2 and 22 feeds per 24 hours. The intakes of drinking water expressed as either per cow or as kg per unit of DM (Table 3.23) were significantly higher ($P<0.01$) on the soyabean meal than on the barley treatments, but there were no significant differences ($P>0.05$) between the feeding frequency treatments within the two supplements.

The intakes of ME (Table 3.24) were calculated from the DM intakes (Table 3.24) and values of 8.7, 13.7 and 12.3 MJ/kg DM for the silage, barley and soyabean meal, respectively. There were no significant differences ($P>0.05$) in the ME intakes and the intakes expressed as a percentage of requirement between the four treatments.

The intakes of DCP (Table 3.24) were calculated from values of 119, 78 and 459 g DCP/kg DM for the silage, barley and soyabean meal, respectively, and the DM intakes in Table 3.23. The DCP intake

Table 3.25 Experiment 3.7 The mean daily milk yield, composition of the milk and the liveweight of the cows

Treatment		Milk yield (kg/cow)		Milk composition /g kg^{-1})					Mean liveweight	
Supplement	Number of concentrate feeds per 24 hours	Un-corrected	Corrected to 4% fat	Fat	SNF	Total solids	Crude protein*	Lactose	(kg)	Daily change (kg/cow)
Barley	2	10.6	11.9	44.7	84.4	129.1	32.6	44.3	535	- 0.08
Barley	22	9.4	11.2	47.5	83.5	131.0	33.4	42.4	524	+ 0.01
Soyabean meal	2	12.7	11.6	36.7	85.7	122.4	34.5	44.3	532	+ 0.92
Soyabean meal	22	12.3	11.6	37.8	85.4	123.2	34.9	43.5	531	+ 1.08
S.E. difference between two means		0.54	0.51	2.2	1.1	2.7	0.60	0.90	10	0.64

*N x 6.38

expressed as either g per cow or as a percentage of requirement was significantly higher (P<0.001) on the soyabean meal than on the barley treatments (Table 3.24). There were no significant differences in the DCP intakes within the barley and the soyabean meal treatments.

Milk yield, composition and liveweight

The mean daily yields of milk per cow in each treatment are given in Table 3.25. The yields were significantly higher (P<0.001) on the soyabean meal than on the barley treatments. The feeding frequency of the barley and the soyabean meal in either 2 or 22 feeds per 24 hours did not affect the milk yields significantly (P>0.05). When the yields were corrected to a standard level of 4% fat content, the yields were not significantly different (P>0.05) on the four treatments (Table 3.25). There were no significant differences (P>0.05) in the fat, SNF, total solids, crude protein and lactose concentrations of the milk when barley and soyabean meal were given in either 2 or 22 feeds per 24 hours (Table 3.25). The fat and the total solids content of the milk were significantly higher (P<0.01) on the barley than on the soyabean meal treatments. The crude protein concentration of the milk was significantly higher (P<0.01) on the soyabean meal than on the barley treatments. There were no significant differences (P>0.05) in the mean liveweights and the daily changes in weight of the cows between the four treatments (Table 3.25).

Discussion

There are reports of increases in feed consumption, daily milk yield and milk fat content when the food offered to dairy cows is given at frequent intervals rather than at infrequent intervals. For example, in the experiment of Campbell and Merilan (1961) there was an increase of 7.3% and 8.5% in intake when the food was provided either in 7 or 4 feeds per day, respectively, compared with two feeds per day. In a series of experiments, Kaufmann (1976) obtained an increase of 4.3% in the roughage intake by giving roughage and concentrates in 7 feeds per day instead of two. This worker suggested that frequent feeding maintained a high rumen pH value and cellulolytic activity, which in turn led to a faster rate of passage and thus higher intakes of roughage. More recently, Linder et al (1979) reported a 9.5% increase in the forage DM intake when the forage and the concentrates were given in 6 rather than in 2 feeds per day. In a preliminary study, Castle and Watson (Private communication) obtained substantial increases in silage intake by offering a barley supplement in 22 rather than in 2 meals per 24 h, whereas in the present experiment, the feeding of barley in 22 feeds per 24 hours did not increase the silage DM intake (Table 3.23). No logical explanation can be given for these contrasting results. There was, however, an 8.4% increase in the intake of silage DM as a result of feeding soyabean meal in 22 rather than 2 feeds per 24 hours. The silage DM intake was increased by feeding soyabean meal in 22 feeds per 24 hours compared to barley in either 2 or 22 feeds per 24 hours (Table 3.23), but there were no clear reasons to explain the lower intake of silage DM on the soyabean meal compared to the barley when given twice per day (Table 3.23).

The cows used in the present experiment had low daily milk yields, 9.4 to 12.7 kg/cow, (Table 3.25) as they were late in lactation, and the total DM intakes were much lower than in other experiments with higher yielding cows (Castle and Watson, 1979; Castle et al, 1980). More frequent feeding has been reported to increase milk yield with parallel changes in the food intake (Campbell and Merilan, 1961; Meinhold et al, 1976). For example, there was an increase of 14.2% and 15.1% in fat corrected milk yield as a result of feeding either 4 or 7 times per day, compared to twice per day (Campbell and Merilan, 1961). These workers suggested that the higher dry matter digestibility of 3.9 and 3.5% in the treatments given food 4 or 7 times per day would account for the increase in the milk yields as compared to the twice daily feeding treatment. In the study of Linder et al (1979), frequent feeding of forage and concentrates increased the forage consumption markedly but with little effect on milk yield. In the work of Mochrie et al (1956), the animals were given 2, 4 and 8 meals per day in closely controlled amounts, but again the feeding frequency did not affect the milk yield. More recently, Thomas and Kelly (1976) found little difference in milk yields when feed was offered in either 2 or 24 meals per 24 hours to meet either 100% or 80% of the standard requirements for energy. In the present experiment, the feeding of soyabean meal in 22 rather than in 2 feeds per 24 hours increased the total feed intake (Table 3.23) but there was no increase in the milk yield (Table 3.25). The intake of silage DM was 10.7% higher when barley was given in 2 feeds rather than 22 feeds per 24 hours and this resulted in an 12.8% increase in milk yield. The feeding of the soyabean meal increased the DCP intakes to over 300% of requirements (Table 3.24) and this resulted in 25% more milk compared to the barley treatment. The response to this extra DCP supplied by the soyabean meal was 0.15 kg milk per 0.1 kg additional DCP and was much lower than the response in other experiments. For example, the response from soya of 0.38 kg milk (Retter, 1978), the response from groundnut of 0.49 kg milk (Castle and Watson, 1976) and 0.43 kg milk (Castle *et al*, 1977a). The low response in the milk yield to the extra DCP intake in the present experiment was probably due to the use of cows with low milk yields as compared to the use of higher yielding cows in other experiments (Castle and Watson, 1976; Castle *et al*, 1977a; Retter, 1978). The intake of DCP was also extremely high (Table 3.24) with hence a diminishing response rate. When the milk yields were corrected to a standard 4% fat content (Table 3.25) the differences in the yields between the four treatments were not significant (P>0.05) which suggests that the total energy inputs were similar on each treatment.

It is claimed that an increased frequency of feeding keeps the ratio of acetic to propionic acid in the rumen at about 3:1 (Kaufmann, 1976) and therefore prevents a decrease in the milk fat content (Campbell and Merilan, 1961; Kaufmann, 1973; Sutton *et al*, 1978; Johnson, 1979). In the present experiment, slight increases in the milk fat content (Table 3.25) were obtained by feeding supplements of both barley and soyabean meal in 22 rather than in 2 feeds per 24 hours but these increases were not significant. The higher milk fat concentrations (Table 3.25) with supplements of barley than with soyabean meal are in line with the results of Castle and Watson (1976) who reported clear-cut increases in milk fat content when a supplement of barley rather than of groundnut was given with silage diets. A higher energy intake as a result of the frequent feeding of concentrate supplements can lead to an improved supply of microbial protein to the intestines (Kaufmann, 1976) and this can therefore prevent a decrease in the milk protein content. The feeding of both the barley and the soyabean meal in 22 feeds rather than 2 feeds per 24 hours showed small increases in the crude protein concentration in the milk (Table 3.25) but these were not significant. However, the extra protein intake on the soyabean meal treatments clearly increased the milk protein contents (Table 3.25). Gordon and McMurray (1979) also reported significant increases in the crude protein content of the milk when the crude protein content of the supplementary concentrate was increased from 10.3% to 21.2%.

A high protein feed (ARC, 1980) and a high dry matter content in the feed (Castle and Thomas, 1975) can increase the demand for water. The drinking water intake in the present study was, on average, 13.3 kg per day higher on the soyabean meal than on the barley treatments. Cows drink more water on a high- compared to a low-protein diet because they require a large urine volume for the excretion of nitrogenous end products (ARC, 1980).

It is concluded that the feeding of supplements of either barley or soyabean meal in either 2 or 22 feeds per 24 hours had no significant effect on silage DM intake, milk yield, milk fat, milk protein and the total solids contents of the milk. The results of the present experiment are thus in close agreement with those from experiments 3.4 and 3.6.

SUMMARY AND CONCLUSIONS

Three experiments were conducted to investigate the effects of giving the total daily allowance of concentrates to dairy cows in frequent feeds compared with two feeds per 24 hours, with *ad libitum* grass silage. The results of these three experiments are reported in this chapter. The D-value of the silage was 65.5 in Expts 3.4 and 3.6 and 58.7 in Expt 3.7.

In Expt 3.4, the silage DM intakes and the milk yields were similar when the high-protein and low-protein concentrates were given in 2, 4 and 22 feeds per 24 h. Similarly, in Expt 3.7 where supplements of either barley or soyabean meal were offered in 2 and 22 feeds per 24 h, the frequency of feeding had little effect on the daily intake of silage and milk yields. Although a small decrease in the silage DM intake occurred when concentrates (Expt 3.6) and barley (Expt 3.7) were given in 22 feeds instead of 2 feeds per 24 h, there were small increases in the milk fat content and total solids of the milk when concentrate supplements were given in 22 rather than in 2 feeds per 24 h (Expts 3.4 and 3.7).

A small increase in the intake of silage DM on the high- compared with the low-protein supplements increased the milk yields markedly in Expts 3.4 and 3.7. However, the level of protein in the concentrate supplement did not affect the milk composition in Expt 3.4 although in Expt 3.7 the fat content and the total solids content of the milk were substantially higher on the barley than on the soyabean meal. The crude protein content of the milk was markedly higher on the soyabean meal than on the barley. In Expt 3.6, the silage DM intake on the high- and low-protein concentrates and the feeding behaviour of the cows on the four treatments was similar.

It is concluded that with dairy cows yielding a maximum of 18 kg milk/day there appears to be no advantage in offering the concentrates more frequently than the common recommendation of two meals per 24 h. However, a significant response in milk yield can be obtained by increasing the protein content of the concentrate supplements.

C H A P T E R 4

GENERAL DISCUSSION

GENERAL DISCUSSION

In Chapter 3 a series of feeding experiments with lactating dairy cows was reported in which the effects of different types of supplementary foods on the feed intake, milk yield, milk composition, water consumption and liveweight change were investigated. The results of these experiments were discussed individually and conclusions were drawn, but in the present chapter all the results will be integrated and evaluated with respect to information available from the literature.

Feed intake

The feeding of silage as the sole constituent of the diet is generally considered to supply inadequate amounts of nutrients to obtain high milk yields from lactating dairy cows (Castle and Watson, 1975; Retter, 1978). Thus, in order to achieve high milk yields, supplementary foods were given with the silages in the experiments reported in Chapter 3.

Supplementation of silage generally reduces the intake of silage and the size of the reduction depends on the type and level of supplement offered. In the experiments described in Chapter 3, different types and amounts of supplementary foods were used, but it was not always possible to calculate the substitution rate (decrease in silage DM intake per kg supplement DM) between the various supplements and treatments as the control treatment of silage only was not included in some experiments. However, the general effects of the supplements on silage intake merit some further discussion.

In Expt 3.1, hays in the long, short and ground and cubed forms were used as the supplements to the silage. The hay in the ground and cubed form was particularly useful in maintaining a high voluntary intake of silage and gave marked increases in the total forage intakes compared with the long and short hay supplements. The increases in the forage intakes by giving hay in the ground form compared with the long and short hays was 9.9% and 8.6% on the low concentrate treatment and 14.2% and 14.9% on the high concentrate treatment. In previous feeding experiments at this Institute, hay in different physical forms was not studied but long hay only was used as a silage supplement (Retter, 1978). In one experiment, supplements of long hay with D-values of 62.8 and 70.0 gave similar substitution rates, with an average reduction of 0.88 kg DM of silage per kg hay DM. In the experiment of Tayler and Aston (1976a) substantial increases in silage intake were obtained by changing the physical form of the dried grass supplement. In that study, dairy cows consumed 11% more silage with a supplement of dried grass pellets (MF 0.63) than a supplement of wafers (MF 2.63) when both were given in the same quantities with silage _ad libitum_. The fineness of forages can affect the physical breakdown (Castle _et al_, 1979; Deswysen, 1980), and the rate of passage of the feed (Deswysen, 1980), and therefore it can influence the forage intake. In Expt 3.1, the concentrate supplement reduced forage intake to a lesser extent than the supplement of hay and was therefore helpful in giving a larger increase in the total DM intake. The substitution rate of 0.50 kg forage DM/kg concentrate DM was much lower than the mean value of 0.84 kg silage DM/kg hay DM calculated from eight separate comparisons (Retter, 1978). In Expt 3.2, supplements of barley and sugarbeet pulp had smaller effects on forage intake than concentrate in Expt 3.1 and reduced the intake of silage DM by only 0.44 and 0.36 kg per kd DM of barley and sugarbeet pulp, respectively. In this experiment, it appeared that the addition of relatively small amounts of soyabean meal to the main supplements of either barley or sugarbeet pulp had partially offset the effect of giving barley and sugarbeet pulp alone. For example, the substitution rate of barley plus soya was 0.44 kg DM compared to 0.51 kg DM with a supplement of barley alone (Castle and Watson, 1975; 1976). Similarly, a small depression in silage DM intake of 0.32 kg per kg DM occurred with a mixture of 83% barley and 17% groundnut (Castle and Watson, 1976). In Expt 3.3, there were no major decreases in the intake of silage DM when increasing amounts of a high-protein concentrate were consumed with the low and the high D-value silages. In this particular experiment, both the silages had high intake characteristics and the mean daily intake of silage DM of 11.9 kg per cow was higher than the intake in the other experiments reported in Chapter 3. The high-protein supplement did not reduce the silage intake as found with the low-protein concentrate in Expt 3.1, and the supplements of barley and sugarbeet pulp in Expt 3.2.

The effect of giving high-protein concentrates with silage was also noted when comparing the forage intakes in Expts 3.1 and 3.3. From the results of these two experiments, it was calculated that the intake of forage DM was 2.46 kg per day higher in the high-protein concentrate treatment (Expt 3.3) than on the low-protein concentrate treatments (Expt 3.1) when approximately the same amounts of concentrates were eaten with silages of similar D-value. The results of Expt 3.3 agree with the results of other experiments at this Institute in which supplements of high-protein concentrates such as groundnut and soyabean meal did not depress the intake of silage DM. The feeding of groundnut in two experiments (Castle and Watson, 1976;

Castle *et al*, 1977a) increased the mean intake of silage DM by 0.14 kg/kg supplement DM. Soyabean meal had a similar effect to groundnut and increased silage DM intake by 0.06 kg per kg DM soyabean meal (Retter, 1978).

In the recent work of Steen and Gordon (1980b), it was noted that forage DM intake decreased when increasing levels of concentrate were given with a diet of high-digestibility silage. These workers found reductions in forage intake of 0.52 and 0.36 kg DM/kg concentrate DM with 68 and 64 D-value silages, respectively. This type of decrease in the intake of silage DM did not occur in Expt 3.3 when increasing levels of high-protein concentrates were given with low D and high D-value silages. It would seem that the fairly high levels of supplementation, and the use of concentrates with a low crude protein content as used in the experiment of Steen and Gordon (1980b) caused the difference between the results of the two experiments. The significant difference in the silage DM intake on the low compared with the high D-value silages in Expt 3.3 was probably a reflection of the high crude fibre concentration in the low D-value silage. The physical breakdown and the rate of digestion of crude fibre is reduced when the forages mature and this can lead to a slow removal of digesta from the rumen and influence intake (Osbourn, 1980).

The effect of giving concentrate supplements in more than two feeds per 24 hrs on feed intake, milk yield and milk composition was investigated in Expts 3.4, 3.6 and 3.7. In all the three experiments, the silage was offered *ad libitum* and the mean daily concentrate DM intake was 4.99 kg per cow. From the results of these three experiments it was noted that the number of concentrate feeds per 24 hrs had no significant effect on the silage DM intake and hence on the total DM intakes. There were only small and non-significant increases in the daily silage DM intake of 0.14 and 0.02 kg per cow with the high- and low-protein supplements, respectively, in Expt 3.4, and 0.68 kg with the high-protein supplement in Expt 3.7 when the supplements were offered in 22 rather than in 2 feeds per 24 hrs. In contrast, larger decreases in the silage DM intake of 0.48 and 0.39 kg/day with high- and low-protein supplements in Expt 3.6 and 0.82 kg per cow with barley in Expt 3.7 occurred when concentrate feeds were given in 22 instead of 2 feeds per 24 hrs. The results of the feed intake in the above three experiments on feeding frequency are discussed in relation to other frequency of feeding experiments in which food was not given in restricted amounts. Smith <u>et al</u> (1978) reported a decrease in the daily feed intake of 0.20 kg per cow when forage and concentrates were provided in two instead of one feed per day. In the experiment of Linder <u>et al</u> (1979), the mean daily concentrate intake was 6.50 kg per cow, and when the concentrates were offered in six feeds per day there was a daily increase in the forage DM intake of 0.30 kg per cow compared with twice daily feeding. In a further comparison, these workers reported an increase in the daily intake of forage DM of 1.10 kg per cow by feeding forage and concentrates in six feeds compared to two feeds daily. In the experiments of Kaufmann (1976), the mean daily concentrate intake was 11.0 kg DM per cow and the daily intake of hay DM increased by 0.24 kg per cow when hay and concentrate were offered in seven feeds rather than in two feeds per day. Campbell and Merilan (1961) also reported an increase in the daily feed intake of 1.5 and 1.3 kg per cow when dairy cows were offered their daily feed in either four or seven meals, respectively, instead of twice daily. From the results of the three frequency of

Table 4.1 The daily intakes of feed in the different experiments

Expt No.	Total DM intake (kg per cow)	Daily DM intake as % of liveweight
3.1	13.25	2.77
	13.19	2.79
	14.24	2.97
	14.90	3.07
	14.89	3.04
	15.98	3.25
3.2	12.59	2.66
	15.35	3.16
	15.87	3.22
3.3	12.20	2.36
	13.94	2.67
	14.77	2.82
	13.87	2.66
	15.21	2.93
	16.42	3.09
3.4	14.44	2.79
	14.58	2.84
	14.57	2.80
	13.92	2.76
	14.14	2.77
	14.03	2.73
3.5	12.76	2.14
	13.06	2.23
3.6	10.87	1.84
	9.98	1.67
	10.58	1.78
	10.32	1.72
3.7	12.58	2.37
	11.76	2.26
	12.36	2.33
	13.04	2.47

feeding experiments and the information available in the literature it appears that an increase in the frequency of feeding has an extremely variable effect on intake.

The total DM intakes expressed as either kg per cow or as a percentage of liveweight have varied quite widely in the experiments reported in Chapter 3, and a summary of the data is given in Table 4.1. In Expts 3.1, 3.2, 3.3, 3.4 and 3.7 lactating dairy cows were used, whereas Expts 3.5 and 3.6 were conducted with dry cows. An increase in the level of supplementation reduced the intake of silage DM in Expts 3.1 and 3.2 as previously reported but led to an increase in the total DM intake. Similar results have been noted in other experiments (Retter, 1978; Castle _et al_, 1980) where an increase in the amount of supplementary foods depressed silage intake, but gave an increase in the intake of total DM. There was a particularly low DM intake of 2.66 and 2.36% of the liveweight in Expts 3.2 and 3.3 when low-digestibility silages were eaten with only small amounts of concentrates. Several experiments have indicated that a diet of silage offered either alone or with a small amount of low-protein concentrates will limit intake per cow (Castle _et al_, 1977a; Retter, 1978 and Castle _et al_, 1980). In these three experiments, a diet of high-digestibility silage was offered alone as a control treatment and the mean DM intake was equivalent to 2.42% of the liveweight. In Expt 3.3 the mean intake of 2.89% of the liveweight on the high-D silages compared to 2.62% on the low-D silages was the result of significant increases in the silage DM intake on the high-D silage treatments. The important feature of the high-protein concentrate in increasing the forage intake and hence the total DM intake was also noted when the results of Expts 3.1 and 3.3 were compared. In these two experiments, the mean intake of 2.84% of liveweight on the low-protein concentrate treatments (Expt 3.1) was clearly lower than the 3.09% on the high-protein concentrate treatment (Expt 3.3) when approximately the same amounts of concentrates were eaten with similar D-value silages. A similar result was obtained in Expt 3.4, with mean intakes of 2.81% and 2.75% of the liveweight on the high- and the low-protein treatments, respectively. This confirms that the high-protein supplements did not depress the silage intake to the same extent as the low-protein supplements and therefore resulted in higher total DM intakes. Similar results were noted by other workers when low-protein supplements were compared with high-protein supplements on a basal diet of silage. In the experiment of Castle and Watson (1976), intakes of DM expressed as a percentage of liveweight were 2.80% and 2.87% on supplement treatments with either barley alone or a mixture of barley and groundnut. In another experiment, the mean intakes were 2.26% and 2.40% of liveweight with supplements of sugarbeet pulp and groundnut, respectively (Castle et al, 1979). In Expts 3.5, 3.6 and 3.7, the amounts of supplementary foods on offer were similar to those in Expts 3.1, 3.2 and 3.4, but it would appear that the low DM intakes in Expts 3.5 and 3.6 were because the animals were non-lactating. In Expt 3.7, the cows were in the latter part of their lactations and had low milk yields. Both the non-lactating stage and the low milk yield period contribute to a low DM intake (ARC, 1980).

The total DM intake of the lactating dairy cow is influenced by body size, milk yield and the stage of lactation (MAFF et al, 1975) and recent predictive equations have indicated that the major factors affecting the total DM intake are the concentrate intake, liveweight, week of lactation and the milk yield and can explain 76% of total

Table 4.2 The observed and the calculated daily DM intakes

Expt No.	Total feed intake (kg/cow/day)			Difference	
	Observed (O)	Calculated (A)*	Calculated (B)*	(O - A)	(O - B)
3.1	13.25	13.66	11.48	- 0.41	+ 1.77
	13.19	13.58	11.41	- 0.39	+ 1.78
	14.24	13.92	11.91	+ 0.32	+ 2.33
	14.90	14.02	13.39	+ 0.88	+ 1.51
	14.89	14.09	13.40	+ 0.80	+ 1.49
	15.98	14.17	13.50	+ 1.81	+ 2.48
3.2	12.59	13.60	10.35	- 1.01	+ 2.24
	15.35	14.20	13.15	+ 1.15	+ 2.20
	15.87	14.43	13.17	+ 1.44	+ 2.70
3.3	12.20	14.56	10.94	- 2.36	+ 1.26
	13.94	14.94	11.94	- 1.00	+ 2.00
	14.77	15.25	13.03	- 0.48	+ 1.74
	13.87	15.01	11.58	- 1.14	+ 2.29
	15.21	15.17	12.47	+ 0.04	+ 2.74
	16.42	15.56	13.15	+ 0.86	+ 3.27
3.4	14.44	14.71	13.19	- 0.27	+ 1.25
	14.58	14.60	13.20	- 0.02	+ 1.38
	14.57	14.77	13.21	- 0.20	+ 1.36
	13.92	14.08	12.49	- 0.16	+ 1.43
	14.14	14.30	12.58	- 0.16	+ 1.56
	14.03	14.49	12.86	- 0.46	+ 1.17
3.7	12.58	14.44	10.99	- 1.86	+ 1.59
	11.76	14.04	10.57	- 2.28	+ 1.19
	12.36	14.57	11.48	- 2.21	+ 0.88
	13.04	14.51	11.39	- 1.47	+ 1.65

*A MAFF et al (1975)

*B Vadiveloo and Holmes (1979)

variation in the feed DM intake (Vadiveloo and Holmes, 1979). From the data in Expts 3.1, 3.2, 3.3, 3.4 and 3.7, DM intakes were calculated (Table 4.2) using equation 22 in Bulletin 33 (MAFF et al, 1975) and equation 2 (Vadiveloo and Holmes, 1979). In general, the results in Table 4.2 indicated that the calculated DM intakes from Bulletin 33 were in closer agreement with the observed DM intakes than the calculated DM intakes using equation 2 (Vadiveloo and Holmes, 1979). The differences between the observed and the calculated values in Table 4.2 varied from a minimum of - 0.02 to a maximum of + 3.27 kg DM per cow/day and did not follow any clear cut pattern. The equation of Vadiveloo and Holmes (1979) consistently over calculated the intakes of DM with a mean daily value of 1.81 kg DM/cow whereas the equation from Bulletin 33 gave both over- and under-estimates. The study of Vadiveloo and Holmes (1979) showed that equation 2 over-predicted intakes of DM by 1.0 kg in early lactation and underpredicted by 0.4 kg in the middle part of lactation compared with observed intakes. In a group feeding situation, predictions using the equation from Bulletin 33 would give a similar mean value to the observed results. The over-estimate from the equation of Vadiveloo and Holmes (1979) is a little surprising as part of the basic data used by these authors came from earlier experimental data at this Institute. There are other factors such as the health of the animals (Bines, 1976), heritability of food intake (Miller et al, 1972), the energy concentration of the diet (Bines, 1976; ARC, 1980) and stage of lactation (Bines, 1976) which can all influence the DM intake.

Table 4.3 Effects of level of concentrate supplementation on the response in milk yield

Expt No.	Concentrate DM intake (kg/cow/day)	Milk yield (kg/cow/day)	Response kg milk/kg extra concentrate
3.1	3.43	18.3	-
	6.79	19.4	0.33
3.2	0	18.0	-
	4.87	20.5	0.51
	5.06	20.8	0.55
3.3	1.28	17.1	-
	2.56	18.6	1.17
	3.84	21.0	1.88
	1.28	19.6	-
	2.56	21.2	1.25
	3.83	22.8	1.25

Milk yield

In the experiments described in Chapter 3, different types and amounts of supplements had variable effects on the feed intake and hence on the milk yields.

In Expt 3.1 the supplement of hay in the ground and cubed form increased the forage and the total feed DM intake, and as a result milk yields were increased on the two ground hay supplement treatments. On the low rate of concentrate intake, hay in the ground form gave marked increases in milk yield of 10.2% and 7.8% compared with long and short hay supplements. At the high rate of concentrate intake, much smaller increases of 1.5% and 3.1% compared with long and short hays were probably due to the high level of nutrient intake relative to the milk potential of the cows. In other recent feeding experiments, only small increases in milk yield were obtained when long hay was used as a supplement with high quality silages (Retter, 1978). In one of these experiments where the silage had low intake characteristics, a supplement of long hay with a D-value of 65 resulted in a substantial increase in the forage intake and in milk yield. In another experiment, a supplement of long hay with a D-value of 70 resulted in a 5% increase in milk yield. Tayler and Aston (1976a) reported that a decrease in the modulus of fineness of dried grass offered as a supplement to silage increased the feed intake and hence the milk yields. In this latter experiment, an increase of 11% in silage intake and 19.3% in milk yield was obtained when the same quantity of DM as a dried grass supplement was offered in either the form of pellets (MF 0.63) or as wafers (MF 2.63).

In Table 4.3 a summary of the response in milk yield per kg of additional concentrate intake is presented. The values given in

Table 4.3 ranged from 0.33 to 1.88 kg milk. In Expts 3.1 and 3.2, low-protein concentrates were eaten, and the decreases in forage intake were fairly large with values of 1.66 kg (Expt 3.1) and 2.08 and 1.78 kg (Expt 3.2), and this resulted in a low response in milk per kg of extra concentrate intake. In marked contrast, a much higher response in milk yield was obtained in Expt 3.3 as the high-protein concentrate offered in this experiment did not cause a major reduction in silage and hence the total DM intake increased. It has been reported that a supplement of dried grass reduced the intake of silage to a lesser extent than barley and therefore this resulted in higher milk yields (Castle and Watson, 1975). These workers obtained responses of 0.42 and 0.84 kg milk/kg extra supplement when the daily DM intakes of barley and dried grass were 6.0 and 6.3 kg per cow. A mean response of 0.78 kg milk/kg concentrate was reported from ten feeding trials (Gordon, 1981) in which a basal diet of silage was offered _ad libitum_. A similar response of 0.79 kg milk/kg concentrate DM was obtained from the data of 16 feeding trials in which cows were given silage _ad libitum_ (Thomas, 1980). In the study of Østergaard (1979), a response of 1.20 kg milk/kg concentrate was obtained when the daily concentrate DM intake was 7.7 kg per cow. The mean responses reported in the above experiments and in Table 4.3 are all lower than the responses of 1.47 kg milk (Strickland, 1975) and 1.35 kg milk (Johnson, 1977) obtained when basal diets of hay were given in restricted quantities. It would appear that the low responses in milk yield with diets of _ad libitum_ silage and low-protein concentrates are probably due to the net effect being on the total nutrient intake which is quite different from that obtained when restricted amounts of forages are used. A particularly large response of 1.88 kg milk (Table 4.3) was calculated

Table 4.4 The responses in milk yield per MJ increase in ME intake

Expt No.		kg milk/MJ increase in ME
3.1		0.04
3.2		0.05
		0.06
3.3		0.08
		0.18
		0.09
		0.11
3.4		0.32
	MEAN	0.12

in Expt 3.3 as there was no significant depression in silage intake with the high-protein concentrate. Similarly, it was noted that the high level of supplementation offered with high quality silage in Expt 3.1 gave a smaller response in milk yield compared to that in Expt 3.2 in which lower quality silage was given with a low level of supplementation (Table 4.3). The experiments of other workers have indicated that high levels of supplementation reduce the response in milk yield with high-digestibility silages (Parker, 1976; Steen and Gordon, 1980b). In the work of Parker (1976) responses in milk yield were - 0.02 and 0.71 kg milk/kg extra concentrate with 67 and 64 D-value silages. Similarly, Steen and Gordon (1980b) obtained responses of 0.18 and 0.48 kg milk/kg extra concentrate with 68 and 64 D-value silages.

From the data of ME intakes and the milk yields (Expts 3.1, 3.2, 3.3 and 3.4), the responses, kg milk/MJ increase in ME intake, were calculated (Table 4.4), and these ranged from 0.04 to 0.32 kg milk per MJ. In the four experiments reported in Table 4.4 cows of similar milk yield were used and it appears that the higher responses in Expts 3.3 and 3.4 compared to Expts 3.1 and 3.2 were directly and indirectly a protein effect. A mean response of 0.10 kg milk/MJ (Thomas, 1980) was obtained from sixteen feeding experiments, and the high yielding groups gave a higher response than low yielding groups, 0.12 and 0.08 kg milk/MJ ME intake, respectively. The mean response in the four experiments (Table 4.4) was 0.12 kg milk/MJ. In other experiments, responses of 0.09 (Castle et al, 1977a; Gordon, 1980c) and 0.14 kg milk per MJ increase in ME intake were reported (Retter, 1978).

Table 4.5 The responses in milk yield to extra DCP intake

Expt No.	kg milk/100 g increase in DCP intake
3.1	0.28
3.3	0.35
	0.61
	0.34
	0.42
3.4	0.32
3.7	0.15

In Expts 3.4 and 3.7 significant increases in milk yield were obtained when high-protein concentrates replaced low-protein concentrates as silage supplements. It would seem that in Expt 3.4 the increase in energy and protein intakes consequent upon the increase in silage DM intake both contributed towards higher milk yields on the high-protein concentrate treatments. However, in Expt 3.7 energy intakes were similar on the low- and the high-protein treatments and it would appear that the higher milk yields on the high-protein treatments were directly due to the higher protein intakes. Similar responses in milk yield to high-protein supplements offered with diets of silage ad libitum have been reported also by other workers (Castle and Watson, 1976; Laird et al, 1979; Gordon, 1981). The response in milk yield with the high-protein supplements may be attributed to the low degradability of the proteins in the rumen (Verite and Journet, 1977), an increase in silage DM intake and an increase in the overall digestibility of the ration (Gordon, 1981). From the data on DCP intakes and milk yields (Expts 3.1, 3.3, 3.4 and 3.7), the responses in milk yield stated as kg/100 g additional DCP intake were calculated (Table 4.5). The values ranged from 0.15 to 0.61 kg milk. The low response of 0.15 kg milk in Expt 3.7 was possibly due to the fact that the cows were in late lactation and had low milk yields. The high response of 0.61 kg milk (Expt 3.3) was found when low D-value silage was offered with a high-protein supplement. In other experiments, the response to extra DCP was 0.49 kg milk (Castle and Watson, 1976; Castle et al, 1977a) and 0.38 kg milk (Retter, 1978) per 100 g additional DCP.

The feeding of concentrates in more than two feeds per 24 hrs had no major effect on the DM intake, and the differences in the milk yields on the different frequency treatments were also not significant. In Expts 3.4 and 3.7 a small increase in the total DM intake occurred when high-protein supplements were given in 22 compared to 2 feeds per 24 hrs but there was no increase in the milk yields. A similar result occurred in Expt 3.7 when a low-protein supplement was given in 22 rather than in 2 feeds per 24 hrs. However, a small increase in the DM intake contributed to a small but non-significant increase in milk yield of 3.9% when feeding a low-protein supplement in 22 instead of 2 feeds per 24 hrs (Expt 3.4). The results of these experiments and those in the literature have produced variable and often contradictory results on the topic of frequency of feeding. In the work of Campbell and Merilan (1961) marked increases in milk yield were obtained due to extra feed intakes on the higher frequency of feeding treatments. In this latter experiment, uncorrected yields of milk increased by 8.9% and 7.0% when food was supplied in four and seven feeds respectively instead of two feeds daily. Similarly, Meinhold _et al_ (1976) reported an increase in feed intake with a 13 - 22% higher FCM yield as a result of both feeding and milking dairy cows four times compared to twice daily. In contrast, Linder _et al_ (1979) obtained only a small increase in milk yield of 0.90% when a substantial increase in feed intake occurred by offering forage and concentrates in six rather than in two feeds per 24 hrs. In a further comparison, milk yields were increased by 3.15% when a small increase in feed intake was obtained by giving concentrates in six feeds compared to twice daily. The experiments of other workers (Mochrie _et al_, 1956; Thomas and Kelly, 1976) showed no responses in milk yield by offering food more

Table 4.6 Efficiency of utilisation of ME for lactation ($k_{\ell o}$)

Expt No.	ME used for lactation (MJ/cow/day)	ME secreted in milk (MJ/cow/day)	$k_{\ell o}$ (%)
3.1	97.1	54.2	55.8
	92.8	55.5	59.8
	101.0	60.0	59.4
	107.0	60.4	56.4
	119.0	58.9	49.5
	124.0	62.2	50.2
3.2	76.8	50.4	65.6
	90.9	58.4	64.2
	93.4	61.4	65.7
3.3	77.9	53.8	69.1
	78.5	57.3	73.0
	91.9	65.5	71.3
	104.0	60.6	58.3
	111.0	65.6	59.1
	114.0	72.5	63.6
3.4	109.0	55.9	51.3
	107.0	57.7	53.9
	106.0	57.8	54.5
	113.0	50.7	44.9
	102.0	50.8	49.8
	100.0	54.7	54.7

frequently in controlled amounts. In a recent summary study it has been shown that a higher frequency of feeding can increase daily weight gain with an improved efficiency of food utilisation in growing ruminants (Gibson, 1981). This worker analysed the published data from 15 reports in which cattle had either a fixed food intake or a fixed intake of concentrates but the intake of roughage varied. In a few experiments the intake of the whole diet varied also. From the analysis of the data it was concluded that more frequent feeding increased daily weight gain and the efficiency of food utilisation by 16.2 ± 4.8% and 18.7 ± 6.0%, respectively. These improvements were due mainly to an increase in frequency of feeding from either one or two meals to four meals per day. It was further suggested that cattle should be given food four times daily to ensure maximum efficiency for growth. With dairy cows, it is clear that only few results have shown a marked increase in the milk yield as a result of more frequent feeding.

In previous feeding experiments at this Institute, it was reported that the supplementation of silage with high-protein concentrates resulted in the higher partial efficiency of utilisation of ME for lactation ($k_{\ell o}$) than with low-protein supplements (Thomas and Castle, 1978). Values for the efficiency of utilisation of ME for lactation ($k_{\ell o}$) were calculated for Expts 3.1, 3.2, 3.3 and 3.4 and are given in Table 4.6. In Expts 3.1 and 3.4 the mean $k_{\ell o}$ values of 55.2% and 51.5% with low-protein supplements were both lower than the mean of 62.0% obtained with high-protein supplements of dried grass offered with high-digestibility silage (Thomas and Castle, 1978). In Expt 3.2, the addition of small amounts of soyabean meal to the control treatment and to the supplement treatments of barley and sugarbeet pulp

Table 4.7 The daily requirements of Tissue Protein (TP)

Expt No.	TP (g per cow) required for			
	Milk production	N loss in hair and scurf	N loss in urine	Weight gain or loss
3.1	578	11.4	56.7	18.0
	580	11.3	56.6	40.5
	629	11.5	56.9	48.0
	660	11.5	57.0	76.5
	646	11.7	57.0	27.0
	674	11.7	57.0	57.0
3.2	538	11.3	56.6	- 12.3
	648	11.6	57.0	129
	661	11.7	57.3	101
3.3	516	12.2	58.0	- 28.0
	573	12.3	58.3	51.0
	666	12.3	58.3	48.0
	604	12.2	58.1	- 2.20
	676	12.2	58.1	45.0
	741	12.4	58.4	88.5
3.4	580	12.3	58.1	10.5
	588	12.1	57.8	15.0
	573	12.3	57.8	21.0
	487	11.9	57.5	- 24.6
	499	11.9	57.8	22.5
	528	12.3	58.0	21.0
3.7	346	12.5	58.6	- 8.96
	314	12.3	58.3	1.50
	438	12.4	58.4	138
	429	12.4	58.4	162

Table 4.8 The daily requirements of Tissue Protein (TP)

Expt No.	Milk yield (kg/cow/day)	Total TP required	TMP supplied (g/cow)	Deficiency for TP
3.1	17.6	664	505	159
	18.0	688	505	183
	19.4	745	541	204
	19.4	805	584	221
	19.1	742	587	155
	19.7	800	627	173
3.2	18.0	594	412	182
	20.5	846	571	275
	20.8	831	558	273
3.3	17.1	558	416	142
	18.6	695	482	213
	21.0	785	525	260
	19.6	672	525	147
	21.2	791	584	207
	22.8	900	630	270
3.4	17.3	661	548	113
	17.7	673	551	122
	17.2	664	551	113
	15.3	532	528	4.0
	15.2	591	535	56.0
	15.9	619	528	91.0
3.7	10.6	408	429	- 21.0
	9.4	386	406	- 20.0
	12.7	647	406	241.0
	12.3	662	426	236.0

resulted in higher $k_{\ell o}$ values than the value of 44.2% calculated from a supplement of barley alone (Thomas and Castle, 1978). From the data in Expt 3.3 (Table 4.6) it was noted that the high-protein concentrate supplement offered with low D-value silages gave the highest $k_{\ell o}$ values when compared with other experiments in which low-protein supplements were used (Table 4.6). In Expt 3.3, a marked decrease in the $k_{\ell o}$ values occurred when the high-protein concentrate was used as a supplement with high D-value silages. Similarly, a low mean $k_{\ell o}$ value of 51.7% was reported by Thomas and Castle (1978) when groundnut cake was given with high D-value silage. In Expt 3.4, the $k_{\ell o}$ value was 3.4% units higher on the high- compared to the low-protein concentrate treatment (Table 4.6).

The daily requirements of tissue protein (TP) for the cows in the experiments described in Chapter 3 were calculated according to the method reported earlier in Chapter 2, and the values are given in Tables 4.7 and 4.8. The total TP requirements in Table 4.8 were obtained by adding the TP requirements for milk production, loss of N in hair, scurf, urine and liveweight gain or loss detailed in Table 4.7. It was noted from the data in Table 4.7 that the values for TP required for loss of N in hair and scurf and loss of N in urine were extremely similar on the different treatments, and therefore had only a small effect in the total TP requirements in the different experiments. In general, the demand for total TP (Table 4.8) increased as the milk yields increased on the various treatments. In Expts 3.2, 3.4 and 3.7, small increases in milk yields on some treatments did not increase the total TP requirements as the higher liveweight gain on other treatments with low milk yields increased the total TP requirement. It was also noted from the data in Table 4.8 that the TP supplied from microbial protein synthesis (TMP) generally increased as the milk yields increased. However, on most of the treatments TMP alone was not sufficient to meet TP requirements.

Table 4.9 The relationship between dietary energy and protein intakes and milk composition

Expt No.	ME intake (MJ per cow/day)	DCP intake (g per cow/day)	Milk composition ($g\ kg^{-1}$)		
			Fat	SNF	CP*
3.1	153	1780	38.2	89.7	32.8
	153	1780	38.8	88.8	32.2
	164	1870	39.1	88.9	32.4
	177	2160	38.6	90.6	34.0
	178	2190	38.0	90.4	33.8
	190	2290	39.8	90.7	34.2
3.2	125	2458	33.6	84.9	29.9
	173	2570	33.2	87.9	31.6
	169	2466	36.4	87.3	31.8
3.3	126	1396	42.3	85.3	30.2
	146	1823	40.2	86.2	30.8
	159	2219	40.4	87.6	31.7
	159	1973	40.4	86.3	30.8
	177	2437	39.9	87.3	31.9
	191	2818	41.8	88.0	32.5
3.4	166	1982	43.1	88.0	33.5
	167	1991	43.6	88.4	33.2
	167	1953	45.8	89.1	33.3
	160	1355	45.3	87.7	31.8
	162	1390	45.9	88.1	32.8
	160	1371	48.3	88.5	33.2
3.7	130	1330	44.7	84.4	32.6
	123	1233	47.5	83.5	33.4
	123	2933	36.7	85.7	34.5
	129	3014	37.8	85.4	34.9

*N x 6.38

Milk composition

The relationship between the dietary energy and protein intakes on the CP, SNF and the fat concentrations in milk are summarised in Table 4.9. It can be seen that, with the exception of Expt 3.7, CP and SNF values generally increased as the energy and the protein intakes increased also. Thus, the results of the experiments were broadly in agreement with those in other silage experiments (Castle and Watson, 1976; Retter, 1978; Castle et al, 1980) in which higher nutrient intakes with different types of silage supplements gave increases in the CP and the SNF concentration of the milk. The CP and the SNF values in Table 4.9 ranged between 29.0 and 34.9 g kg^{-1} and 83.5 and 90.7 g kg^{-1}, respectively and were generally higher than the mean values of 30.4 for CP and 84.0 g kg^{-1} for SNF calculated from other similar experiments (Castle and Watson, 1975; 1976; Castle et al, 1977a, b; Retter, 1978; Castle et al, 1980) in which diets of high-digestibility silage were given as the sole feed. The results given in Table 4.9 and those of the above experiments indicate that low energy and protein intakes on rations of silage only result in low CP and SNF contents and that the addition of supplementary foods can increase the amounts of these constituents in milk. In Expt 3.7, it seems that excessive amounts of protein rather than energy intake was the important factor in increasing the CP and SNF contents of the milk. An increase in the level of energy will normally increase the CP and SNF contents, but usually lowers the milk fat content (Rook, 1973). In the results in Table 4.9 milk fat contents increased in some experiments and decreased in others as both energy and protein intakes increased. In Expts 3.1, 3.2 and 3.3 the average milk fat concentrations were lower than the mean value of 42.1 g kg^{-1} obtained in six feeding experiments in which a diet of high-digestibility silage was offered as the sole feed (Castle and Watson, 1975; 1976; Castle et al, 1977a, b; Retter, 1978; Castle _et al_, 1980). The supplements with a high protein content tended to reduce the milk fat content when comparing the various supplements in Expts 3.4 and 3.7. Similarly, numerous experiments have reported some reductions in milk fat content with high compared to low protein supplements when both were given with grass silages _ad libitum_ (Castle and Watson, 1975; Gordon, 1979; Castle _et al_, 1979). Dietary factors such as lack of physical fibrousness, fine grinding of forages and the proportion of forage to concentrate in the diet can also influence the milk fat content (Rook, 1973;), but these were not applicable in the experiments reported in Table 4.9.

There were small and non-significant increases in the milk fat concentration when concentrate feeds were given in 22 rather than 2 feeds per 24 hrs with silage _ad libitum_ (Expts 3.4 and 3.7). In Expt 3.4, milk fat concentrations increased from 43.1 to 45.8 g kg^{-1} with the high-protein concentrates and from 45.3 to 48.3 g kg^{-1} with the low-protein concentrates. Similarly, in Expt 3.7 an increase in the milk fat concentration from 44.7 to 47.5 g kg^{-1} was observed with a supplement of barley and from 36.7 to 37.8 g kg^{-1} with soyabean meal. From experiments reported in the literature, the response in the milk fat content to changes in the frequency of feeding have been variable. Campbell and Merilan (1961) obtained values of 41.0, 44.0 and 46.0 g kg^{-1} when the daily feed intake was given in 2, 4 and 7 meals, respectively. In the experiments of Kaufmann (1976), milk fat contents were 36.9 and 40.0 g kg^{-1} when hay and concentrates were offered in either 2 or 7 feeds daily. The feeding of concentrates in 5 rather than in 2 meals per day on a high-concentrate low-hay diet resulted in milk fat concentrations of 27 and 20 g kg^{-1} respectively (Sutton et al, 1978). The work of Linder et al (1979) also showed an increase in the milk fat content from 38.3 to 39.2 g kg^{-1} when the number of concentrate feeds were increased from two to six per day. In contrast, these workers obtained little increase in the milk fat content when giving a mixture of forage and concentrates in six feeds instead of two feeds daily. Similarly, Burt and Dunton (1967) reported no increase in the milk fat content when forage and concentrates were given in ten rather than in four feeds daily. Smith et al (1978) also obtained similar fat contents when giving forage and concentrates in either one or two feeds daily. The results of Thomas and Kelly (1976) showed little effect on the milk fat content when increasing the frequency of feeding of the food in controlled amounts.

Water consumption

The intakes of drinking water and the water consumed per kg DM intake in the experiments described in Chapter 3 varied according to the milk yield of the cows, DM intake and the type of the supplementary foods. In all the experiments, the intakes of drinking water generally increased as the milk yields increased and this fact has been noted by other workers (Castle and Thomas, 1975; Castle et al, 1980). In Expt 3.7, there were large differences in the CP contents of the supplements of barley and soyabean meal, and the average amount of water drunk was 13.2 kg per day higher on soyabean meal compared to barley when the differences in the CP content of the concentrate supplements were smaller (Expt 3.4). The intakes of drinking water were similar on the various protein concentrate supplements. The use of high-protein feeds increases the demand for drinking water (Castle and Watson, 1975; Castle et al, 1979; ARC, 1980). In the experiment of Castle and Watson (1975), intakes of drinking water were markedly higher with dried grass of high-protein content than with a supplement of low-protein barley. Similarly, in another experiment (Castle et al, 1979), the amount of water drunk was higher with groundnut than with a supplement of barley. An increase in DM intake generally led to a higher intake of drinking water (Expts 3.1, 3.2, 3.3, 3.4 and 3.7), which agrees with the results in other studies (Retter, 1978; Castle et al, 1980).

The values of the water intake per kg DM consumed (water in feed + water drunk - water in milk/DM intake) ranged between 3.42 and 4.74 kg on the different treatments in Expts 3.1, 3.2, 3.3, 3.4 and 3.7 and can be compared with a mean intake of 3.60 kg water per kg DM intake given by the ARC (1965) for cattle at an environmental temperature of 10 to 15°C. A similar value of 3.70 kg per kg DM consumed at a mean temperature of 8.2°C was reported from a study of 14 commercial herds (Castle and Thomas, 1975). The water intake per kg DM was fairly similar on the different treatments in Expts 3.1, 3.3 and 3.4 and ranged between 3.42 to 3.90 kg. However, the high values of 4.34, 4.74 and 4.61 kg water occurred in Expts 3.2 and 3.7. In Expt 3.2, the supplement treatments of barley and sugarbeet pulp increased the drinking water intake compared to the control treatment, and this increased the ratio of water intake to feed DM. The high value of the water intake per kg DM on the supplement of soyabean meal in Expt 3.7 was mainly as a result of the high intakes of drinking water on the soyabean meal treatments.

Liveweight change

The daily liveweight changes of the dairy cows in the experiments described in Chapter 3 were all calculated by linear regression. In general, on most treatments, the animals increased in liveweight, e.g. only a small daily loss in liveweight of 0.11 kg per cow occurred on the control treatment in Expt 3.2, and 0.22 and 0.08 kg per cow in Expts 3.4 and 3.7, when low-protein supplements were given. These values are lower than a mean daily liveweight loss of 0.44 kg per cow calculated from five feeding experiments (Castle and Watson, 1976; Castle *et al*, 1977a, b; Retter, 1978; Castle *et al*, 1980) in which high-digestibility silage was the sole constituent of the diet. The results of numerous feeding experiments in which a basal ration of grass silage was given with different types of supplements have shown losses in the daily liveweight of dairy cows. For example, losses of 0.84, 0.21 and 0.04 kg per cow were found with supplements of barley, groundnut cake and a mixture of barley plus groundnut cake (Castle and Watson, 1976). Liveweight losses of 0.40 and 0.25 kg per cow per day were reported in the experiment of Retter (1978) with supplements of high and super quality hays. A mean liveweight loss of 0.54 kg per cow was calculated when silage was supplemented with sugarbeet pulp (Castle *et al*, 1979). The high losses in body weight on some treatments in the above experiments were probably due to the mobilisation of body reserves by the cows to reach their maximum potential milk yields. All the above experiments were conducted in the middle part of lactation (weeks 8 - 28 approximately) which may not be of vital importance although a high body weight loss in early lactation generally reduces the reproductive efficiency due to delay in remating and a low conception rate (Haresign, 1980).

In Expts 3.1, 3.2 and 3.3 there was a tendency for the daily liveweight of the cows to increase as the level of concentrate supplementation increased. Similarly, Castle et al (1977a) reported increases in daily liveweight of 0.07, 0.24 and 0.32 kg per cow when daily DM intakes of groundnut cake were 1.2, 2.3 and 3.4 kg per cow respectively. In contrast, Castle et al (1980) obtained no increase in liveweight as the level of concentrate intake increased.

In Expt 3.4 level of protein in the concentrate supplement did not affect the liveweight. However, a substantial increase in liveweight gain occurred in Expt 3.7 on the soyabean meal compared with the barley treatments. In the work of Gordon (1979) there was no major difference in liveweight change between the supplements containing 137 and 209 g CP/kg fresh weight, but a small loss of 0.2 kg per cow occurred with a supplement containing 95 g CP/kg fresh weight.

Practical conclusions

Certain results in this thesis could have a useful practical value in the feeding of dairy cows, and are briefly discussed below.

For example, the results of Expt 3.1 indicated that a supplement of hay in the ground and cubed form offered with concentrates at a low rate of feeding gave marked increases in feed intake and hence increased the milk yields. However, with a high rate of concentrate feeding, hay in the ground and cubed form was not as useful. It would be appropriate to investigate the value of ground and cubed hay as a supplement to silages of different D-values given with a high-protein concentrate supplement.

In Expt 3.2, the differences in the feed intake, milk yield and milk composition between supplements of barley and sugarbeet pulp for silage were small and not significant. Thus for most practical feeding purposes with dairy cows, the two feeds can replace each other on an equal weight basis. Without any doubt, beet pulp was not inferior to barley.

The results of Expt 3.3 showed that amounts up to 4.5 kg per cow/day of a high-protein concentrate can be given as a useful supplement to both low-D and high-D value silages. This level of supplementation did not cause a reduction in the silage DM intake and the response in milk yield per kg of concentrate DM intake did not decline. There is probably only a limited place for this type of supplement but further studies on the use of high-protein concentrates as silage supplements would seem to be well worthwhile.

Finally, from the three experiments (Expts 3.4, 3.6 and 3.7) on the frequency of feeding concentrates, it was clear that an increase in the number of feeds per 24 hrs had little or no effect on milk yield. The level of concentrate intake in these experiments was not high, but it would seem that on the average dairy farm there is probably little advantage in having more than two concentrate meals per 24 hrs when silage is available *ad libitum*.

All these conclusions require further investigation at a developmental level before real firm practical suggestions can be made. In particular, the economics of each system should be evaluated carefully.

A P P E N D I C E S

APPENDIX 1 CHEMICAL ANALYSIS OF FEEDS AND MILK

The methods used for the determination of dry matter, total nitrogen, true protein, ether extract, crude fibre, in vitro digestibility of the foods and the determination of the fat and lactose in the milk are referred to in Chapter 2. These methods are fully described here.

Feeds

Dry matter (Toluene method). In this method, 25 g of wet minced silage was refluxed in toluene (boiling point 110^{o}C). The water was vaporised along with the toluene and both were condensed into a graduated tube which allowed the volume of water to be measured. The volume occupied by the volatiles was estimated from the acidity of the water distillate.

The acidity of the water distillate was measured by titrating with N_{10} NaOH using phenolphthalein indicator. If W was the weight of silage (g), V was the observed volume of water (ml) and T was the titre of N_{10} NaOH (ml), then the percentage DM was calculated as —

$$\%DM = \frac{100 - 0.998V\ (1 - 0.001375T)}{W}$$

Total nitrogen. To a dry 500 ml Kjeldahl flask were added 2 glass beads, 3 Kjeltabs and 1 ml of copper sulphate solution. A 0.75 g sample of dried ground feed was weighed out on a 9 cm filter paper and transferred to the Kjeldahl flask together with 25 ml of sulphuric acid. The flask was placed on the heating unit until foaming and charring ceased. When the digest was clear, gentle boiling was continued for a further 2 hrs.

After the digest cooled, 250 ml of distilled water was added to wash down the neck of the flask and the contents of the flask were thoroughly mixed. Sixty ml of sodium hydroxide solution (48% m/m) were carefully poured down the neck of the Kjeldahl flask to form a bottom layer. The Kjeldahl flask was then immediately connected to the distillation unit with the tip of the tube attached to the condenser outlet immersed in 25 ml of 4% boric acid containing three drops of mixed indicator solution in a 500 ml conical flask. The contents of the Kjeldahl flask were mixed thoroughly and the heating was commenced immediately to avoid frothing and about 150 ml of distillate was collected in about 30 minutes. Shortly before the completion of distillation, the tube connected to the condenser was removed from the liquid in the conical flask and the outside of the tube was rinsed with distilled water. For the blank determination, the above method was follwed using the filter paper only. The distillate was titrated against N_{10} HCl taking titrations to the same end point as with blank distillates. The nitrogen content of the feed was obtained from the following formula:-

$$14 \times N \times T \times \frac{100}{W \times 1000} \quad g/100$$

where N = normality of N_{10} HCl

T = sample titre - blank

W = weight of feed sample

The results were expressed as crude protein (total N x 6.25).

True protein. The tannic acid solution was prepared by dissolving 4 g tannic acid in water and adding 0.1 ml concentrated H_2SO_4 per 100 ml of final solution. 0.3 g of the dried ground sample was weighed into

50 ml centrifuge tubes and mixed with 2 ml of dilute "Teepol" solution. Fifty ml of boiling tannic acid was added and the tube was placed in a boiling water bath for 15 mins. The tube was removed from the water bath, allowed to stand for 15 mins and centrifuged for 10 mins at 2500 rpm. The liquor was removed by suction using a tube with an end covered with fine washed muslin. Any particles of feed sticking to muslin were washed into the tube with cold water and the volume was made up to 30 ml with distilled water. The tube was centrifuged and washed twice as before and finally the residue was washed into a 500 ml Kjeldahl flask for N determination.

Ether extract. A Soxhlet thimble containing 2 g of the ground sample was extracted with 100 ml diethyl ether for 16 hrs into a weighed 150 ml round flat-bottomed flask. The excess ether was removed from the thimble and added to the ether extract in the flask. The percentage of ether extract in the flask with a 2 g of sample was calculated as follows:-

$$\text{Ether extract\%} = \frac{\begin{matrix}\text{Wt of flask} \\ \text{+ extract}\end{matrix} - \begin{matrix}\text{Tare weight} \\ \text{of flask}\end{matrix}}{\text{Wt of sample DM}} \times 100$$

Crude fibre. A reagent was prepared by mixing 500 ml glacial acetic acid, 50 ml concentrated nutric acid, 20 g trichloroacetic acid and 450 ml distilled water.

Replicate samples of 0.9 g of the defatted sample were weighed into two 500 ml wide-necked conical flasks. 100 ml of reagent solution was added, washing down the sides of the flask. The contents were then gently boiled and refluxed over the microburner after adding the acid. After cooling the flask under the tap, the contents were filtered through a prepared Gooch crucible and thoroughly washed with warm distilled water. The crucible was dried at 100°C overnight, cooled and weighed. After ashing at 550°C for 3 hrs, it was cooled and weighed again. The crude fibre was calculated as follows:-

$$\text{Crude fibre \%} = \frac{W_2\ (100 - X)}{W_1}$$

where X = % ether extractives

W_1 = wt of defatted sample taken

W_2 = loss in weight on ignition

In vitro digestibility. The various stages involved in determining the *in vitro* digestibility are described below:-

For silage, 12.5 ml (about 0.500 g DM) of the homogenate prepared from the fresh minced silage was measured in triplicate into tubes, whereas with the hays and concentrates, exactly 0.500 gm DM of the ground sample (1 mm) was weighed into crucibles and tubes.

One litre of rumen liquor from each of the three rumen-fistulated sheep was filtered through muslin and saturated with CO_2. The liquor was added to four times the volume of McDougall's buffer (McDougall, 1948), and 1 ml of molar ammonium sulphate solution per 50 ml of rumen liquor buffer mixture was added. Inoculations were made by adding 50 ml of this mixture rumen liquor buffer mixture) to each tube. The tubes were then swept with CO_2, closed with stoppers fitted with Bunsen valves and placed in a water bath at 38.5°C. The digests were adjusted electrometrically to pH 6.9 at 24 hrs and the rumen liquor stage was terminated at 48 hrs by injections of 1.5 ml followed by 2.5 ml of HCl into each tube. Aqueous pepsin solution was then added to each tube after electrometric adjustment of pH to 1.2. After a further

48 hrs digestion, the residues were recovered in the presence of inert filter-aid (hyflo supercel) by filtration through a fibre glass paper. The residues were then dried at 100°C, weighed, ignited at 480°C and weighed again. A parallel determination of total OM enabled the digestibility coefficient of the OM to be calculated after allowing for the residual OM in the control tubes arising from the rumen liquor. Then

$$\text{OMD\%} = \frac{\text{OM in 0.5 g sample - (OM of sample residue - OM of control residue)}}{\text{OM in 0.5 g sample}}$$

The DOMD% *in vitro* was calculated as —

$$\text{OMD\%} \times \frac{\text{OM g/kg}}{1000}$$

Milk

Fat. Ten ml of Gerber sulphuric acid were measured into a milk Gerber butyrometer taking precautions to ensure that no acid touched the neck. Using a standard pipette, 10.94 ml of milk was added to the butyrometer and care was taken not to wet the neck while delivering the milk. After addition of 1 ml amyl alcohol, the butyrometer was stoppered and shaken until the contents were thoroughly mixed. The butyrometer was then centrifuged at 1100 rpm for 4 mins. The stopper was adjusted if necessary to bring the fat column onto the scale and finally the butyrometer was placed in the water bath at 60°C for 3 mins. The fat content of the milk was read on the butyrometer to the nearest 0.05%.

Lactose. A 50 ml volumetric flask was weighed before and after the addition of 20 ml of milk by pipette. Five ml of precipitating reagent (25 g zinc acetate + 12.5 g dodeca-tungsto-phosphoric acid + 20 ml glacial acetic and made up to 200 ml with distilled water) were added and diluted to 50 ml without mixing to avoid formation of foam. The flask was stoppered and the contents were mixed by vigorous shaking. After 15 mins the solution was filtered through a Whatman No. 42 filter paper into a conical flask. The optical rotation of this solution was determined on an automatic polarimeter 143D (Thorn Automation Limited). The instrument was calibrated using a standard solution containing 2.6 g/100 ml of "Aristar" grade sucrose which gave a rotation of 0.407 at 20°C. The volume correction for protein and fat was made by multiplying their percentages in milk by standard factors (Biggs and Szijarto, 1963).

Calculations:-

if a = observed rotation (degrees)

v = volume of solution (ml)

l = length of tube (dm)

w = wt of lactose hydrate (g)

sp. rotation of lactose hydrate + 61.9 (20°C)

then $\frac{a \times v}{l \times w} = 61.9$

$\therefore w = \frac{a \times v}{l \times 61.9}$

lactose hydrate % $= \frac{a \times v}{l \times 61.9} \times \frac{100}{w}$

where w is the wt of milk (g)

lactose anhydrous % $= \frac{a \times v}{l \times 61.9} \times \frac{100}{w} \times \frac{95}{100}$

$$= \frac{a \times v}{w} \times \frac{100 \times 95}{l \times 61.9 \times 100}$$

APPENDIX 2 STATISTICAL ANALYSIS

Five basic designs were used in the experiments described in this thesis. Each design is described in the appropriate section and the mean values are presented in the various tables.

An example of each design with numerical data and the analysis of variance is given on the following pages:-

Expt 3.1 Six-treatment cyclic changeover design

Six treatments
Four periods
Twelve cows
Two blocks

Total DM intake (kg/cow/day)

Block 1

Period	Cow No 191		197		195		3		46		193	
1	A	13.2	B	11.8	C	11.9	D	11.2	E	12.8	F	12.9
2	B	11.1	C	12.7	D	10.5	E	12.6	F	14.0	A	13.3
3	D	10.1	E	12.7	F	11.9	A	12.7	B	11.7	C	13.1
4	C	12.5	D	10.9	E	12.0	F	12.2	A	14.1	B	11.6

Block 2

Period	Cow No 86		146		4		190		149		178	
1	A	19.2	B	15.2	C	18.6	D	14.8	E	17.1	F	18.0
2	D	15.0	E	15.6	F	18.6	A	16.4	B	16.3	C	18.2
3	B	14.2	C	16.2	D	15.5	E	14.7	F	17.8	A	18.8
4	E	14.5	F	16.5	A	20.1	B	13.3	C	17.0	D	16.2

A - F are the six treatments

Analysis of variance

Source	df	SS	MS	F
Blocks	1	226.374	226.374	598.873***
Periods	3	2.773	0.924	2.444NS
Blocks x periods	3	1.139	0.379	1.003NS
Cows in blocks	10	43.195	4.320	11.426***
Treatments (Direct + Residual)	10	44.167	4.420	11.693***
Error	20	7.559	0.378	
Total	47	325.210		
Direct effects (adjusted for residual effects)	5	38.901	7.780	20.582***
Residual effects (ignoring direct effects)	5	5.266	1.053	
Direct effects (ignoring residual effects)	5	42.247	8.449	
Residual effects (adjusted for direct effects)	5	1.920	0.384	1.016NS

Treatment	Adjusted Direct means	Adjusted Residual effects
A	15.98	+ 0.230
B	13.25	- 0.400
C	14.90	+ 0.280
D	13.19	+ 0.260
E	14.24	- 0.170
F	14.89	- 0.200
SED	± 0.341	± 0.402

*** : P<0.001

NS : Not significant

Expt 3.2 Three-treatment extra-period balanced changeover design

Three treatments
Four periods
Six cows
Two blocks

Total ME intake (MJ/cow/day)

	Block 1						Block 2					
	Cow No						Cow No					
Period	88		110		52		76		83		108	
1	A	125	B	176	C	178	A	114	B	193	C	166
2	B	182	C	185	A	123	C	174	A	143	B	156
3	C	167	A	134	B	176	B	174	C	172	A	104
4	C	152	A	138	B	168	B	152	C	167	A	114

A, B and C are the three treatments

Analysis of variance

Source	df	SS	MS	F
Blocks	1	242.000	242.000	2.548NS
Periods	3	528.125	176.042	1.854NS
Blocks x Periods	3	45.750	15.250	0.161NS
Cows x Blocks	4	2325.690	581.422	6.123*
Direct effects (adjusted)	2	10777.400	5388.70	56.746***
Residual effects (adjusted)	2	219.212	109.606	1.154NS
Error	8	759.694	94.962	
Total	23	14897.900		

Treatment	Adjusted Direct means	Adjusted Residual effects
A	125	4.751
B	173	- 1.219
C	169	- 3.532
SED	± 5.032	± 5.626

NS : Not significant
* : P<0.05
*** : P<0.001

Expt 3.7 4 x 4 balanced Latin Square

Four treatments
Four periods
Four cows

Milk yield (kg/cow/day)

	Cow No							
Period	4		152		68		96	
1	A	12.1	B	9.6	C	15.3	D	10.3
2	B	9.5	D	12.6	A	11.9	C	9.2
3	C	13.3	A	12.0	D	13.7	B	8.1
4	D	12.4	C	12.9	B	10.2	A	6.6

A, B, C and D are the four treatments

Analysis of variance

Source	df	SS	MS	F
Periods	3	5.493	1.831	3.116NS
Cows	3	40.891	13.630	23.199**
Treatments	3	28.560	9.520	16.204**
Error	6	3.525	0.588	
Total	15	78.469		

$$SED = SE \times \sqrt{2}$$

$$= 0.383 \times 1.414 = \pm 0.542$$

Treatment	Mean
A	10.6
B	9.35
C	12.7
D	12.3

NS : Not significant
** : P<0.01

Expt 3.6 Four-treatment extra-period balanced changeover design

Four treatments
Five periods
Four cows
One block

Chewing time (mins/kg DM intake)

Period	Cow No 40		43		28		116	
1	A	62.2	B	54.9	C	55.2	D	67.7
2	B	53.6	D	62.9	A	53.5	C	62.5
3	C	59.1	A	51.2	D	54.0	B	67.0
4	D	55.1	C	59.6	B	46.6	A	54.9
5	D	56.5	C	59.5	B	51.2	A	59.6

A, B, C and D are the four treatments

Analysis of variance

Source	df	SS	MS	F
Periods	4	76.643	19.160	1.15NS
Cows	3	262.688	87.592	5.29*
Direct effects (adjusted)	3	71.511	23.837	1.44NS
Residual effects (adjusted)	3	42.635	14.211	0.86NS
Error	6	99.150	16.525	
Total	19	76.643		

$$SED = SE \times \sqrt{2}$$

$$= 1.855 \times 1.414 = \pm 2.62$$

Treatment	Adjusted Direct means	Adjusted Residual effects
A	55.5	0.03
B	55.0	0.35
C	59.1	2.10
D	59.6	- 2.45

NS : Not significant
* : P<0.05

Expt 3.5 Two-treatment crossover design

Two treatments
Three periods
Four cows

Silage DM intake (kg/cow/day)

Group	1	2	1	2
Cow	52	105	73	39
Period				
1	A 9.7	B 9.9	A 7.1	B 9.5
2	B 9.5	A 8.9	B 7.8	A 9.2
3	A 8.4	B 8.1	A 7.5	B 7.7

A and B are the two treatments

Analysis of variance

Group 1

			Error SS
Cow: 52	9.7 - 2(9.5) + 8.4	- 0.90	0.81
Cow: 73	7.1 - 2(7.8) + 7.5	- 1.00	1.00
	Total Group 1	- 1.90	

Group 2

Cow: 105	9.9 - 2(8.9) + 8.1	+ 0.20	0.04
Cow: 39	9.5 - 2(9.2) + 7.7	- 1.20	1.44
	Total Group 2	- 1.00	3.29 Total

Error SS = 3.29 ÷ 6 = 0.548

$$\text{Treatment SS} = \frac{(-1.90 \;-\; -1.00)^2}{2(6)2} = \frac{(-0.9)^2}{24} = 0.034$$

Source	df	SS	MS	F
Treatment	1	0.034	0.034	NS
Error	2	0.548	0.274	

$$\text{SED} = \text{SE} \times \sqrt{2}$$

$$= 0.214 \times 1.414 = \pm 0.30$$

NS = Not significant

Treatment	Mean
A	8.5
B	8.8

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