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THE EFFECT OF BULKY SUPPLEMENTARY FEEDS ON THE INTAKE OF SILAGE BY DAIRY COWS

by

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DUMFRIES

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ABBREVIATIONS

ARC	Agricultural Research Council
CP	Crude protein
CV	Co-efficient of variation
DAFS	Department of Agriculture and Fisheries for Scotland
DM	Dry matter
DMI	Dry matter intake
GE	Gross energy
K	Potassium
MAFF	Ministry of Agriculture, Fisheries and Food
ME	Metabolizable Energy
NS	Not significant
*	Significant at 5% level (P<0.05)
**	Significant at 1% level (P<0.01)
***	Significant at 0.1% level (P<0.001)
RDP	Rumen Degradable Protein
SED	Standard Error of the Difference
UDP	Dietary Undergradable Protein
VFA	Volatile Fatty Acids

SUMMARY

The literature is reviewed on silage production; voluntary intake of grass silage by ruminants; and on the growing and feeding of fodder beet.

Three dairy cow feeding experiments were carried out: in Experiment 1 a study was made of the effects of feeding fodder beet with two levels of concentrate: Experiment 2 examined the feeding of high levels of fodder beet: and in Experiment 3 the effect of feeding fodder beet with two protein levels in the concentrate were examined.

In a 12 week cyclic changeover design experiment with 12 British Friesian cows the effect of feeding fodder beet (Kyros) at three levels (0, 2 and 4 kg DM d^{-1}) and two levels of concentrate (4 and 8 kg DM d^{-1}) with *ad libitum* silage were examined. Silage dry matter intake was decreased when fodder beet was fed but total dry matter intake was increased. There were no significant effects on milk yield, milk composition, liveweight and liveweight change. There was a significant increase in milk protein yield. There was no significant interaction between level of fodder beet feeding and level of concentrate.

Experiment 2 examined the effects of feeding fodder beet (Kyros) at up to 6 kg DM d^{-1} on feed intake and cow performance. Feeding fodder beet increased total dry matter intake and decreased silage intake, improved milk fat yield, but there were no significant effects on milk yield or milk composition. There were no digestive disturbances recorded at any level of fodder beet feeding and there were no refusals of fodder beet.

Experiment 3 was also a changeover design with three 3-week periods. The effects of feeding fodder beet (Trestel) with two levels of protein in the concentrate, low (129 g kg^{-1} DM) and high (229 g kg^{-1} DM) with <u>ad libitum</u> silage were examined. Silage dry matter intake decreased when fodder beet was fed with both the low and high protein content, but the total dry matter intake was increased. Feeding fodder beet with the high protein concentrate significantly increased milk yield, milk composition, milk yield constituents compared to the zero fodder beet/low protein treatment. There were no significant effects on liveweight or liveweight change.

Experimental work was also carried out at the metabolism unit (Auchincruive) to evaluate the digestibility of fodder beet and the effect on rumen fermentation.

Six Suffolk x Grey Face wether sheep (average liveweight 55 kg) were allocated to a cross over design to measure the digestibility of organic matter and gross energy of fodder beet

in vivo. Fodder beet was fed at two levels with a complete standard diet. They were both supplemented with urea and minerals to meet requirements. Measurements of feed intake and faecal output were taken over the last nine days of a 21 day period. The mean values obtained were:
organic matter digestibility 0.962; gross energy digestibility 0.953; organic matter 924 g kg^{-1} DM, and ME 13.1 MJ kg^{-1} DM.

The nylon bag technique described by Ørskov and Mehrez (1977) was used to estimate the effect of feeding fodder beet on hay dry matter disappearance from nylon bags. Using 3 sheep fitted with permanent rumen canulae, the pH and VFA concentration in the rumen were measured when fodder beet (FB) was fed and compared with two control diets, barley/maize (BM) and sugar beet shreds (SBP). Hay was fed with all three diets in the ratio 50:50 on a DM basis. The rumen pH with feeding FB was 6.34 this value was intermediate between SBP 6.38 and BM 6.20. Hay dry matter disappearance from nylon bags feeding FB was intermediate between SBP and BM.

In a second experiment 3 wether sheep fitted with permanent rumen cannulae were used to calculate the organic matter disappearance of fodder beet. The sheep were fed standard diets (900 g DM hay + 200 g DM compound feed). The organic matter disappearance of fodder beet from nylon bags was very high compared with barley/maize, molassed sugar beet shreds and hay.

GENERAL INTRODUCTION

Fodder beet (Beta Vulgaris) if successfully cultivated, can give high yield of dry matter up to 12 t DM ha^{-1} from the roots, and a further 2 to 5 t DM from tops (Heppel 1985 and MAFF 1985a). The root has a high metabolisable energy content (ME) 13 MJ kg^{-1} DM and can be used in dairy cow diets as a substitute for silage or concentrate. Pearce (1983) reported that fodder beet can be included in ration at between 10 and 25 kg cow^{-1} d^{-1}. Feeding trials with fodder beet have shown that the total dry matter intake increased and silage dry matter intake decreased. Most workers have shown improvement in milk yield and milk quality when fodder beet are fed.

The object of this work is to evaluate the use of fodder beet as a supplement for dairy cattle and the investigation was carried out in two stages.

i) Three dairy cow feeding experiments were carried out to examine the effect of feeding fodder beet on:

  a) total dry matter intake

  b) silage dry matter intake

  c) milk yield and milk quality

  d) liveweight and liveweight change

ii) Two experiments were carried out using sheep to examine the fodder beet.

Experiment 1 to calculate the:

a) organic matter digestibility of fodder beet

b) gross energy digestibility of fodder beet

c) ME content in fodder beet

Experiment 2 to characterise fodder beet as a supplement:

a) by comparing the effects of dietary fodder beet with inclusion of other supplements on:

1) rumen pH

2) VFA concentrations

3) hay dry matter digestion *in sacco*

b) to measure *in sacco* digestion rates for fodder beet and other supplements.

R E V I E W O F L I T E R A T U R E

CHAPTER 1

PRACTICAL ASPECTS OF FORAGE DIETS FOR DAIRY COWS

In the UK, silage making only gained widespread acceptance after 1945. The present methods of silage making have arisen from developments during the last 100 years.

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 (a) chopping the crop (or leaving unchopped) and (b) putting into the silo, treading, covering and weighting. The transfer of the crop 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.

In the late 1940's, 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 buck rakes and, when lined with concrete, it resulted in small losses of material.

By 1950, silage production had risen to about 5% of the amount cut for hay (Mercer, 1952), and by 1957 it was even higher at 15% of the total (Hendry, 1958). As late as 1968 only

12-15% of the total conserved grass dry matter (DM) was conserved as silage. During the period 1960 to 1978 the amount of silage made increased sharply which has averaged 25% per annum Wilkinson (1981) (Figure 1), and the present amount in 1980 is about 6 million tonnes of silage dry matter are produced (Wilkins, 1980).

1.1 Factors influencing good silage making

1.1.1. Stage of growth of grass

The value of cutting grass for conservation at any early stage of maturity has been known for a long time as Sutton and Voelik wrote in 1891 "The earlier the meadow be cut, the more and the better produce it will yield throughout the year, the later it is left, the smaller and poorer the outcome will be" (Watson and Nash, 1960).

Before 1940, the technique of silage making was not highly developed and it was difficult to ensile immature grass. As a result the grass was generally cut and ensiled at the seed-head stage when the crop was relatively easy to handle and butyric silage was avoided. The silage quality was of secondary importance, the crop had a low D-value and therefore would only support maintenance when offered to lactating dairy cows. Silage of high quality from early cut grass was advocated therefore, as a feed for dairy cows. This crop, it was claimed, would not only support the maintenance requirements of the cow but would be a source of protein and replace some, if not all, of the concentrate ration (Turner, 1957 and Jones,

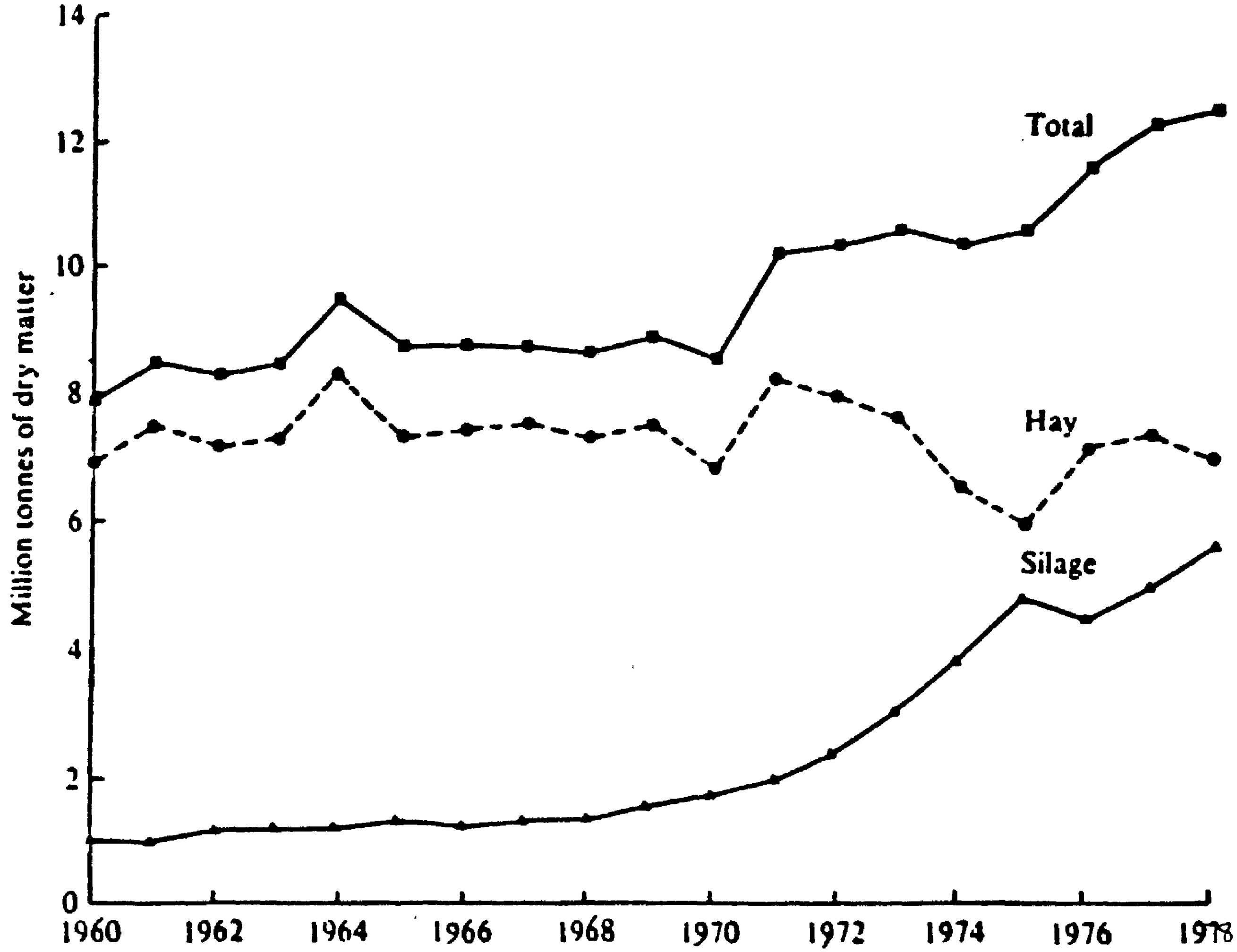


Fig. 1. . Estimated production of conserved grass in the U.K. 1960-1978

(Wilkinson, 1981)

1960).

The importance of cutting at an early stage of maturity was shown by (Murdoch and Rook, 1963) but it was not until the 1970's that a real interest was shown in silage with a high D-value (Castle, 1975). Before ear emergence the D-value of grass is generally over 70 and relatively stable. As the ears begin to emerge, there is a low rate of fall of digestibility which eventually declines rapidly and may reach 0.5 units of D-value per day (Minson, et al, 1960).

1.1.2. Silage temperature during ensiling

The temperature rise of grass during ensiling is an indication of the extent of continued respiration and fermentation. Initially, the temperature rise is due to the respiration of the grass until all the oxygen ensiled with the grass is utilized (Murdoch, 1961), when no oxygen remains, an anaerobic fermentation occurs until the increased acidity results in the death of the micro-organisms.

The heat produced is a result of the breakdown of the soluble sugars and therefore heating causes a loss of feeding value (Watson and Nash, 1960). The control of silage temperature is therefore extremely important and can be influenced by wilting, chopping and the stage of growth which all affect consolidation additives which limit plant enzyme activity and fermentation. The speed of filling and efficiency of sealing are important as they effect oxygen availability.

With non-wilted herbage temperatures below 25°C have been found to be satisfactory for silage production when using chopped and lacerated grass (Murdoch and Holdsworth, 1960). Over-wilted, long mature herbage is not easily consolidated in the silo and therefore results in higher temperatures. Watson and Ferguson, (1937) found that temperatures between 25-40°C were desirable for a satisfactory fermentation, with less risk of butyric acid production and no reduction in feeding value.

It can therefore be concluded that higher quality silage can be made successfully at a low temperature, if other factors, including the use of an effective additive are satisfactory.

1.1.3. Grass species for silage

An example of the variation between grass species was shown in comparison of a tetraploid, Reveille, with a diploid S_{24}, perennial ryegrass (Castle and Watson, 1971). The tetraploid ryegrass not only yielded more DM per hectare but the grass was also of higher digestibility and produced more milk per cow than the diploid ryegrass. The ensiling characteristics of the tetraploid ryegrass were also superior to the diploid as the former contained a greater quantity of soluble sugar which produced more lactic acid (Castle and Watson, 1971). This result agreed with a comparison of herbage species and varieties for ensiling characterisitics when varieties with a high water soluble carbohydrate content such as perennial ryegrass produced superior silages than timothy and cocksfoot which contain only low levels of sugar (Jones, 1970).

1.1.4. Use of additives

There are three main types of additives. Those that encourage fermentation by supplying extra carboydrates to be converted to acids.

Supplying more sugars to the grass for the bacteria to convert into acid, eg molasses, which contains approximately 500 g sugars per kg, was used widely as a silage additive until acids came on the market. The application rate varies from 10 to 20 L molasses per t, with the highest rate being applied to young, wet and leafy crops. The molasses must be thoroughly incorporated with the crop (Castle, 1982).

By the late 1960's, 70% of all silage made in Norway was treated with formic acid with good results (Castle and Watson, 1970) but it was not introduced into the United Kingdom until 1965. Initial investigations in this country were conducted in 1951 when both formic and glycollic acids were shown to produce better silage than molasses (Murdoch et al, 1955). Degradation of protein to amino acids is reduced slightly by formic acid treatment (Wilkinson et al, 1976), and there is evidence that N retention is increased following the addition of formic acid to direct-cut silage (Waldo et al, 1971). A mixture of formalin and formic acid (Wilson and Wilkins, 1974) has been found to be more effective than formalin and sulphuric acid.

There is a wide range of other additive on the market containing a variety of ingredients. The effectiveness of some of these additives at their recommended rate of application is questionable (Crawshow, 1977). However, the use of an effective additive is an advantage to production and utilization of high quality silage (McIlmoyle, 1976).

1.1.5 Wilting

The wilting of silage was first advocated in the USA in 1938 (Murdoch et al, 1955a), but it was not until the early 1950's that interest in wilting was shown in the United Kingdom (Murdoch, 1954).

The first reason given for wilting the crop was that the effluent produced from low DM silage resulted in a large loss of nutrients, blocked drains because of mould growth and caused pollution. It was concluded that effluent could be reduced considerably by wilting to 25% DM, and that this value could be achieved by wilting for 6 - 12 h of daylight. However, over-wilting was found to be deleterious as it resulted in heated silage (Murdoch, 1954). Comparisons have been made between wilted and additive-treated silage and also the effect of additive treatment on wilted silage.

Much progress has been made in reducing losses in silage making, also fermentation quality has been improved by wilting crops prior to ensiling and by use of chemical additives (Table 1) (Wilkinson, 1981).

Castle and Watson (1970a) found that wilting did not have the same beneficial effects as the use of formic acid. However, in a contrasting situation where a non-treated, non- wilted silage was well preserved, the use of formic acid did not increase DM intake whereas wilting resulted in a marked increase in intake (Hinks *et al*, 1976).

It may be concluded that as an insurance against an incorrect type of fermentation, and also to reduce the effluent losses, it is advantageous to wilt for approximately 24 h, but the application of an additive can also be useful.

Table 1 Typical losses of dry matter (%) during the conservation of grass as hay or silage under conditions of good management.

	Silage		Hay
	No wilting*	Wilted in field**	Dried in field***
Loss % in field			
Respiration	-	2	8
Mechanical losses	1	4	14
During storage			
Respiration	-	1	1
Fermentation	5	5	2
Effluent	6	-	-
Surface waste	4	6	2
During removal from store	3	3	1
TOTAL	19	21	28

* Formic acid added at 2.5 kg/tonne of fresh crop, ensiled in a bunker silo

** 36 hours wilt in the field, ensiled in bunker silo

*** 6 days drying in the field, no rain

(Wilkinson, 1981)

1.1.6. The production of high quality silage

Each aspect of silage production, described in this section must be considered for the production of high-quality silage. The management of the sward and a knowledge of sward development are of major importance as a high digestibility in the cut sward is one of the main factors in making high quality silage. A uniform sward is essential to allow an accurate prediction of cutting date, and the grass species must be high yielding and responsive to fertiliser N. Cutting early can lower the yield of DM but this can be largely offset by the use of adequate fertiliser N. The lower yield at one cut may also be offset by taking two or three cuts per season. A simple perennial ryegrass mixture has all the prescribed charactertistics plus a high soluble sugar content and is an ideal grass for high quality silage production.

A highly mechanised harvesting and ensiling system allows the grass to be ensiled quickly, after being wilted, chopped and an effective additive applied. The latter two factors plus the high digestibility herbage will ensure that the silage remains at a low temperature and preferably below 25^{o}C. With the aid of the tractor, a clamp silage is easily consolidated which must be followed by a complete covering and sealing with a weighted polythene sheet, with this sheet and impermeable wall the DM losses are reduced to a minimum and a high quality silage can be produced. The following rules are therefore a useful guide to the production of high quality silage.

1. Use simple perennial ryegrass mixtures.
2. Cut early before ear emergence.
3. Take 2 or 3 cuts in the growing season.
4. Wilt for 24 hours.
5. Chop to less than 25 mm.
6. Apply an effective additive, eg. formic acid.
7. Fill the silo quickly.
8. Consolidate the grass tightly to keep the temperature low.
9. Seal the top and edges of the silo with weighted polythene.

CHAPTER 2

FACTORS AFFECTING THE VOLUNTARY INTAKE OF GRASS SILAGE

In the United Kingdom, the winter feeding of ruminant livestock has traditionally been dependent on the use of conserved forages together with cereals. Silage making is not a new concept, it was popular in some parts of Britain as early as the 1870's, but the difficulties in feeding it to tied cows, a lack of adequate machinery to handle it, and the unpredictability of the quality of the end product, all contributed to its decline. There was, however, resurgence of interest in silage after 1945 as harvesting and storage methods became more mechanised and less demanding on labour. In addition, self-feed, easy feed and mechanical feeding systems have been devised for either clamp or tower silos which greatly reduce the labour requirements making this type of feed more attractive to farmers.

Dry matter intake of silage alone are generally inadequate as a source of energy for high yielding cows, although in one experiment a daily milk yield of 22.7 kg per cow was obtained when the cows ate 69.1 kg per day of wet silage made from young short grass (Crichton, 1941). This was, however, an exceptional result, and in a more recent series of feeding trials (Table 2) a mean milk of 13.58 kg per cow day^{-1} was reported when the sole feed was silage with a mean DOMD of 704 g kg^{-1} DM offered *ad libitum* to the dairy cows.

Table 2 Silage DOMD and intake, milk yield, milk composition and liveweight change with diets of silage only

Reference	Silage DOMD g kg^{-1}	Silage DM intake kg cow^{-1}	Milk yield kg/cow d^{-1}	Liveweight kg	Milk comp (g/kg) Fat	SNF	Totals	P	Lactose	Liveweight change kg d^{-1}
Brown, 1959	good	10.8	10.8	492.3	38.7	86.6	-	-	-	+0.49
Brown, 1959	medium	9.5	7.2	463.7	33.3	89.0	-	-	-	+0.46
Castle and Watson, 1975	704	11.6	14.5	481.0	43.4	82.0	125.4	29.9	44.4	-
Castle and Watson, 1976	703	10.8	14.6	474.0	41.9	83.7	125.6	29.0	46.9	-0.97
Castle *et al*, 1977	684	11.3	14.8	485.0	40.2	84.0	124.2	30.3	45.4	-0.21
Castle *et al*, 1977a	710	10.4	15.1	432.0	41.8	82.9	124.7	29.6	45.6	-0.52
Castle *et al*, 1977a	706	10.7	13.3	433.0	42.7	84.1	126.8	29.5	46.5	-0.31
Castle *et al*, 1977a	712	10.9	13.7	440.0	44.8	83.9	128.7	30.1	45.8	-0.12
Castle *et al*, 1980	712	12.8	16.0	-	40.6	86.6	127.1	32.5	46.3	-0.52
Rae, *et al*, 1986	good	11.4	15.8	-	37.8	-	-	29.5	-	-
Mean	704	11.0	13.6	462.6	40.5	84.7	126.1	30.1	45.8	-0.21

milk comp - milk composition
P - Protein

Milk yields of 7.2 and 10.8 kg per cow d^{-1} 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 4% fat-corrected milk (FCM) on a good quality, all silage ration. There are circumstances in which low yields of this level may be acceptable. The relatively low solids-not-fat (SNF) content of the milk and loss of weight by the cows (Table 2), make this system of feeding unacceptable, especially, with cows of high-yield potential.

2.1. Factors affecting voluntary intake in ruminant animals

In natural conditions where adequate supplies of food are available, animals do not starve but neither do they over-eat. Therefore there appears to be a regulatory mechanism within the animal which controls its food intake. As a general rule an animal which eats more, will either produce more milk, wool, muscle or fat.

The main aim in livestock farming is to increase output of meat or milk within the limits of economic consideration. To get maximum performance in terms of liveweight gain or milk yield, intake above the level required for maintenance of the animal must be achieved. The food should be of as high a quality as possible, thus improving the efficiency of food utilization.

The major factors affecting food intake in the cow are size and milk yield of animal, the composition and physical form of the diet and the time of access to the food. There are important inter-relationships between these factors. Intake is also influenced by the climatic environment, especially where summer temperatures are high, when appetite may be markedly depressed (Bines, 1979).

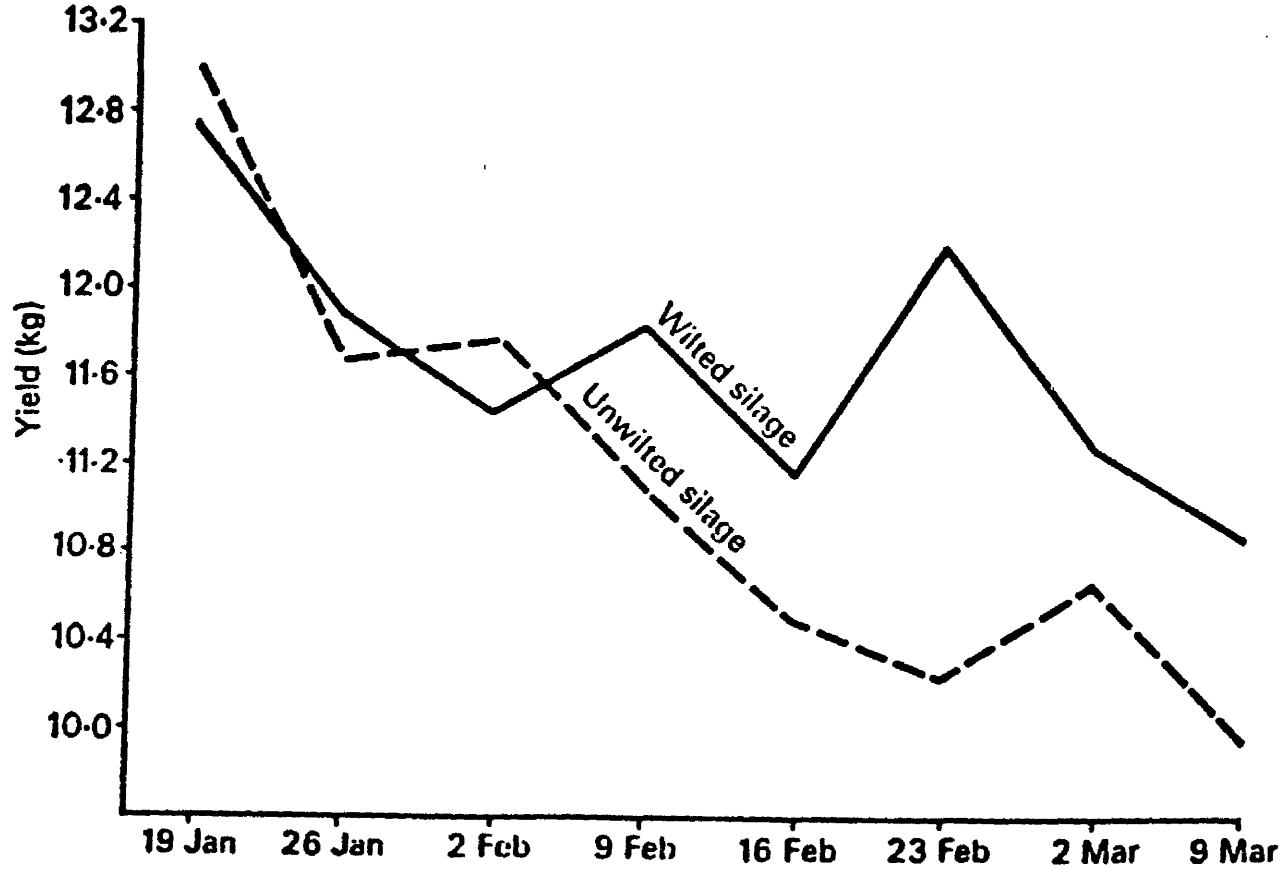
2.2. Food Factors

2.2.1 The effect of moisture content on the intake of silage.

Dodsworth and Campbell (1952) fed two pairs of sheep to appetite on silage: one pair received silage of 226.6 g kg dry matter, the other pair received the same silage which had been watered down to 168.5 g kg dry matter. Silage fresh weight intake was roughly the same for both groups but the sheep receiving the high dry matter silage achieved a much higher level of DM intake throughout the trial.

Wilted or unwilted silage which had DM contents 265 and 187 g kg respectively were offered to dairy cows for 4 h per day and resulted in a daily DM intake of 12.0 and 8.5 kg cow^{-1} for the wilted and unwilted silage respectively (Murdoch, 1960). However, Alder *et al* (1969) showed that although the milk yield on a wilted silage treatment was slightly higher than that on an unwilted silage, the difference was not significant, but the intake of wilted silage was higher than that of unwilted silage (Figure 2). England and Gill (1983) showed that when calves

Figure 2 **COMPARATIVE FEEDING VALUE OF SILAGES MADE FROM WILTED AND UNWILTED GRASS**



(Alder, 1969)

were fed wilted grass silage the daily intake increased from 18.4 to 19.9 g silage dry matter per kg liveweight and increased liveweight gain from 0.40 kg d^{-1} to 0.48 kg d^{-1}. In another experiment, although the wilting of grass silage from 20.5 to 30.8% DM slightly improved the fermentation quality, there was no increase in the DM intake and milk yield of dairy cows (Castle and Watson, 1970a). The wilting of silage may not therefore prove beneficial under all circumstances.

2.2.2. The effect of the concentrate supplementation on the intake of silage.

Silage is the main feed in the diet of many dairy cows, and supplements such as barley and other concentrates are normally offered in addition to the silage. This increases the overall concentration of nutrients in the diet to increase the total DM intake and milk production. 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 (Castle and Watson, 1975, 1976, Castle _et al_, 1977, and Mo, 1980). In four comparisons in which dairy cows were offered _ad libitum_ silage of 70.4 D values (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.

The quality of the roughage which concentrates are supplementing may be an important factor in the determination of the dry matter intake. Blaxter (1961) showed that when concentrates were added to low quality roughage the resultant decrease in intake of roughage was less than the extra dry matter supplied by the concentrates. With good quality roughage the loss of dry matter intake when concentrates were fed was greater than the amount of dry matter consumed as concentrates, creating a slight net loss in dry matter intake. Increasing the amount of concentrates generally depresses the voluntary intake of roughages, the depression being greater for roughages of high digestibility than of lower digestibility (Figure 3) (Østergaard, 1979). Leaver (1973) showed that the intake of roughage was depressed by increasing the level of concentrate supplementation, the greatest depressions occuring with roughages of high digestibility (Figure 4). Laird et al, (1981) found that the total dry matter intake was greater with silage plus concentrate as opposed to silage alone, although silage intake decreased when concentrate increased (Table 3).

Barley depresses the silage intake because of 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 and Thomas et al, 1980).

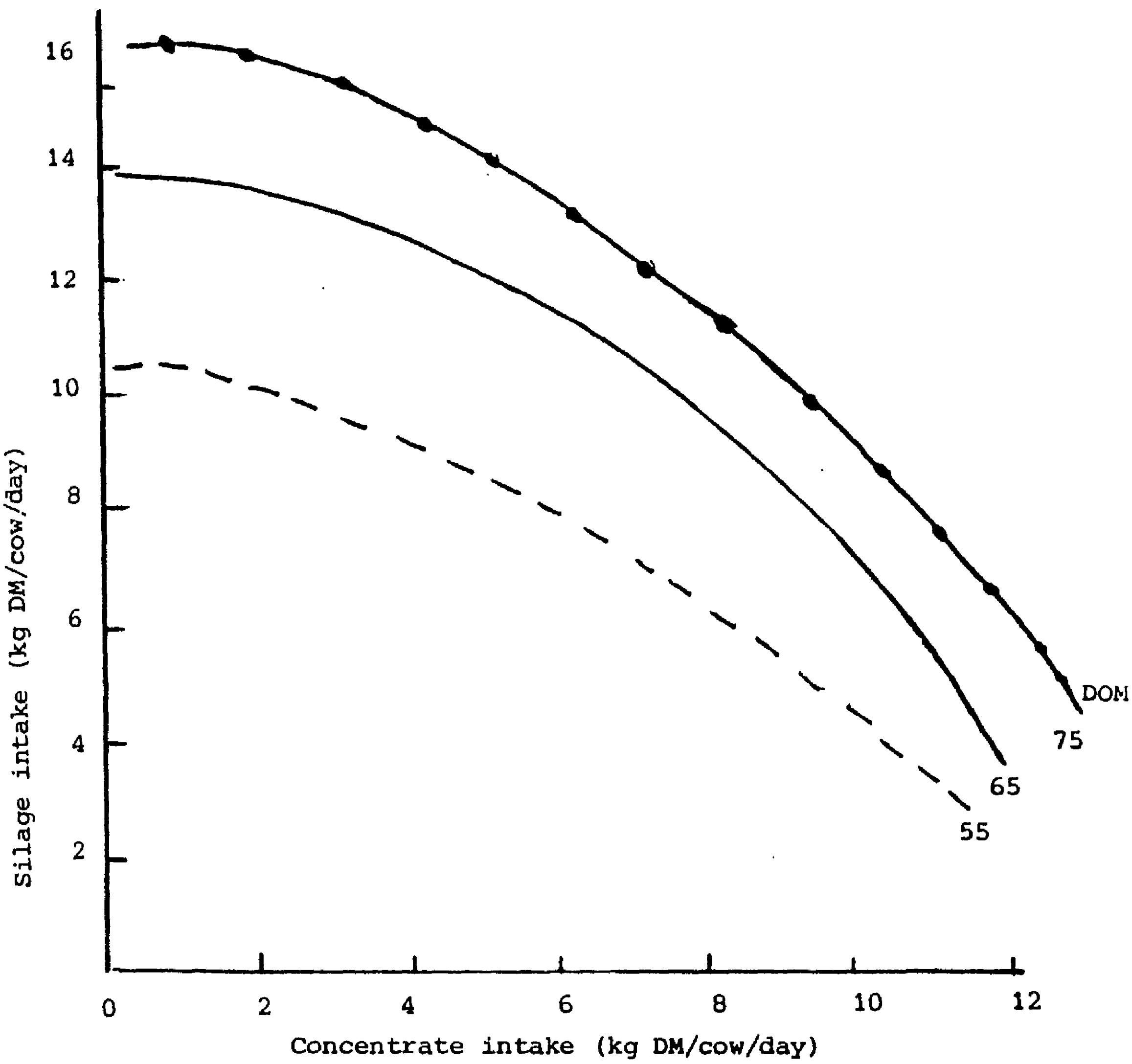


Figure 3 The effect of the digestibility of the organic matter (DOM) in silage on silage intake at different levels of concentrate intake

(Østergaard, 1979)

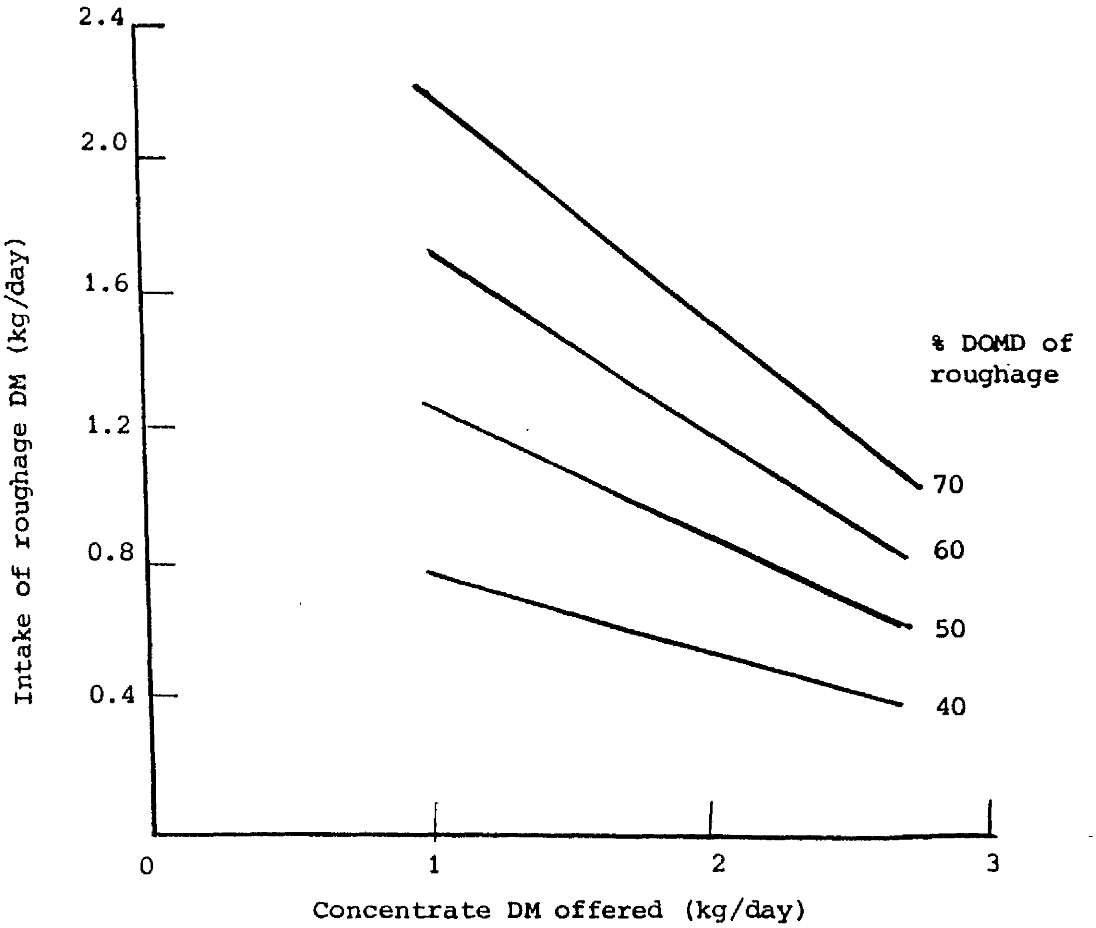


Figure 4 Effect of amount of concentrate offered on the intake of roughages differing in digestibility, fed to dairy youngstock.

(Leaver, 1973)

Table 3 Daily intakes of dry matter per cow from silage and concentrate supplements for the four feeding treatments

	A	B	C	D	
Silage fresh weight (kg)	51.21	45.66	42.52	33.91	***
Silage DM (kg)	10.29	9.17	8.64	6.94	***
Conc. supplement DM (kg)	2.17	4.65	6.26	7.62	***
Total DM intake per day	12.46	13.82	14.90	14.56	***

(Laird, et al, 1981)

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). Tayler and Aston (1976), Thomas and Castle (1978), Castle (1982a) found that dried grass cubes and groundnut cake have less of a depressing effect on silage intake than barley. 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 forages. A supplementary concentrate with a high starch content such as barley, encourages the multiplication of starch-digesting micro-organisms in the rumen which compete for nutrients with celluloytic bacteria (Elshazly et al, 1961). This reduces the number of celluloytic bacteria, causes a depression of cellulose digestibility and results in a decrease in feed intake.

The inherent problem associated with the feeding of concentrate is that the rumen pH may be depressed to values below 6 which is known to inhibit the cellulolytic micro flora, and this to reduce the digestion and intake of the cellulosic feeds (Osbourn et al, 1970; Mould and Orskov, 1983).

2.2.3. Effect of level of protein supplementation on silage intake

In an experiment reported by Murdoch (1962) when the supplements consisted of barley and various proportions of groundnut ranging from 0 to 25%, the intake of silage was 36.6 kg/day when the barley was the sole supplement, and 41.0 kg/day when the supplement contained 25% groundnut. The increase in silage intake was also accompanied by an increase in milk yield, with a maximum value when the concentrate contained 16% groundnut and a total CP content of 207 g/kg DM. Gordon (1977) showed similar response to protein from soya bean meal. In this experiment soyabean meal was included in the supplementary concentrate to increase the CP content from 90 to 210 g/kg on fresh basis. Although the intake of silage was not reported, the increase in milk yield from 18 .0 to 21.7 kg/ cow per day on the 90 and 210 g/kg CP supplements may be attributed to different intakes of silages.

The optimum rate of feeding extra protein was investigated in an experiment with dairy cows (Castle et al,1977) in which groundnut cubes with a crude protein content of 379 g/kg were offered at either 0.00, 0.07, 0.14 or 0.21 kg/kg milk. The

DM intake was similar at each level of supplementation and therefore the total DM intake increased progressively as the level of supplementation increased. The highest milk yields were obtained when the cubes were offered at either 0.14 or 0.21 kg/kg milk. Concentrate balancer cube was also given as a supplement for dairy cows offered silage (Laird, et al, 1981). The high protein cube (360 g kg^{-1} CP) was offered at 0.15 kg/kg milk and compared with an 180 g kg^{-1} CP cube offered at 0.30, 0.375 and 0.45 kg/kg milk. The consumption of silage was highest on the treatment including the concentrate supplement with high crude protein.

In a trial by Laird et al (1979) with ad libitum silage when concentrates of 140 and 180 g kg^{-1} crude protein (CP) were compared, the intake of grass silage was increased by 10% when the concentrate containing the high protein content was offered.

As the protein content of barley is inadequate for the adequate supplementation of high quality silage, other possible supplements have been investigated. A comparison was made by Castle and Watson (1975) of barley with high D-value dried grass as a supplement for dairy cows offered high quality silage . The dried grass had a DOMD 700 g/kg, contained 233 g kg^{-1} CP in the DM, and was compared with barley with 107 g kg^{-1} CP in the DM. The two supplements were offered to dairy cows at either 0.2, 0.3 and 0.4 kg/kg milk, and at each level the intake of silage was higher with dried grass than with barley. The higher intakes were accompanied by significantly higher milk yields. The higher intake of silage by the dairy cows offered dried grass compared with barley can be attributed to a lower depression of cellulose digestibility by the dried grass.

Gordon (1979) showed that increasing protein content in the concentrate resulted in increasing silage intake and milk yield (Table 4). The experiments indicated that in general a higher level of protein in the concentrate ration results in higher silage intake. Castle (1982a) reported that up to approximately 4 kg day^{-1}, soya and groundnut cake improved silage intake by 0.13 kg kg^{-1} supplement. They state that the higher nitrogen content of groundnut, dried grass and soya together with their low starch contents has less of a depressing effect on the digestion of fibre in the rumen than barley.

Recently Murphy et al (1985) found increased silage DM intake from 7.45 to 7.9 and 8.39 kg daily and milk yields were increased from 17.25 to 18.19 and 18.50 kg daily by inclusion of protein sources in the concentrate supplement compared with barley only.

Table 4 Silage intake with supplementary concentrates of different protein concentration.

	Protein concentration of concentrate g/kg fresh weight				
	95	137	174	209	SE of mean
Silage intake (kg DM/cow/day)	6.8	7.5	7.8	7.4	0.32
Milk yield (kg/cow/day)	18.0	19.3	20.4	21.7	0.54

(Gordon, 1979)

2.2.4. The products of fermentation and their effect on silage intake.

The condition of the grass and the methods of production dictate which bacteria become dominant and therefore the type of fermentation. The silage acidity increases until all organisms are killed and therefore a stable silage is produced. The extent of the change in composition from grass to silage is dependent on the length of time for stability to be reached.

During fermentation in the silo, the soluble constituents of grass, eg soluble carbohydrates, undergo a series of chemical changes. The resultant products are a possible cause of the limitation to silage intake. There are two major types of fermentation involving either the lactobacilli, or lactic acid producing bacteria, or the clostridia which result in butyric acid type fermentation (Wilkinson et al, 1976). A lactic acid type of fermentation results in a rapid decrease in pH because of the conversion of soluble carbohydrates to lactic acid. This produces a stable silage and therefore limits the extent of further chemical changes. This type of lactic acid silage is highly acceptable to stock and is essential for the production of high quality silage.

A linear and multiple regression analysis between the composition and the intake of 70 silages by sheep showed that the amount of lactic acid as a percentage of total acid content was positively correlated with voluntary intake (Wilkins et al, 1971). The importance of lactic acid was also shown by comparing the intake of 5 heifers given a basal ration containing sorghum silage with that supplemented with lactate to give either 5.9 or 9.0% lactic acid in the DM. Although the lower level of lactic acid addition failed to increase intake, the 9.0% treatment resulted in a 17% increase in DM intake over the control (Senel and Owen, 1966).

A butyric acid type of fermentation may occur when there is insufficient acid production. This happens either when the grass has a high moisture content or when it has a low concentration of soluble sugars. A butyric fermentation is accompanied by many changes, such as the degradation of protein to ammonia. The ammonia acts as a buffer, increases the pH and thus favours the continuation of the butyric fermentation. The silage is unpalatable to animals (Wilkinson et al, 1976). The acceptability of a butyric silage is low, and large amounts of butyric acid results in a depression in food intake (Ulyatt, 1965). However, the putrefaction which accompanies a butyric silage is undoubtedly part of the reason for the poor acceptability and intake of this type of silage.

Acetic acid, the third major fermentation acid, has also been suggested as a factor which may limit intake. A study of 70 silages has shown a negatively correlated acetic acid content with silage intake (Wilkins et al, 1971). Intra-ruminal infusions of acetic acid have significantly decreased the DM intake of hay by 35% (Montgomery et al, 1963).

2.2.5. Effect of pH on silage intake

The fermentation acids all contribute to the overall pH of a silage and there is evidence from a number of studies that silage with a low pH limits the voluntary intake (Wilkins et al, 1971, Brown and Radcliffe, 1972). However, the partial neutralization of silage with sodium bicarbonate has produced contrasting and conflicting results. An increase in silage pH from 4.0 to 5.4 resulted in a significant increase in DM intake, ranging from 9.7 to 20.7% with cattle and sheep (McLeod et al, 1970) and a 12% increase in the intake of male calves was obtained by increasing the pH of maize silage from 3.95 to 5.45 (Thomas and Wilkinson, 1975). In contrast silage pH was increased from 4.5 to 5.4 and 5.5 by the addition of sodium bicarbonate and ammonia but this did not increase the intake of sheep (Wilkins 1974).

2.2.6. Effect of chopping on silage intake

In the early days of silage making, the grass crop was ensiled mainly in the long state with no attempt to chop the herbage. As time has passed, the crop has been subject to an increasing degree of mechanical treatment, and it is now possible to find herbage that is precision-chopped to a length of approximately 10 mm before it is ensiled.

Chopping herbage prior to ensiling has three main effects on the silage fermentation process; the crop is inoculated with bacteria, plant juices are liberated and the oxygen content of the crop is reduced (Castle 1982). However, when grass is passed through machinery such as a forage harvester, grass juice collects on the metal parts and it is an excellent medium for development of the lactic acid bacteria. As a result, in one study the number of bacteria increased from 10^5 per kg fresh grass to approximately 5×10^8 per kg after forage harvesting (Castle, 1982).

The dry matter intake of chopped silage by cows was greater than the intake of unchopped silage and the lacerated silage 3.01, 3.38, 4.2 kg respectively (Murdoch, 1965). The different forage harvesters used for silage production at the present time produce a wide range of chop lengths, and effect of these on intake have been investigated by Dulphy and Demarquilly (1973). The silages were made with (i) a flail harvester, (ii) a harvester with knives on a plate and (iii) a precision-chop forage harvester to produce silage with chop lengths of 100-250mm, 50-150 mm and 5-15mm respectively. The shorter chopped silage had a better fermentation quality, higher digestibility and voluntary intake. The intake of the short chopped silage was 11.9 and 43.9% greater than the intake of the medium and long silages respectively.

Dulphy et al (1975) found that the celluolytic activity and rate of digestion were not significantly affected by the quality and chopping of silage and if the two factors above could not explain the lower intake of long silage, the speed of physical breakdown could perhaps partly explain the result. In contrast, England and Gill (1983), observed there was no response in dry matter intake or digestible energy (DE) to chopping. But liveweight gain was increased from 0.42 to 0.46 kg d^{-1} by short chopping.

Pathak and Pal (1983) reported that when 9 Murrah buffalos were fed 30 kg green forage daily with concentrate and there were no significant differences in dry matter intake, milk yield and milk composition between diets with the roughage cut 5, 2.5 or 1 cm. Milk yield tended to increase, and fat content to decrease, as chop length decreased. Shelford and Vaage (1986) fed 18 dairy cows in early to mid lactation three different particle lengths of forage 10, 15 and 20 mm. Slightly higher, but not significantly different intake and milk yield were achieved with the chopped silage, 14.6, 14.4 and 13.9 kg DM d^{-1}

respectively and 25.8, 25.3, 24.7 kg d^{-1} respectively. Protein and lactose percentages were not influenced by the particle length of the forage lengths. Dulphy et al(1984) found increased length of silage particles decreased silage intake by both heifers and sheep. Recently Vaage (1986) showed increase in forage intake from 13.9 to 14.6 and 14.4 kg d^{-1}; concentrate intakes were 9.7, 9.9 and 10.1 kg d^{-1}; milk yields 24.7, 25.3 and 25.8 kg day^{-1} respectively when three particle lengths of forage (20, 15 and 10 mm) were examined.

2.3. Management Factors

2.3.1 Effect of time of access of food

The time for which the animals have access to food also has an important bearing on the dry matter intake. Murdoch (1962) reported an experiment where dairy cows were given different times of access to silage of two different dry matter levels (Table 5). It was found that by increasing the time of access from 3 to 24 hours per day (minus the time when the cows were being milked) increased intake by up to 2.2 kg DM^{-1}. Campling (1966) observed that dry cows ate 2.1 kg d^{-1} more dry matter

when given access to silage for 24 h d^{-1} compared to those with access for only 5 h d^{-1}.

In another experiment, Leaver and Yarrow (1977) found with dairy heifers self fed on maize silage, a reduction in time of access from 5 hours to 3 hours led to a reduction in intake of only 7%. Harb and Campling (1983) increasing access from 5 to

22 h increased silage intake by 37% and increased milk yield by 11%.

Table 5 Effect of dry matter content of the silage and time of access on intake

Treatment	Dry matter as g/kg	Silage intake kg/d	DM intake kg/d	DM as %
1- Unwilted silage Restricted	197	49.0	9.6	100
2- Unwilted silage 24 h access	219	53.9	11.8	122
3- Wilted silage Restricted	287	47.1	13.5	141
4- Wilted silage 24 h access	312	46.1	14.4	150

Murdoch (1962)

2.3.2. Effect of frequency of feeding roughage on food intake

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 instead of twice daily (Table 6). Johnson (1979) reported an increase in milk fat content when concentrate were given in 5 instead of 2 feed daily. Kaufmann (1973) reported the higher feeding frequency (14 times per day v.s. 2 times per day) was found to lead to slightly higher roughage intake and significantly higher milk fat content with higher feeding frequency. More recently, Ikhatua and Adu (1983) concluded that increasing the feeding frequency from once to twice or 3 times daily resulted in higher feed intake and liveweight gains. Feed DM intake was positively correlated with frequency of feeding.

In contrast, Horton and Nelson (1981) found no effect on the total amount of grain when heifers were fed 2, 4 and 8 times a day and similarly Gill and Castle (1983) found that no significant effects on silage intake, total nutrient intake, milk yield and liveweight when fed the cows concentrate, 2 and 22 x per day. Luhmann (1983) found with cows and heifers that the DM intake was positively correlated with frequency of feeding.

Table 6 Mean averages for production characteristics

Feeding frequency/d	2X	4X	7X
Total daily feed intake (kg)	17.70	19.20	18.95
Total milk (kg)	15.68	17.13	16.82
Solids-not-fat (kg)	1.44	1.57	1.56
Milk fat g kg/d	645	755	777
Milk fat g/kg	4.1	4.4	4.6
Total solids kg/d	2.08	2.33	2.34

Campbell and Merilan (1961)

2.4 Animal Factors

In one experiment, Campling and Balch (1961) found that when boluses of swallowed hay were collected at the caridia and removed by hand, cows ate 70-85% more than their normal diet of hay. There are also general factors affecting intakes, these include size and age of the animal i.e. the older and heavier an animal the larger the capacity of its gut and hence it will normally have an increased appetite. As females are usually smaller than males, they would be expected to have smaller intakes.

In pregnant animals, two opposing effects influence food intake. The increase need for nutrients for foetal development causes DM intake to rise in the later stage of pregnancy. However, the effective volume of abdominal cavity is reduced as the foetus increase in size, and thus reducing the size of the rumen. As a result intake will be depressed, especially with a predominantly roughage diet (McDonald et al, 1981).

2.4.1. Thermostatic Regulation

McDowell et al, (1976) measured intake of Holstein heifers calving at different times of the year. When all heifers were fed essentially ad libitum, heifers calving in January and February, when the maximum daily temperatures were 7.2°C, consumed 14% more food than those calving in July and August when the temperature was 30.6°C. Head et al (1976) showed that food intake was not consistently affected at temperatures under 26°C but above 26°C the food intake reduced. Milk yield declined at environmental temperatures above 18°C. Above the thermonental zone, body temperature rises and so food intake decrease in order to reduce the heat production associated with feeding,digestion, absorption and metabolism and to prevent an excessive increase in body temperature (Forbes, 1986).

2.4.2 Chemostatic Regulation

Alterations in the level of the metabolites circulating in the blood affect food intake. In the energy metabolism of ruminants volatile fatty acids are produced in the rumen. Acetic, propionic and butyric are important and some or all may act as regulators. Rook _et al_ (1963) found that when acetic acid was infused into the rumen there was a significant depression in the _ad libitum_ intake of hay, also Egan (1965) reported that infusion of acetic acid at a physiological level caused depression of feed intake, propionic and butyric infusion have less effect than acetic acid. Ulyatt (1965) observed that the intake depression by infusion of acetate was greater on a poor than on a good quality diet because acetate metabolism is more rapid in animals on a high than a low plane of nutrition. He found the food intake decreased when the dose rate of acetic acid and propionic acid increased. The dry matter digestibility was also depressed as a result of adding acetic acids to the rumen (Rook _et al_, 1963).

CHAPTER 3

SECTION I

THE CULTIVATION OF FODDER BEET

After a neglect of about twenty years, between 1950-1970, due largely to their high demand for labour at singling and harvesting, fodder beet has returned to cultivation. This is mainly due to genetic advances in monogermy and bolting resistance and improved harvesting methods. These changes, first made in sugar beet, have now been bred into fodder beet varities. This means that the crop can be grown with minimal manual labour (Heppel, 1985). In 1948 there were only a few acres, mainly experimental areas at a number of research centres, but in 1985 the total area grown in England and Wales was 8219 ha (MAFF, 1985) and in Scotland about 415 ha (Department of Agriculture and Fisheries, Scotland, 1986).

A well-grown crop can be expected to yield (12 t) of dry matter per hectare from the roots, and the best crops may give a harvested root yield of 85 tonnes/ha fresh weight (15 tonnes ha^{-1} dry matter), and a further 2 to 5 t DM from the tops (MAFF, 1985a). The root has an ME content of about 11.8 to 13.0 MJ Kg^{-1} DM and a D value of 78 to 85 but is low in crude protein: 40 to 80 g kg^{-1} DM. The crude protein content of the leaf varies from 100 to 200 g kg^{-1} DM, but the energy content is lower at 9 to 10 MJ kg^{-1} DM. The utilised metabolisable energy (UME) output per hectare of beet can thus be as much as 150% of that of grass silage (Heppel, 1985). In a recent study fodder beet gave the highest yields of dry matter and metabolisable energy although not much higher than maize or ryegrass (Table 7). Fodder beet often gives its highest yields in years when ryegrass gives its lowest due to summer drought.

3.1.1 Varieties

In recent years many monogerm varieties have been evaluated but interest has been mainly concentrated on 2 Danish varieties, Kyros and Hugin, and the French variety, Trestel.

Heppel (1987) reported different dry matter yield and different DM content in roots and tops of the different varieties (Table 8). There are three groups of varieties:-

1. High dry matter with about (17-23%) dry matter in the root, and highest yield potential especially of tops. Roots are least prone to frost, mechnical damage, storage losses and resistant to bolting. Roots are deep in the ground over 60%, so they are the most prone to soil contamination but well suited to lifting with sugar beet harvesters. Hugin, Krake, Monofix and Trestel are typical.
2. Medium dry matter (14-17% DM) in the root. Kyros is typical and a very smooth root. Under 50% of the root in the ground. The root remains relatively clean, even in wet years, and can be hand-harvested or lifted by purpose-built fodder beet harvesters or by top-lifting sugar beet harvesters. The variety produces a high yield of tops, has outstanding resistance to bolting and is one of the

Table 7 The relative output of various fodder crops in England and Wales

	Fresh yield t/ha	Dry Matter g/kg	Dry Matter Yield t/ha	Metabolisable Energy Yield GJ/ha
Fodder beet roots	75	180	13.5	160
Swedes*	69	96	6.6	84
Kale*	35	156	5.4	59
Maize (forage)*	50	250	12.9	136
Perennial Ryegrass (3-5 cuts)	53	250	13.3	140
Winter wheat (grain)	8.4	860	7.3	99
Winter barley (grain)	6.9	860	5.9	76

(MAFF, 1985a)

*In Scotland yield of swedes and kale are about 20% higher than in England and Wales but the maize crops are lower (Heppel, personal communication).

highest yielding varieties available to farmers (MAFF, 1985a). Kyros is widely cultivated in Denmark, Western Europe particularly in France, Germany, Great Britain and Ireland (Danish Plant Breeding, 1983).

3. Low dry matter (10-14% DM) the roots, are only 33% below ground with very small tops and lowest energy yield potential. They are most prone to mechanical damage and store least well. Peramono and Red intermediate are typical varieties (Danish Plant Breeding, 1983, MAFF, 1985a).

3.1.2. Husbandry

3.1.2.1. Climate

Fodder beet grows best in warm conditions where it can be sown early and can continue growing until well into the autumn. It does not grow well in the colder and wetter regions. The most important factors affecting the dry matter yield of the crop are the temperatures in May and June and the moisture supply towards the end of the growing season in September and October. High rainfall towards the end of the growing season will result in low dry matter contents, while low rainfall will produce high dry matter contents (Table 9). Mean temperatures above normal in the early stages of the growing period in May and June tend to raise the final dry matter content at harvest by giving the young plants a good start (Boyle, 1952; Alstergaard, 1983).

Table 8 The mean DM yield and DM content in roots and tops, results of variety trials from 1982 to 1986.

Variety	DM yield as % means Roots	Tops	Total	DM content g/kg Roots	Tops
Mean, t.ha	10.6	3.4	14.0		
Bioma	99	107	101	180	103
Hugin	105	106	105	196	109
Jumbo	99	90	82	187	110
Kyros	106	101	105	178	108
Monobomba	101	102	102	175	106
Monofix	106	116	108	200	106
Monorosa	99	117	103	193	110
Monoval	97	89	95	164	102
Monovigor	103	108	104	180	104
Trestel	108	125	117	186	108
Vermon	93	85	90	183	105
Wintergold (mangel)	87	56	80	117	106

(Heppel, 1987)

Table 9 The mean dry matter content in fodder beet as influenced by different climatic conditions in Britain.

		DM content g/kg
(a)	very wet	180
(a)	normal rainfall	190
(a)	slight rainfall	200
(b)	very wet	190
(b)	normal rainfal	200
(b)	slight rainfall	210
(c)	very wet	200
(c)	normal rainfall	210
(c)	slight rainfall	220

(a) May and June colder than normal

(b) May and June normal temperature

(c) May and June warmer than normal

(cited Boyle, 1952)

3.1.2.2. Soils

Fodder beet is adapted to all well-drained, free working deep loam soils with a pH of 6.25 to 7.00 and not below 6 MAFF (1985a). An alkaline sandy soil may cause a certain amount of heart-rot, through boron deficiency (MAFF, 1985a). On thin, stony soils with a pan, root growth may be stunted and fangy. High yields of fodder beet can be obtained on clay soils, but in dry years the difficulty of lifting is increased, particularly with deep set types.

3.1.2.3. Seed bed preparation and sowing depth

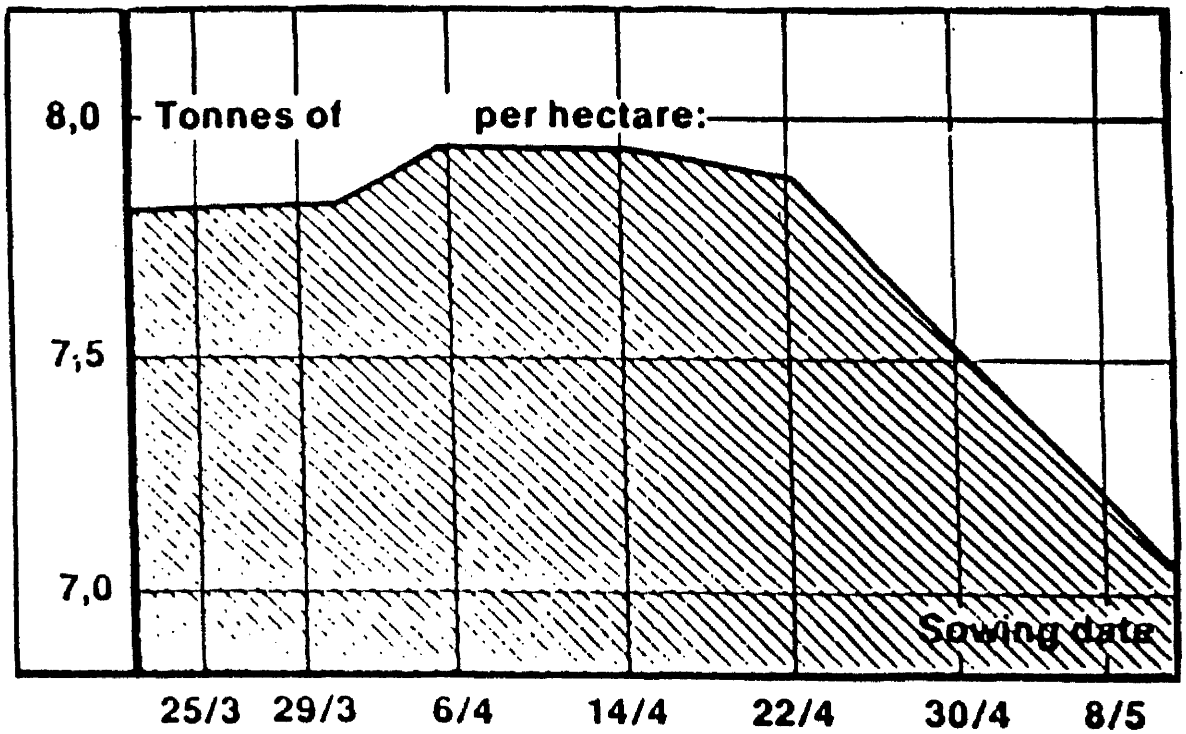
It is important that field operations are not begun until the soil is suitable, when surplus moisture has drained from the ploughed layer and weather conditions are suitable.

A fine firm seedbed is required. The soil must be level, with Dutch harrowing, it is possible to establish a homogeneous flat surface by merely treating the top soil layer. This ensures a uniform sowing depth, which is very important for crop establishment. The optimum sowing depth for fodder beet is 18 to 25 mm. This depth assumes that the seeds are covered by 5 to 10 mm of moist soil. Deeper sowing may be necessary to reach moist soil in a dry seed bed (MAFF, 1985a).

3.1.2.4. Sowing date

Results have been published of sowing date in Denmark under different conditions as shown in Figure 5. The best sowing date when the soil conditions are favourable is about 10 April.

Figure 5 Sowing date



(Alstegaard, 1983)

Sowing can be delayed until about the 22nd April without any appreciable loss of yield.

3.1.2.5. Fertiliser

The largest single expense of growing fodder beet is inorganic fertiliser which at moderate levels of soil fertility is required in the $N:P_2O_5:K_2O$ ratio of about 3:2:4+ which is broadly similar to that of slurry, 3:1:6 and fresh farmyard manure, 3:2:9. In an experiment reported by Heppel (1985) it was found that fodder beet can be grown with slurry only. With the cost of inorganic fertilisers removed, and a farm by-product exploited, the production of beet becomes a possible 'low-input' enterprise. The level of fertiliser applied depends upon the individual field soil analysis and whether salt has been used. Fertiliser should be applied before drilling and general recommendations as shown in Table 10 (MAFF, 1985a) for England and Wales and Table 10A (SAC, 1985) for Scotland.

3.1.2.6. Harvesting date

Weather conditions play an important role in beet harvesting, since prolonged rain can make it difficult for the machines and hard night frosts may badly damage the crop. Ideally the beet should be harvested in October or November (Augustinussen, 1983).

Taunton (1985) found the dry matter increases by 0.6 tonnes of dry matter per ha per week when harvesting fodder beet from September to the end of October. Yields also have been shown to increase by as much as 1 tonne per week from September until November (Evans, 1986). This result agreed with 12 trials carried out in Denmark which shows the average yields of fodder beet on 5 different harvesting dates (Table 11). There was a significant increase in dry matter production until 12 November, whilst the yield of tops dropped throughout the trial period.

3.1.3. Storage

Efficient storage of fodder beet depends to some extent on the management of harvesting and to a considerable extent on good clamping, or storage technique. The biggest problem with storing fodder beet is over heating, this is because the roots continue to respire in store particularly if excess top or leaf debris is present, which restricts natural ventilation. The temperature should range between 3^{o} and $5^{o}C$, whether in clamp or barn, at this temperature the level of dry matter loss and rot fungi is minimised (Augustinussen, 1983).

Some loss in feed value during the storage period is inevitable, particularly if the beet are to be stored until late spring. This is due largely to the roots continuing to respire in store and also due to attacks by micro-organisms and insects in the late store period.

Table 10 Fertiliser Recommendations (kg/ha)

Soil nutrient status

	England and Wales				
	0	1	2	3	over 3
Nitrogen	125	100	75	nil	nil
Phosphate	100	75	50	50	nil
Potash	200	100	75	75	75
Magnesium	100	50	nil	nil	nil

(MAFF, 1985)

Table 10A Fertiliser Recommendations (kg/ha)

		Scotland	
	Low	Moderate	High
Nitrogen	150	110	70
Phosphate	120	70	50
Potash	225*	150	75

*Part of the K_2O for fodder beet can be replaced by salt, eg. 400 kg salt/ha can replace 100 kg K_2O/ha.

Apply salt at least 4 weeks before sowing.

(SAC, 1985)

Table 11 Dry matter yield of fodder beet harvested at different dates.

Harvesting date	Dry Matter Yield, t/ha Roots	Top	Dry Matter Loss %
1 October	10.6	4.7	10.2
15 October	11.4	4.5	9.4
20 October	12.1	4.2	7.8
12 November	12.5	4.0	7.3
26 November	12.4	3.6	6.6

(Augustinussen, 1983)

A tonne of fodder beet roots occupies about 1.4 m^3 and they should be stored to a maximum height of 2 to 3 metres and 4 to 5 m wide without ventilation pipes (Heppel, 1985) but above this width it is advisable to insert ducts either down the centre of the clamp or every 4 to 5 m down the side. The amounts of protective covering required on outdoor clamps will depend upon the winter weather conditions. Fodder beet is usually covered with straw to retain moisture and with the onset of colder weather, protection from freezing winds should be provided by covering the straw with polythene sheeting held in place with earth or tyres.

SECTION II

EFFECTS OF OFFERING FODDER BEET ON DM INTAKE AND PRODUCTION

3.2.1. Feeding levels

According to Dutch recommendations, fodder beet is most efficiently utilized by dairy cows when fed in amounts of up to 25 kg per day, up to 45 kg per day can be fed without ill effects. It is considered, in Holland, that optimum utilization is obtained with a limit of 25 kg of beet daily (Boyle,1952) but up to 45 kg fresh weight can be fed without ill effects. Stock should be introduced to fodder beet gradually for it is possible that when large quantities of beet are fed, without allowing a transition period, that there may be rapid change in the micro flora of the digestive tract leading to digestive disturbances.

Several reports on feeding high levels of fodder beet to livestock have been recorded, under Danish conditions. Typical rations using large quantities of fodder and designed to provide for maintenance and 14 kg of milk, include up to 39 kg fodder beet, 22 kg lucerne silage and 2.2 kg hay (Boyle, 1952). Under UK conditions Roberts and Dickson (1985) recommended the 3 rations in (Table 12) to produce 15, 20 and 30 kg of milk daily.

Table 12 Three different rations to produce 3 different levels of milk

Milk yield (kg/day)	15	20	30
Feed intake (kg/day)			
Silage (230 g kg DM, ME 10.2 MJ kg/DM)	40	38	31
Fodder beet (185 g/kg DM)	15	15	15
Compound (CP 160 g/kg)	1.25	4.25	10.5

(Roberts and Dickson, 1985)

Castle (1953) found a cow may eagerly consume as much as 36 kg fresh weight of fodder beet a day but there arises at this high level of root feeding the problem of adequately balancing the ration. Bailey *et al*, (1953) found that the largest amount of fodder beet eaten in a day was 45 kg fresh weight and the beet had 199 g/kg DM. No digestive disturbances were recorded, and the dung of the animals was not unduly loose compared with that of similar animals eating hay basal rations. Similarily, other workers have reported feeding fodder beet between 20 kg fresh weight day and 40 kg d^{-1} without any problem (Castle *et al*, 1961, 1963; Brabander *et al*, 1976, 1978, 1981; Oprea *et al*, 1978; Krohn and Andersen, 1979; Jans, 1983, Kubes, 1984 and Kerouanton, 1986).

Verite and Journet (1973) showed that when increasing amounts of fodder beet (2.5, 7.5, 10 and 12 kg DM) about (14; 42; 56 and 67 kg fresh weight) were fed there was a decrease of cellulolytic activity in the rumen liquor and decrease of rumen liquor pH.

Trials carried out in recent years with high yielding dairy cows showed that when they were given a choice of concentrate, fodder beet, silage and barley straw for 24 hours, they showed a distinct preferance for fodder beet and average daily intake for 12 cows was 17.6 kg DM, one cow consumed more than 15 kg beet DM/day (78 kg fresh weight) on average during the first 20 weeks after calving without digestion problems (cited Larsen, 1985).

3.2.2. Forage replacement

The effect of feeding fodder beet on increasing total dry matter intake has been reported from many different experiments. Very little research work has however been carried out on fodder beet for dairy cows in Great Britain. The bulk of the experimental work has been done in Europe, principally in Belgium, Germany, Scandinavia and Eastern Europe. Fortunately, most workers agree with each other on the effect of fodder beet feeding. Experiments have tended to be based on *ad libitum* forage, some times supplemented with concentrates, and then fodder beet is added to these control diets.

When fodder beet is added to a forage diet, in normal quantities, it does not replace the forage on a 1:1 basis. The actual replacement rate varies from 0.3-0.9 kg forage DM kg fodder beet DM depending on the qualities of forages.

Castle *et al* (1961) fed twelve Ayrshire cows on the 3 diets and showed that the addition of fodder beet increased the total daily DM intake from 13.2 kg to 14.8 and 16.1 kg DM^{-1} when fed fodder beet (0.0, 2.68, 5.18 kg DM). The largest effect was on the silage intake which fell from 4.9 kg DM^{-1} of silage for ration without fodder beet to 4.0 and 3.1 kg DM for ration with fodder beet.

Castle, *et al* (1963) found a similar increase in total dry matter intake when 3.73 kg DM day^{-1} of fodder beet was fed in a diet with fixed amounts of concentrate, hay and *ad libitum* silage (Table 13) to 12 Ayrshire cows. They reported a reduction in silage dry matter intake, but there was an increase in total dry matter intake of 2.27 kg d^{-1} at the high concentrate level and 2.05 kg DM d^{-1} at the low concentrate level. On average, for each 1 kg beet dry matter eaten there was a reduction of 0.42 kg of dry matter in the amount of basal feed (silage) consumed.

Table 13 The feed intake kg DM d^{-1} for fodder beet, hay, concentrate and silage.

Fodder beet	Concentrate	Hay	Silage	Total
3.73	5.20	2.95	3.7	15.58
3.73	2.60	3.00	3.9	13.20
-	5.00	3.04	5.2	13.20
-	2.60	3.04	5.6	11.20
SED	±0.15	±0.041	±0.19	±0.21

Castle _et al_ (1963)

During the course of two trials with two rumen fistulated cows, to study the voluntary intake of a diet containing fodder beet associated with each of the 4 following forages offered _ad libitum_ (1); grass silage (2); lucerne hay of medium or excellent quality (4) maize silage. The substitution rate was only partial between beets and hay (1 kg DM of beets, 0.5 kg DM of hay) when the amounts of beet were lower than 5 or 10 kg DM (according to hay quality) (Verite and Journet, 1973).

Brabander _et al_, (1974) fed basal forages of grass hay with a high dry matter content, grass hay and grass silage of a moderate quality. An average daily dry matter intake of forage alone was respectively 8.76, 7.24 and 8,45 kg and when beet was added at 2.72, 3.04 and 2.85 kg dry matter, the intake increased to 10.39, 8.88 and 10.00 kg DM. These results indicate that the fodder beets had a favourable effect on the intake of the basal ration. On average for 1 kg dry matter from fodder beets, the intake of dry matter from the basal forage was reduced by respectively 0.40, 0.46 and 0.46 kg dry matter. The effect of restricted quantity of fodder beet on roughage intake by dairy cattle was studied in 6 trials reported by Brabander *et al* (1976 and 1978). They found in all trials fodder beet decreased the intake of basal forage, and the substitution rate of the fodder beets varied from 0.4 to 0.96 and seemed to be dependent on the quality of the basal forage. With moderate forage quality the substitution rate ranged from 0.40 to 0.46 with higher quality forage the substitution rate varied between 0.65 and 0.96.

Krohn and Anderson (1979), fed different sources of carbohydrate, one of the source of carbohydrate was sugar (fodder beet) and the other was starch (barley) to the cows there was no significant difference on the feed consumption between both feeds. Both barley (starch) and beets (sugar) only reduced the silage intake by 0.4 to 0.5 kg DM for each kg DM.

Coenen (1981) reported an increase in total dry matter intake when 4 kg of maize silage was replaced with 22 kg fodder beet. In the study of Burgstaller *et al* (1982) the relationship between fodder beet and total dry matter intake was positive when wilted grass silage was fed. The consumption of wilted grass silage decreased by 0.4 kg DM^{-1} beet.

Recently, Roberts (1985) found when dairy cows were fed silage *ad libitum* and concentrate at 6 kg/day with 3 levels of fodder beet and soya bean meal the total dry matter intake increased as fodder beet level increased. The substitution rate of fodder beet and sbm* for silage DM was 0.48 and 0.53 for comparison between treatments zero beet and treatments 2 kg DM fodder beet + 0.5 kg DM sbm* and treatment 4 kg DM fodder beet + 0.9 kg DM sbm* respectively. In contrast, Izumi *et al* (1976) with eight lactating Holstein cows studied the effect of feeding fodder beet with maize silage on feed intake compared with the ration without fodder beet. They found the total dry matter intake was not significantly different for cows fed silage only than the cows with fodder beet.

3.2.3. Soil contamination

The feed value of the beet depends on the amount of soil contamination which is reflected by the ash content of the dry matter. Soil contamination of whole beet fed as a separate feed from the forage is a nuisance but not a serious problem at lower levels of soil contamination (less than 5%). Beet are still eaten well and most of the soil is left behind and not eaten. However, when dirty beet are chopped, or mixed with silage, then the soil is mixed with the diet and soil intake can be high. The intake of the beet and the silage is depressed, and a lot of feed can be wasted. This is greatly influenced by the care taken at harvest but the beet must be cleaned and then chopped before feeding. On light soil, it is sufficient to give

*sbm = soya bean meal

the beet a 'dry cleaning' although the use of water is often necessary if they are grown in heavy clay soils.

SECTION III

3.3. Effect of fodder beet supplementation on cow performance

The effects of fodder beet feeding on milk yield depend on the level of feeding and other components of the diets. Before, 1956 several reports on the adverse results of feeding fodder beet to livestock recorded suspected poisoning in cattle (Penny, 1954). The adverse effects were mostly due to the sudden introduction of fodder beet in large quantities to the daily rations of livestock. Other workers have reported successful trials with fodder beet feeding and shown increased or satisfactory milk yield and milk composition when fodder beet are fed, either as a supplement to forage or replacing some of compound in the diet.

Fodder beet was used in Danish trials with dairy cattle in the 1940's. By the careful management of two selected groups (each of 8-10 cows), with a production of about 5,000 kg of milk per cow per annum in the first lactation, the yield was successfully increased to 10,000 and to 11,000 kg of milk per cow in the second and third lactations, maximum yield for a single cow was 58.5 kg of 4% B.F. milk and the ration was 30kg of fodder beet, 15 kg of grass silage, 5 kg of lucerne hay supplemented with 16-18 kg of concentrates (Larsen, 1983).

In 1952 Boyle reported that under Danish conditions, ration including fodder beet (27 kg fodder beet, 27 kg lucerne and 3.6 kg barley) were fed to provide for maintenance and 14 kg of milk.

In a study on the effect of feeding fodder beet immediately after lifting from the field to milk cows (Bailey et al, 1953) found the mean milk yield was 12 kg of milk daily when the cows were fed 18 kg fodder beet. This quantity of beet was consumed readily and the cattle milked normally.

Castle et al, (1961) observed that when Ayrshire cows were fed three levels of fodder beet (0, 13.6 and 27 kg fodder beet) there was a significant difference $p<0.05$ in milk yield between 0 and 13.6 kg fodder beet. There was no significant difference between 0 and 27 kg fodder beet and slightly decrease in fat percentage of the milk with the treatment including fodder beet. This result agreed with Boyle (1952); he reported that when fodder beet comprises a high proportion of the ration of a dairy cow there may be a slight lowering of the butter fat content of milk, and he suggested when the ration is properly balanced for protein, minerals and vitamins this should not occur.

In 1963 Castle et al showed a small but significant increase in milk yield when fodder beet was fed at 3.8 kg DM compared to zero fodder beet diet. There was no significant effect on fat percentages of milk although they tend to be lower when fodder beet was fed.

Castle *et al* (1961) reported an improvement in the protein content of milk from 31.4 to 32.7 g kg^{-1} when the level of beet feeding was increased from 0 to 5.2 kg DM day^{-1}. A study by Izumi *et al* (1976) showed no significant differences in milk yield, milk composition and body weight when fodder beet was fed to dairy cows (Table 14).

Krohn and Andersen (1979) investigated the influence of 2 different sources of carbohydrates on the milk yield, milk composition, liveweight and liveweight gain. One of the sources of carbohydrate was sugar (fodder beet) and the other was starch (barley). The influence on changes in milk production of the individual rations: (1) 6 kg DM beets and no barley, (2) 3 kg DM beets and 3 kg DM barley and (3) no beets and 6 kg barley are given in (Table 15). There was a tendency towards a higher yield with ration include 6 kg DM barley. Fat content in milk tended to fall from ration including 6 kg DM fodder beets to ration include 6 kg DM barley. They suggested that this may be due to the increasing starch content in the ration which includes barley and the energy intake was also greatest.

Table 14 Average milk production, milk composition and body weight

	Silage	Silage+ beet pulp	Silage+ fodder beet	Silage+ beet pulp+ fodder beet
Milk yield kg/d	20.6	21.9	21.7	22.1
Milk fat content g/kg	38.6	39.5	38.8	39.0
Milk protein	32.8	33.3	32.6	33.1
Body weight kg	642	648	647	648

(Izumi _et al_, 1976)

Table 15 The influence of the feed ration on the milk yield, the composition of milk, liveweight and liveweight gain.

	Ration 1	Ration 2	Ration 3
Milk yield kg/d	22.2	22.1	24.8
Fat content g/kg	44.0	42.4	39.6
Protein content	33.9	34.3	34.0
Liveweight kg	539	574	562
Daily gain g	+20	+72	+74
Fat yield g/d	982	929	976
Protein yield g/d	751	756	839

(Krohn _et al_, 1979)

Ration 1 - 6 kg DM FB

Ration 2 - 3 kg DM FB + 3 kg DM FB

Ration 3 - 6 kg DM B

In a study to examine the effect of two different rations Oprea et al (1978) showed that the diets containing fodder beet had no significant effects on milk fat compared with the ration without fodder beet. Kubes (1984) also reported that daily milk yield did not differ significantly when fodder beet was fed, but was higher than the treatment without fodder beet.

Burgstaller et al (1982) found when fed fodder beet at 3 levels (0, 2.8 or 5.5 kg DM d^{-1}) milk fat and milk protein contents were increased as the fodder beet increased, but the milk yield was not influenced by feeding fodder beet. Gaivoronskil (1980) found that when 8-10 kg of fodder beet was fed with silage/concentrate or silage/haylage/concentrate diets there was an increase in production of 4% FCM by 6.5-21.4% respectively.

Brabander et al (1981) reported a small response in milk yield when fed fodder beet, but they found a positive influence on milk fat content with fodder beet, however, a limit of 4.5 kg DM day^{-1} fodder beet was recommended to avoid digestive problems. In a study, by Coenen (1981) he suggested that 4kg of the maize silage could be replaced with 22 kg fodder in ration containing 10 kg grass silage, 22 kg maize silage and 5 kg concentrate and milk yield would be raised from 21 to 25 l d^{-1}.

Gfrorer (1982) observed that when fodder beet was fed alone, milk yield and milk composition were better than the yields attainable with ensiled green maize, hay, green herbage or grass silage (table 16). Although the use of fodder beet alone is not a practical dairy cow feeding system.

Roberts (1985) reported an improved milk yield and milk composition (Table 17) when he fed dairy cows silage ad libitum and concentrate with 3 levels of fodder beets 0, 12 or 24 kg^{-1} and the cows received extra soya bean with low and high levels.

A comparison between diets of (a) urea-treated maize silage (30-35% DM) supplemented with soya concentrate (24% CP) or (b) fodder beet (15% DM) fed together with ensiled lolium perenne (45% DM) and soya concentrate + fat (18% CP) indicated that both diets gave similar milk production levels (Kerouanton 1986).

Table 16 Daily milk yield and milk composition with fodder beet, ensiled green maize, hay, green herbage or grass silage.

	Fodder beet alone	Ensiled green maize	Hay	Green Herbage	Grass Silage
Milk yield kg/d	13.77	13.23	11.69	13.41	12.12
Fat g/kg	45.1	39.3	38.5	37.7	38.4
Protein g/kg	38.47	35.0	34.1	33.4	33.1

Gfrorer (1982)

Table 17 Milk yield and milk composition

	a	b	c	SED
Milk yield kg/d	23.0	23.3	23.9	1.55
Milk composition g/kg				
Fat	42.3	44.2	45.9	1.25*
Protein	33.0	34.5	35.3	0.76*
Lactose	48.1	47.9	47.3	0.42*
Yield of solids g/d				
Fat	964	1027	1095	63.2*
Protein	757	801	841	48.8*
Lactose	1095	1113	1128	47.1

(Roberts, 1985)

a - silage + concentrate 5.2

b - silage + 2 kg DM fodder beet + 0.5 sb + concentrate 5.2kg

c - silage + 4 kg DM fodder beet + 0.5 kg DM sb + concentrate 5.2 kg

CHAPTER 4

THE EFFECTS OF FEEDING FODDER BEET ON FEED INTAKE AND COW PERFORMANCE

EXPERIMENT 1

4.1. Introduction

Previous studies with feeding fodder beet have showed that total dry matter (DM) intake increased and forage intake decreased. This experiment had the objective of examining the effects of feeding fodder beet roots at three levels and two levels of concentrates with *ad libitum* silage on feed intake and animal performance.

4.2. Materials and Methods

4.2.1. Design

Twelve British Friesian autumn calving cows were allocated at random to 6 treatments in a cyclic change over design (Davis and Hall 1969), with four 3 week periods (Table 18).

The treatments involved 2 concentrate levels (4 and 8 kg DM) and 3 levels of fodder beet (0, 2 and 4 kg DM). The experiment started on 29 November 1985 and ended on 21 February 1986.

Table 18 Change over design for 12 cows allocated in 6 treatments, 4 periods.

	Period 1		Period 2		Period 3		Period 4	
	Beet	Conc	Beet	Conc	Beet	Conc	Beet	Conc
No cows	kg DM	kg DM	kg DM	kg DM	kg DM	kg DM	kg DM	kg DM
1 & 7	0	4	2	4	0	8	4	4
2 & 8	2	4	4	4	2	8	0	8
3 & 9	4	4	0	8	4	8	2	8
4 & 10	0	8	2	8	0	4	4	8
5 & 11	2	8	4	8	2	4	0	4
6 & 12	4	8	0	4	4	4	2	4

4.2.2. Dairy cow and feed management

Cows were housed with access to individual feeding boxes fitted with transponder-operated calan gates (Plate 1) (Broadbent *et al*, 1970). The cows were housed in cubicles with sawdust bedding. The house was cleaned daily and the sawdust bedding changed once per week. The cows changed gradually from one diet to another over a period of one week (first week of each period). Details of the changeover diets are given in Appendix 1.

All cows were offered weighed amounts of grass silage at 09.00 hrs and 14.00 hrs each day in individual troughs in sufficient quantities to ensure a daily refusal of 5-10% of the original weight. The silage was not available to the cows when either the concentrate or fodder beet was being fed. Silage was prepared from first cuts of perennial ryegrass swards harvested on 25 May 1985. They were cut with a drum mower and wilted for 24 hours before being harvested with a precision chop forage harvester applying formic acid (Add-F, BP Nutrition International Limited, 850 g formic acid l^{-1}) at 2.3 litres tonnes^{-1}. The silage was ensiled in an unroofed silage bunker and sheeted with black polythene (Plate 2). All animals were offered this silage during the 12 week experiment.

Plate 1 Transponder operated calan gates

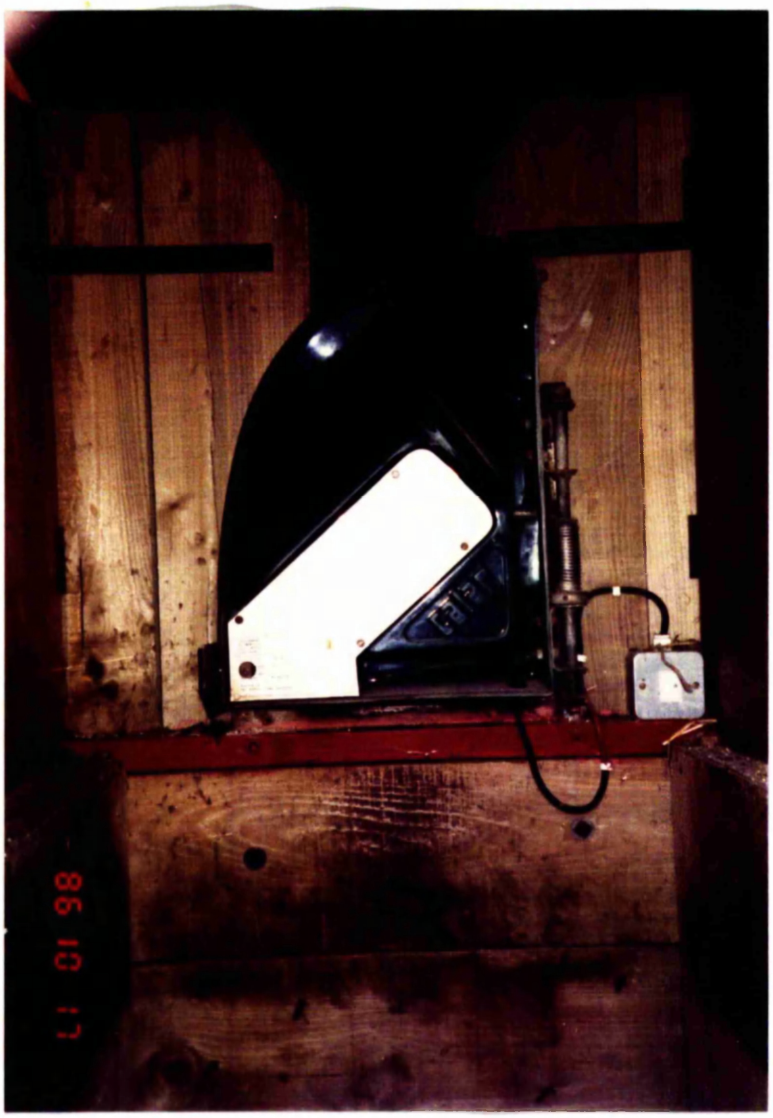


Plate 1 A Transponder operated calan gates

Plate 2 Ensiled silage in an unroofed bunker and sheeted with black polythene

In addition to silage the cows received the following 6 treatments:

Treatment A: 4 kg DM d^{-1} concentrate and *ad libitum* silage.

Treatment B: 4 kg DM d^{-1} concentrate, 2 kg DM d^{-1} fodder beet and *ad libitum* silage.

Treatment C: 4 kg DM d^{-1} concentrate, 4 kg DM d^{-1} fodder beet and *ad libitum* silage.

Treatment D: 8 kg DM d^{-1} concentrate and ad libitum silage.

Treatment E: 8 kg DM d^{-1} concentrate, 2 kg DM d^{-1} fodder beet and *ad libitum* silage.

Treatment F: 8 kg DM d^{-1} concentrate, 4 kg DM d^{-1} fodder beet and *ad libitum* silage.

Concentrate was given in two feeds out of parlour daily at 09:00 hrs and 14:00 hrs in separate feed containers. The feed container was removed as soon as the cows had finished eating and after 45 minutes any refusal was weighed and discarded. The cows were not fed any concentrate in the parlour. The concentrate supplement was in the form of a 9mm pellet.

Fodder beet was roughly chopped with a spade and Herborg fodder beet feeder (Plate 3). After being chopped the fodder beet was mixed to avoid variation in DM between fodder beets. Fodder beet was given in two feeds at 09:45 and 14:45 hrs in a separate feed container, the container was removed as soon as the cows had finished eating and any refusal after 60 minutes was weighed and discarded. During this time the cows on the

Plate 3   Herborg fodder beet feeder

zero fodder beet treatment had access to silage. The variety of fodder beet was Kyros (plate 4) and harvested in October, stored in an unroofed clamp with a covering of straw to protect from frost damage (plate 5).

Water was freely available to all cows in the feeding area. Cows were milked twice daily at 07:00 hrs and 16:30 hrs.

4.2.3. Dairy cow and feed measurements

Milk yields of individual animals were recorded on the last four days of each 3-week period and samples were taken for fat, protein and lactose content analysis. The machine used to determine the milk composition was a 1st Electric Milkoscan 203 (Biggs, 1979).

Liveweight was recorded to nearest 2kg at approximately 10:00 am on Monday, Wednesday and Thursday in each week. Liveweight change was calculated for each cow by linear regression. Liveweight change was also estimated from ME balance as ME intake - (ME required for maintenance + ME for milk production).

An oven dry matter determination of silage, fodder beet and concentrate was estimated on five days per week, by using a forced draught oven (Unitherm Drying oven) at 100^{o}C for approximately 24 hours. Silage, fodder beet and concentrate samples were taken during the last week of each period for the

Plate 4 Fodder beet variety Kyros

Plate 5 Fodder beet stored in an unroofed clamp

determination of chemical composition. The techniques used for the chemical analysis of the feed stuffs were those described by Alexander and McGowan (1966, 1969). The silage, fodder beet and concentrate ME concentration (MJ kg^{-1} DM) were estimated using the equations in Appendix (2). The calculation of ME requirements for maintenance, milk production and liveweight change were estimated using the equations in Appendix (3).

4.3. Statistical analysis

In this experiment the design was a 6 treatment cyclic-change over, with 4 periods and 12 cows (Davis and Hall, 1969). Liveweight change and liveweight was calculated by linear regression using the statistical package minitab (Ryan et al, 1985). Milk yield, milk composition, liveweight and liveweight change were analysed using the EDEX statistical package (Hunter and Mann, 1979). This program also statistically analysed differences between the animal used in this experiment, period and the interaction between treatment (fodder beet and concentrate). An example of the analysis of variance for each type of analysis is given in Appendix (4). Differences between individual treatment means were tested by students "t"test, and significant differences ($P<0.05$), ($P<0.01$) and ($P<0.001$) are indicated by different superscripts.

4.4. Animal Health

None of the rations fed during the experiment caused any digestive disorders and the general health of the cows was excellent, 2 cows had clinical mastitis in treatments E and F during period 3, which caused a small decrease in the yield. There were no missing plots in the analysis.

4.5 Results

4.5.1. Feed composition

The silage was moderate quality with an average ME of 10.4 MJ kg^{-1} DM and a higher than optimum ammonia nitrogen content 128.25 g kg^{-1}. The dry matter increased from period 1 to period 4. Fodder beet dry matter decreased from period 1 to period 4, and had a low crude protein (65 - 84) g kg^{-1} DM, but with high ME (12.8 -13.8) MJ kg^{-1} DM. Concentrate dry matter was 860 g kg^{-1} and crude protein between (196-216) g kg^{-1} DM with an average ME of 13.5 MJ kg^{-1} DM. The average chemical composition of the silage, concentrate and fodder beet are given in Table 19. The physical ingredients of concentrate are given in Table 20. Appendix 5 and 6 contain the chemical composition for each period.

4.5.2. Feed intake

The mean daily weights of DM consumed in each treatment (kg d^{-1}), the total energy intake (MJ day $^{-1}$) and the total crude protein intake (g day^{-1}) are given in tables 21, 22, 23, 24, 25 and 26 respectively. The silage intake in both the low and high

Table 19 The average of the chemical composition of silage, concentrate and fodder beet.

	Silage	Fodder Beet	Concentrate
Oven dry matter (g/kg)	189	163	860
Crude protein (g/kg)	142.5	75.7	201
Organic matter (g/kg DM)	913	909.2	918.25
DOMD _in vitro_ (g/kg DM)	657.5	836.5	803
Ammonia g/kg total N	128.25		
Predicted ME (MJ/kg DM)	10.4	13.3	13.5
Calcium (g/kg)	5.6	1.6	8.4
Phosphorus (g/kg)	2.8	2.3	7.4
Magnesium (g/kg)	1.8	1.6	6.1
pH	4.1		

Table 20 Physical ingredients of concentrate (g kg^{-1})

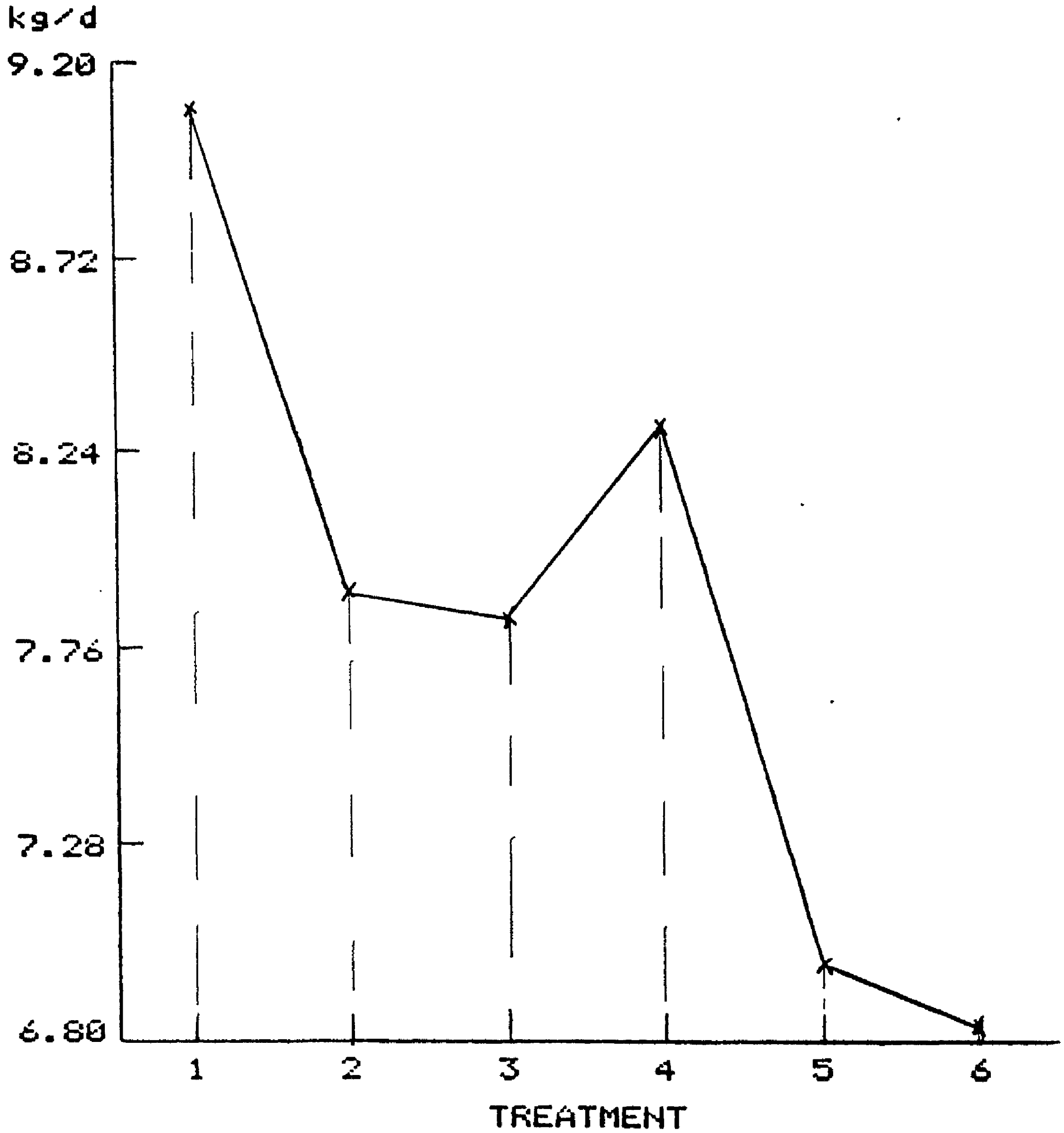
Barley	250
Wheat	200
Maize Gluten	200
Soya	150
Wheat feed	80
Molasses	50
Fish meal	20
Fat supplement	20
Mineral/vitamins	20
Dicalcium phosphate	5
Calcium/magnesium	5

concentrate treatments were highly significantly decreased as the fodder beet level increased (Figure 6). The significant ($P<0.001$) differences in silage DM intake at both concentrate levels were between the zero fodder beet diet and the diets including fodder beet.

The mean substitution rates (r) were 0.62 and 0.33 kg silage DM kg^{-1} fodder beet DM in between treatment A/B and A/C respectively at the low concentrate level. The mean substitution rates (r) were 0.68 and 0.40 kg silage DM kg^{-1} fodder beet DM in between treatment D/E and D/F respectively, at the high concentrate level.

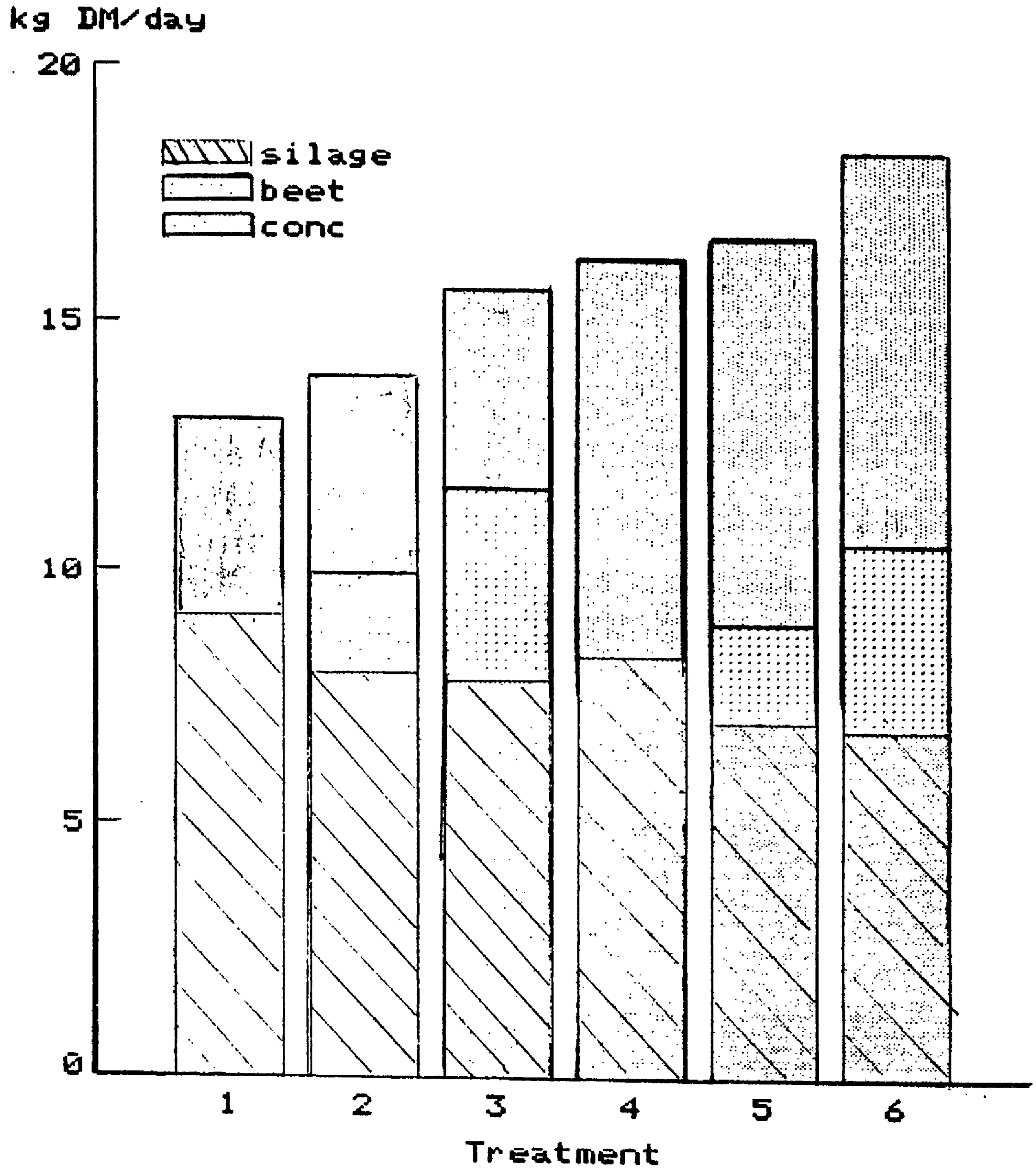
The total dry matter intake kg DM d^{-1} in low and high concentrate were increased as the fodder beet were increased (Figure 7). The significant ($P<0.001$) difference in total dry matter intake were between treatment 2 and 4 kg DM fodder beet compared with zero fodder beet with low concentrate. The significant ($P<0.001$) differences in total dry matter intake were between treatment 4 kg DM fodder beet compared with zero fodder beet and 2 kg DM fodder beet with high concentrate. The significant ($P<0.001$) differences in total ME intake were between treatment, 0,2 and 4 kg DM fodder beet in low and high concentrate.

Figure 6 Daily silage intake (kg d^{-1})



1 = Treatment A
2 = Treatment B
3 = Treatment C
4 = Treatment D
5 = Treatment E
6 = Treatment F

Figure 7 Total dry matter intake (kg DM d^{-1})



1 = Treatment A
2 = Treatment B
3 = Treatment C
4 = Treatment D
5 = Treatment E
6 = Treatment F

Table 21 Mean daily DM intakes (kg/d) at low level of concentrate (4 kg DM/d)

	A	B	C	SED
Fodder beet (kg/d)	0.00 [a]	1.93 [b]	3.77 [c]	***0.078
Concentrate (kg/d)	3.88	3.95	4.00	NS 0.132
Silage (kg/d)	9.09 [b]	7.89 [a]	7.83 [a]	***0.311
Total DMI/d	13.00 [a]	13.78 [b]	15.60 [c]	***0.363

Table 22 Mean daily DM intakes at high level of concentrate (8 kg DM/day)

	D	E	F	SED
Fodder beet (kg/d)	0.00 [a]	1.93 [b]	3.67 [c]	***0.078
Concentrate (kg/d)	7.94	7.74	7.78	NS 0.132
Silage (kg/d)	8.30 [b]	6.99 [a]	6.83 [a]	***0.311
Total DMI/d	16.23 [a]	16.65 [a]	18.29 [b]	***0.363

Table 23 Mean daily ME intake (MJ/d) at low level concentrate

	A	B	C	SED
Fodder beet (MJ/d)	0.00^{a}	25.89^{b}	50.44^{c}	***1.343
Concentrate (MJ/d)	53.12	53.32	54.18	NS 1.673
Silage (MJ/d)	94.70^{b}	82.57^{a}	81.64^{a}	***3.259
Total ME intake (MJ/d)	147.71^{a}	161.83^{b}	185.99^{c}	***4.162

Table 24 Mean daily ME intake (MJ/d) at high level concentrate.

	D	E	F	SED
Fodder beet (MJ/d)	0.00^{a}	25.77^{b}	49.05^{c}	***1.343
Concentrate (MJ/d)	107.27	104.55	105.40	NS 1.673
Silage (MJ/d)	86.47^{b}	72.85^{a}	71.16^{a}	***3.259
Total ME intake (MJ/d)	192.72^{a}	203.11^{b}	225.70^{c}	***4.162

Table 25 Mean daily crude protein intake at low concentrate

	A	B	C	SED
Fodder beet (kg/d)	0.00[a]	0.14[b]	0.29[c]	***0.0057
Concentrate (kg/d)	0.79	0.79	0.81	NS 0.025
Silage (kg/d)	1.30[b]	1.12[a]	1.12[a]	***0.045
Total (kg/d)	2.08[a]	2.06[a]	2.22[b]	***0.055
Total RDP intake (g/d)	1665 (1152)	1656 (1262)	1781 (1451)	
Total UDP intake (g/d)	413 (250)	414 (223)	438 (206)	

Table 26 Mean daily crude protein intake at high level concentrate

	D	E	F	SED
Fodder beet (kg/d)	0.00[a]	0.14[b]	0.28[c]	***0.0057
Concentrate (kg/d)	1.60	1.56	1.56	NS 0.025
Silage (kg/d)	1.18[b]	0.99[a]	0.97[a]	***0.045
Total (kg/d)	2.78[a]	2.70[a]	2.82[b]	* 0.055
Total RDP intake (g/d)	2155 (1511)	2094 (1584)	2199 (1760)	
Total UDP intake (g/d)	623 (325)	608 (493)	629 (279)	

*Figures in brackets are the estimated daily protein requirements from ARC (1984).

The significant ($P<0.05$) differences in total crude protein intake were between treatment 4 kg dry matter fodder beet compared with 0 and 2 kg DM fodder beet in both low and high concentrate. The highly significant ($P<0.001$) increase in total dry matter intake, crude protein intake and ME intake were between low and high concentrate in 0, 2, 4 kg fodder beet (Table 27). The highly significant ($P<0.001$) decrease in silage intake were between low and high concentrate in 0, 2 and 4 kg DM fodder beet (Table 27).There were no significant interactions between concentrate feeding level and fodder beet level for silage intake, total dry matter intake, ME intake and crude protein intake.

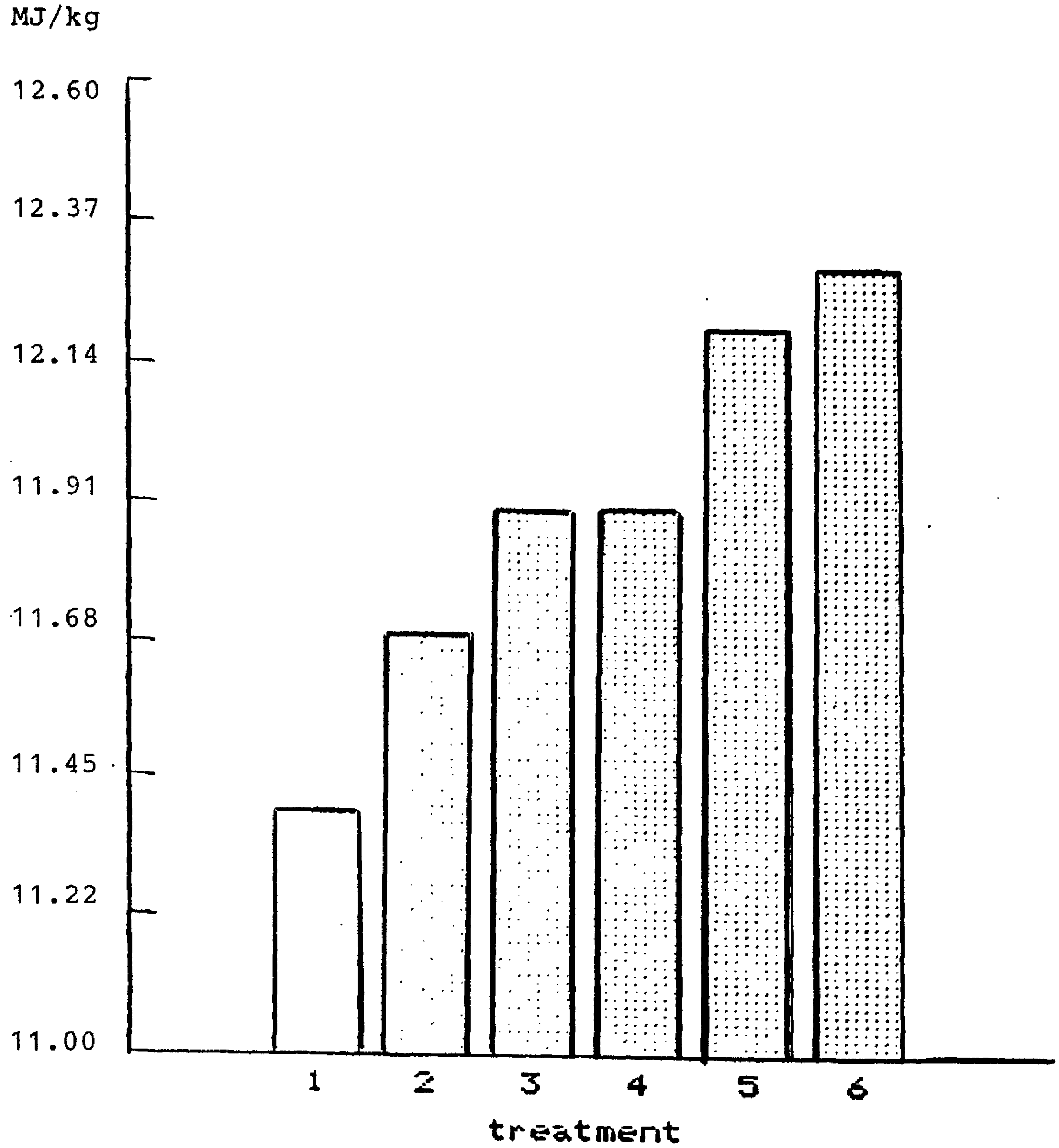
The energy density of the total diets increased from 11.4 MJ kg DM^{-1} for treatment 0, fodder beet to 11.7 and 11.9 MJ kg DM^{-1} for treatment 2 and 4 kg DM^{-1} fodder beet respectively with the low concentrate (Figure 8). The crude protein content declined from 160 g kg DM^{-1} for treatment zero fodder beet to 149 and 142 g kg DM^{-1} for treatments 2 and 4 kg DM fodder beet respectively with the low concentrate level (Figure 9).

With the high concentrate level the energy density of the total diets increased from 11.9 MJ kg DM^{-1} for treatment zero beet to 12.2 and 12.3 MJ kg DM^{-1} for treatments 2 and 4 kg fodder beet respectively (Figure 8). The crude protein content of the diets declined from 171 g kg^{-1} DM for treatment zero

Table 27 Total silage intake, dry matter, crude protein and ME intake in both low and high conc

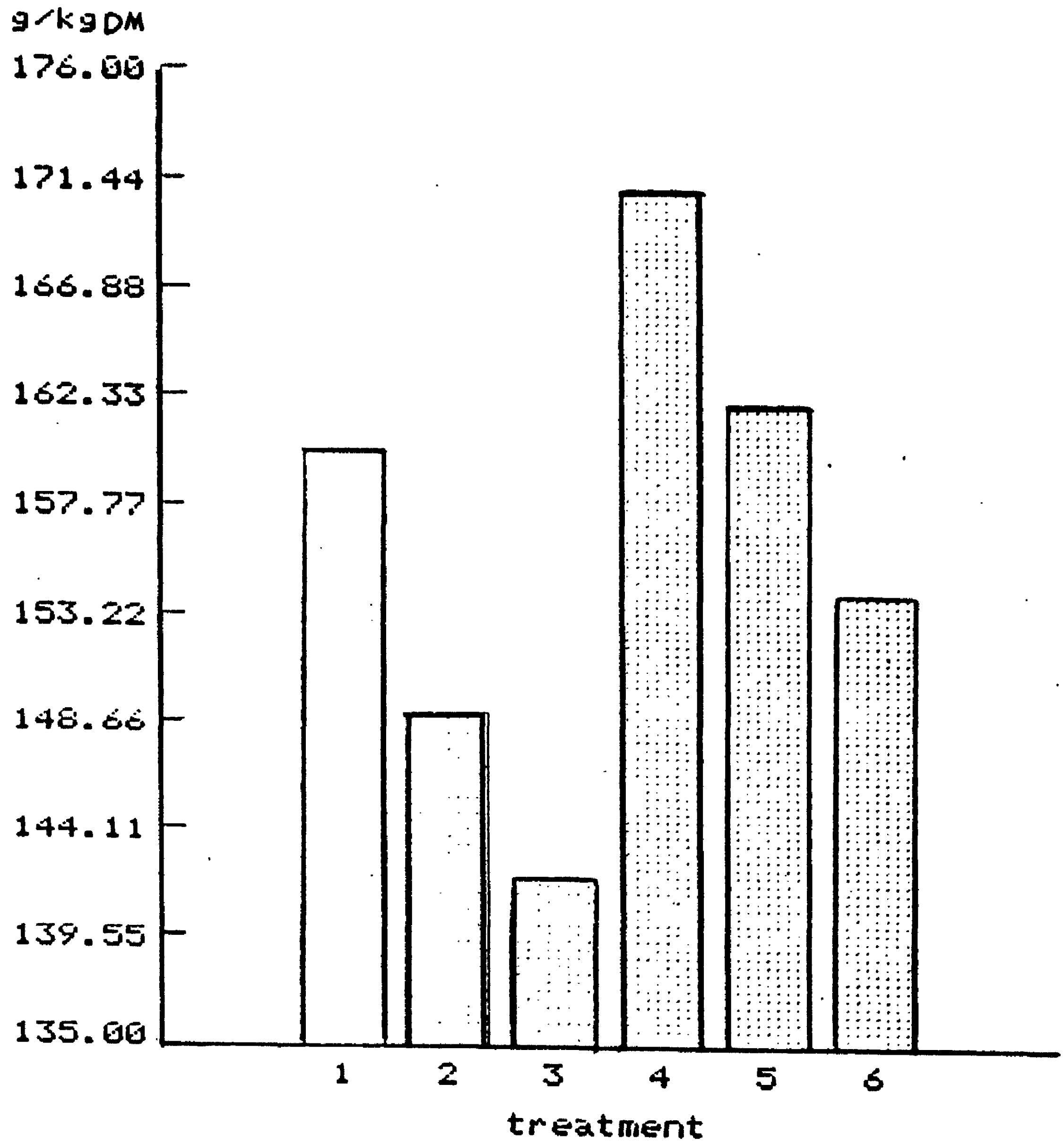
Fodder beet level	Silage intake (kg/day) low 4 kg DM	Silage intake (kg/day) high conc 8 kg	SED	Total dry matter (kg/day) low conc 4 kg	Total dry matter (kg/day) high conc 8 kg DM	SED	Total crude protein (kg/day) low conc 4 kg DM	Total crude protein (kg/day) high conc 8kg	SED	ME intake (MJ/day) low 4 kg	ME intake (MJ/day) high 8 kg	SED
zero	9.09[a]	8.30[b]	0.311***	13.00[a]	16.23[b]	0.363***	2.08[a]	2.78[b]	0.055***	147.71[a]	192.72[b]	4.162***
2 kg DM	7.89[a]	6.99[b]	0.311***	13.78[a]	16.65[b]	0.363***	2.06[a]	2.70[b]	0.055***	161.83[a]	203.11[b]	4.162***
4 kg DM	7.83[a]	6.83[b]	0.311***	15.60[a]	18.29[b]	0.363***	2.22[a]	2.82[b]	0.055***	185.99[a]	225.70[b]	4.162***

Figure 8 ME Density (MJ kg^{-1} DM)



1 = Treatment A
2 = Treatment B
3 = Treatment C
4 = Treatment D
5 = Treatment E
6 = Treatment F

Figure 9   Crude protein density (g kg DM)



1 = Treatment A
2 = Treatment B
3 = Treatment C
4 = Treatment D
5 = Treatment E
6 = Treatment F

fodder beet to 162 and 154 g kg DM^{-1} for treatments 2 and 4 kg DM fodder beet respectively (Figure 9). The relative intake of protein (g day^{-1}) of rumen degradable (RDP) and undegradable protein (UDP) were derived from the mean intake of silage, fodder beet and concentrate using degradability values of 0.85 for silage and fodder beet and 0.72 for concentrate. In all periods and within treatment, the intakes of protein both the RDP and UDP, satisfied the requirements laid down by ARC (1984) (Tables 25 and 26).

4.5.3. Refusals

Some refusals of fodder beet were recorded during period 1, 2, 3 and 4 (Appendix 7) although, only in period 1 did the refusal exceed (10%) of the total fodder beet dry matter offered and no digestive disturbances were recorded. The mean of refusals was (4.9%) of the total fodder beet dry matter offered for all 4 periods.

4.5.4. Milk yield and milk composition

The mean daily milk yields, milk composition and yield of constituents for the different treatments are given in Tables 28 and 29. The feeding of fodder beet has no significant effect on milk yields and milk composition, but the mean daily milk yield increased from 20.64 and 24.09 kg day^{-1} for treatment A and D, the zero level of fodder beet to 21.75 and 24.43 kg day^{-1} for treatment C and F the highest fodder beet levels (4 kg DM beet) in low and high concentrate respectively.

Milk fat content and milk protein content were slightly higher at 40.32 and 30.25 g kg^{-1} for treatment A the zero level fodder beet to 41.47 and 31.44 g kg^{-1} for treatment C the highest level fodder beet (4 kg DM beet) in low concentrate. Milk fat content in the high concentrate treatments decline from 40.02 g kg^{-1} for the zero level of fodder beet to 39.09 g kg^{-1} for the highest level of fodder beet (4 kg DM beet). Milk protein contents increased as the level of fodder beet increase for each of the 3 fodder beet treatments in low and high concentrate levels.

There were no significant treatment effect on milk lactose content. There was significant ($P<0.01$) differences in milk protein yields between the lowest and highest level of fodder beet in both the low and high concentrate treatments. There were no significant treatment effect on milk fat yield and milk lactose yield when fodder beet was fed.

There was a highly significant ($P<0.001$) difference in milk yield, milk protein content and yield of constituents between low and high concentrate at all three levels of fodder beet feeding (Tables 30 and 31). There were no significant increase in fat and lactose content at the high concentrate level compared to the low and high level (Table 32). There were no significant interactions between concentrate feeding levels and fodder beet levels for milk yield and milk composition.

Table 28 The mean daily milk yield, milk composition between 3 levels of fodder beet at low level concentrate

	A	B	C	SED
Milk yield (kg/day)	20.64	20.37	21.75	0.581 NS
Milk fat content (g/kg)	40.32	39.24	41.47	1.471 NS
Milk protein content (g/kg)	30.25	30.95	31.44	0.744 NS
Milk lactose content (g/kg)	48.08	47.84	47.87	0.377 NS
Milk fat yield (g/day)	827.1	792.9	884.5	39.95 NS
Milk protein yield (g/day)	622.5 [a]	628.4 [a]	678.6 [b]	17.89 **
Milk lactose yield (g/day)	992.8	975.1	1036.4	33.05 NS

Table 29 The mean daily milk yield, milk composition between levels of fodder beet at high level concentrate

	D	E	F	SED
Milk yield (kg/d)	24.09	23.50	24.43	0.581 NS
Milk fat content (g/kg)	40.02	39.93	39.09	1.471 NS
Milk protein content (g/kg)	32.32	33.29	33.48	0.744 NS
Milk lactose content(g/kg)	47.90	47.49	47.73	0.377 NS
Milk fat yield (g/d)	954.3	936.4	954.3	39.35 NS
Milk protein yield (g/d)	773.8 [a]	777.3 [a]	814.2 [b]	17.89**
Milk lactose yield (g/d)	1151.0	1118.0	1163.9	33.05 NS

Table 30 The mean milk protein content, milk yield and milk protein yield in both low and high concentrate levels

levels of fodder beet (kg/d DM)	Protein content g/kg low conc 4 kg DM	Protein content g/kg high conc 8 kg DM	Milk yield kg/d low conc 4 kg DM	Milk yield kg/d high conc 8 kg DM	Protein yield g/d low conc 4 kg DM	Protein yield g/d high conc 8 kg DM
zero	30.25[a]	32.32[b]	20.64[a]	24.09[b]	622.5[a]	773.8[b]
2 kg DM	30.95[a]	33.29[b]	20.37[a]	23.50[b]	628.4[a]	777.3[b]
4 kg DM	31.44[a]	33.48[b]	21.75[a]	24.43[b]	678.6[a]	814.2[b]
SED	0.744***		0.581***		17.889***	

Table 31 The mean milk fat yield and milk lactose in both low and high concentrate levels

levels of beet (kg/d)	Milk fat yield (g/d) low concentrate 4 kg DM	Milk fat yield (g/d) high concentrate 8 kg DM	Milk lactose yield (g/d) low concentrate 4 kg DM	Milk lactose yield (g/d) high concentrate 8 kg DM
zero	827.1[a]	954.3[b]	992.8[a]	1151.0[b]
2 kg	792.2[a]	936.4[b]	975.1[a]	1118.0[b]
4 kg	884.5[a]	954.3[b]	1036.4[a]	1163.9[b]
SED	39.357***		33.050***	

Table 32 The mean milk fat content and milk lactose content in both low and high concentrate levels

levels of beet (kg/d)	Milk fat content (g/kg) low concentrate 4 kg DM	Milk fat content (g/kg) high concentrate 8 kg DM	Milk lactose content (g/kg) low concentrate 4 kg DM	Milk lactose content (g/kg) high concentrate 8 kg DM
zero	40.32	40.02	48.08	47.90
2 kg DM	39.24	39.93	47.84	47.49
4 kg DM	41.47	39.09	47.87	47.73
SED	N.S.	1.471	N.S.	0.377

4.5.5. Liveweight and liveweight change

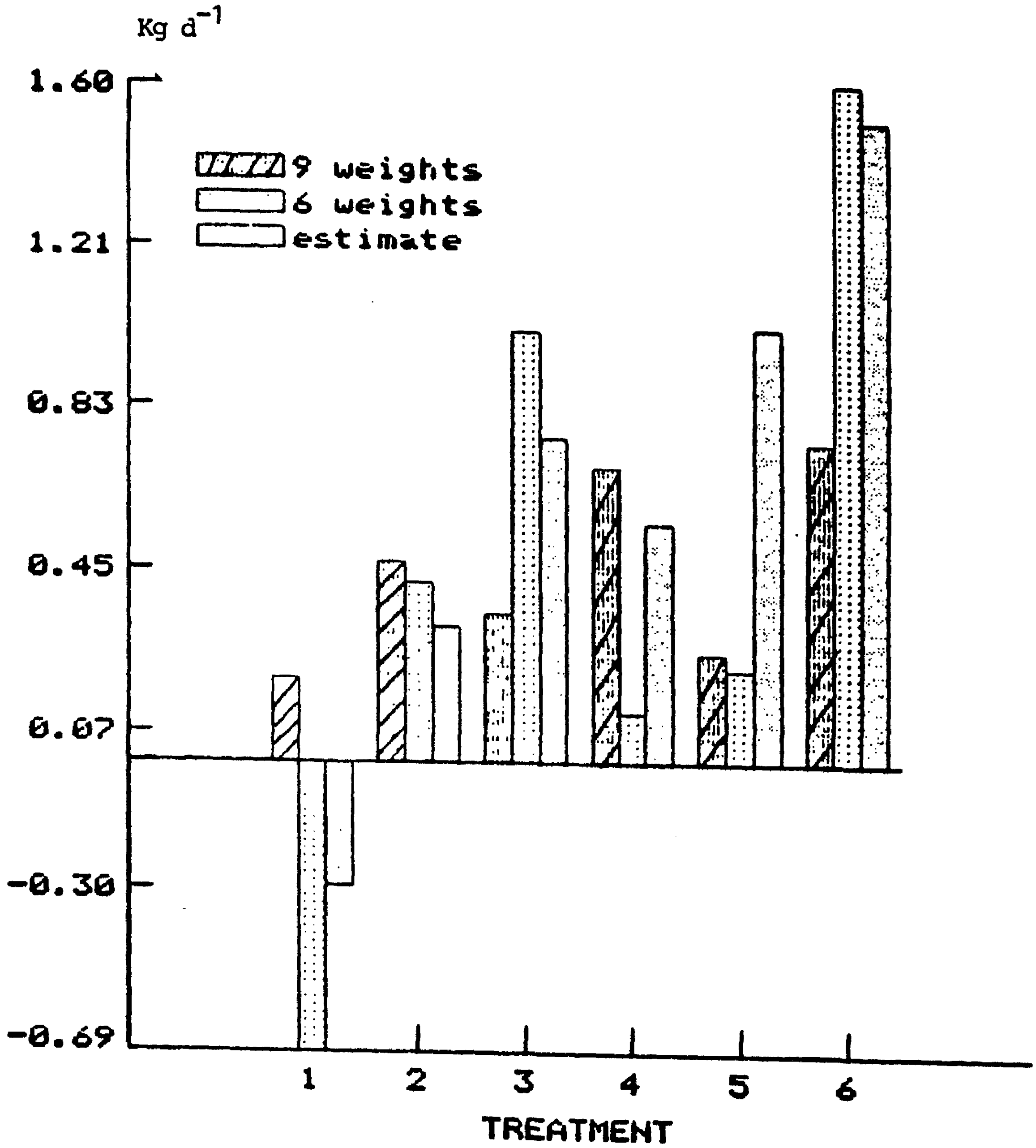
The mean liveweight of the cows at the start and end of the experiment were 516 and 531 kg respectively. The mean liveweight and liveweight change for each treatment are given in (Table 33). The cows on the high concentrate (8kg DM) diets were on average 12 kg heavier. There were no significant treatment effects observed for liveweight and liveweight change, but the mean daily liveweight changes increased as the fodder beet increased (Figure 10).

The liveweight change was estimated in 3 ways:

1. By linear regression using all weights for each three week periods.
2. By linear regression ignored the first three weights, during the change over week and just used 6 weights for two week period.
3. Liveweight change was estimated using the following equation:
   requirement ME for liveweight change MJ d^{-1} = total ME intake MJ day^{-1} - (requirement ME for maintenance + requirement ME for milk production) ARC (1980).

Table 33 Mean liveweight (kg) and liveweight change (kg/day)

Treatments	0/4	2/4	4/4	0/8	2/8	4/8	SED
Liveweight							
9 weights/period	522	520	531	535	532	542	5.2 NS
6 weights/period	524	522	531	538	533	543	5.5 NS
Liveweight change							
9 weights/period	+0.20	+0.47	+0.35	+0.69	+0.26	+0.75	0.527 NS
6 weights/period	-0.69	+0.42	+1.01	+0.12	+0.22	+1.62	0.837 NS
estimated	-0.30^{a}	+0.32^{b}	+0.76^{c}	+0.56^{a}	+1.02^{b}	+1.51^{c}	0.207***



1 = Treatment A
2 = Treatment B
3 = Treatment C
4 = Treatment D
5 = Treatment E
6 = Treatment F

4.6. Discussion

4.6.1. Fodder beet composition

The analysis of fodder beet in this experiment is similar to other *in vitro* analyses (Pearce 1983, West of Scotland Agricultural College 1984 and Roberts 1985), with a high ME content 13.3 MJ kg DM but low crude protein 75 g kg DM. The dry matter of beet declined during the course of the experiment from the first period to the period four (APP 5 and 6) but the average for the four periods was similar to that of MAFF (1985) who reported the dry matter for fodder beet (Kyros) was 166.3 g kg^{-1}.

The feeding value of fodder beet depends on the amount of soil contamination, in this experiment the average of organic matter content was 909 g kg^{-1} DM for four period and this figure is similar to that found by Roberts (1985) and by MAFF (1985). In the experiment reported here the soil contamination of whole beet fed was 4 %. This was not a serious problem, fodder beet were eaten well and most of the soil was left behind. The fodder beet were highly platable and was consumed readily by the cattle. The levels of fodder beet feeding in this experiment were selected to be similar to the moderate and high levels of feeding practised in Great Britain, (Roberts and Dickson 1985).

4.6.2. Dry matter intake

Supplementary soluble carbohydrates are known to depress the digestibility of crude fibre in the rumen (Hamilton 1942;

Head, 1953; Raymond, 1969; Chimwano*et al*, 1976; Mould and Ørskov, 1983) owing to a reduction in the cellulolytic activity of the rumen micro-organisms (El-Shazly *et al*, 1961). As a result the rate of disappearance of roughage from the digestive tract is depressed (Eng *et al*, 1964, Campling 1966a) with a consequent reduction in the intake of roughage. MAFF (1985) reported that fodder beet have very high levels of water soluble carbohydrates about 650 g kg^{-1} DM. The silage DM intake were highly significant decreased when used fodder beet at level 2 and 4 kg DM with low and high concentrate (Figure 6).

Total dry matter intake was increased significantly with feeding fodder beet at different levels and this result agrees with other workers (Castle *et al*, 1961, 1963; Brabander *et al*, 1974, 1981). On average for each 1 kg of beet dry matter eaten there was a reduction of 0.47 kg silage DM at the low concentrate level and this agrees with Castle *et al* (1963) who reported a decrease in silage intake 0.45 for each 1 kg of fodder beet. At the high concentrate level the average for each 1 kg of fodder beet dry matter eaten there was a reduction of 0.54 kg silage dry matter which is a value similar to that of 0.53 found by Roberts (1985). The reduction in silage intake was higher at the high level concentrate.

4.6.3. Milk yield and milk composition

The results of this trial indicate that fodder beet when added to the diet at both a low and high level of concentrate supplementation had no significant effect, but slightly improved milk yield, milk composition and milk yield of solids. This result agrees with most workers (eg Castle et al 1961, 1963, see Section 3.3). This improvement in milk yield and milk quality can be explained by the differences in feed intake, since the voluntary consumption of feed dry matter was higher for animals which received the fodder beet, secondly, the fodder beet provided the greatest supply of energy.

The milk fat content tended to be lower when fodder beet was fed with a high level of concentrate although the difference was not significant. This result agreed with Boyle, 1952, Castle et al, 1961, 1963 and Izumi et al, 1976).

The effects of different concentrate level on production in this experiment are similar to those reported elsewhere (eg Taylor, 1983). With the high level there was an increase in milk yield, milk protein content and yield of constituents.

4.6.4. Liveweight and liveweight change

The liveweight and liveweight change results in this trial tends to be higher with feeding fodder beet. The liveweight change was estimated by three different ways (see Section 4.5.5) because the ME input did not equal the ME output. This may be due to the design of this experiment and that relatively short periods of 21 days result in inadequate assessments of the body weight change (Altman, 1980). Other reasons could be a gut fill effect or the fact that liveweight was only estimated to the nearest 2 kg.

4.7. Summary

The effects of feeding fodder beet at three levels (0, 2 and 4 kg DM d^{-1}) and two levels of concentrate (4 and 8 kg DM d^{-1}) with _ad libitum_ silage were examined in a cyclic changeover experiment using 12 British Friesian autumn calving cows housed in cubicles with access to individual feeding boxes.

The experiment lasted for 12 weeks with four 3-week periods each period 21 days. Diets were changed gradually during the first week of each period. The mean silage, fodder beet and concentrate analyses were respectively: DM 188, 163 and 860 g kg^{-1}, crude protein 143, 76 and 201 g kg^{-1} DM. Metabolizable energy levels predicted from _in vitro_ digestibility were 10.4, 13.3 and 13.5 MJ kg^{-1} DM. Mean values for treatments 0, 2 and 4 kg DM d^{-1} fodder beet at 4 (L) and 8 (H) kg d^{-1} concentrate DM were as follows: total feed intake (kg DM d^{-1}) L 13.0, 13.8, 15.6; H 16.2, 16.7, 18.3; silage intake (kg DM d^{-1}) L 9.1, 7.9, 7.8; H 8.3, 7.0, 6.8: milk yield (kg d^{-1}) L 20.6, 20.4, 21.8; H 24.1, 23.5, 24.4; milk fat content (g kg^{-1}) L 40.3, 39.2, 41.5; H 40.0, 40.0, 39.1; milk protein content (g kg^{-1}) L 30.3, 31.0, 31.4; H 32.3. 33.3, 33.5.

The feeding of fodder beet increased total feed intake, and decreased silage intake, but had no significant effect on milk yield or milk solids content although they tend to be higher with feeding fodder beet but had a significant increase on milk protein yield. Higher liveweight and liveweight change were achieved with fodder beet. There was no significant interaction between level of fodder beet feeding and level of concentrate feeding.

CHAPTER 5

Experiment 2
THE EFFECT OF FEEDING FODDER BEET AT A HIGHER LEVEL ON FEED INTAKE AND COW PERFORMANCE

5.1. Introduction

In the previous experiment (Chapter 4) the levels of fodder beet feeding were zero, 2 and 4 kg DM d^{-1} at two levels of concentrate. There are reports in the literature of digestive upsets when high levels of beet are fed (Pearce, 1983). To avoid digestive problems Roberts and Dickson (1985) recommended 30 kg fresh weight fodder beet per day. Feeding up to 6 kg DM is quite usual in Denmark (Larsen, 1985) without any problems but at high levels of feeding it is recommended that the beet are chopped.

In this experiment four levels of fodder beet (0, 2, 4 and 6 kg DM d^{-1}) were offered and one level concentrate 4 kg DM d^{-1} with *ad libitum* silage. The effect of feeding fodder beet at a higher level (6 kg DM d^{-1}) on the total dry matter intake, silage dry matter intake, milk yield, milk composition, the liveweight and on the liveweight change were investigated.

5.2. Materials and Methods

5.2.1. Design

Four British Friesian autumn calving cows were allocated at random to four treatment sequences in a 4 x 4 balanced change over design (Patterson and Lucas, 1962) each period lasting 3 weeks (Table 34). The treatment involved one level concentrate

(4 kg DM) and four level of fodder beet (0, 2, 4 and 6 kg DM).

Treatment A: 4 kg concentrate DM day^{-1} and _ad libitum_ silage

Treatment B: 4 kg concentrate DM day^{-1}, 2 kg DM d^{-1} fodder beet and _ad libitum_ silage

Treatment C: 4 kg concentrate DM day^{-1}, 4 kg DM d^{-1} fodder beet and _ad libitum_ silage

Treatment D: 4 kg DM d^{-1} concentrate, 6 kg DM d^{-1} fodder beet and _ad libitum_ silage

The concentrate, silage and fodder beet were the same as for Table 19 and 20. Statistical analysis was confined to the mean of the last 7 days of each 3 week period for feed intake and milk production.

Table 34 Change over design for 4 cows allocated in 4 treatment 4 period

Cow No.	Period 1	Period 2	Period 3	Period 4
1	A	B	C	D
2	B	D	A	C
3	C	A	D	B
4	D	C	B	A

5.2.2. Dairy cow and feed management

Cows were housed with access to individual feeding boxes fitted with transponder-operated gates (Broadbent et al, 1970). The cows changed gradually from one diet to another over a period of one week (first week of each period). Details of the changeover diets are given in Appendix 8. Feed management was similar to experiment 1 (Section 4.2.2.). Milk yields and milk composition were measured as in Section 4.2.3., liveweight was recorded as in Section (4.2.3.).

5.2.3. Statistical analysis

Liveweight change and liveweight was calculated by linear regression using the statistical package minitab (Ryan et al, 1985). Milk yield, milk composition, liveweight and liveweight change were analysed using the EDEX statistical package (Hunter and Mann, 1979).

5.3. Animal Health

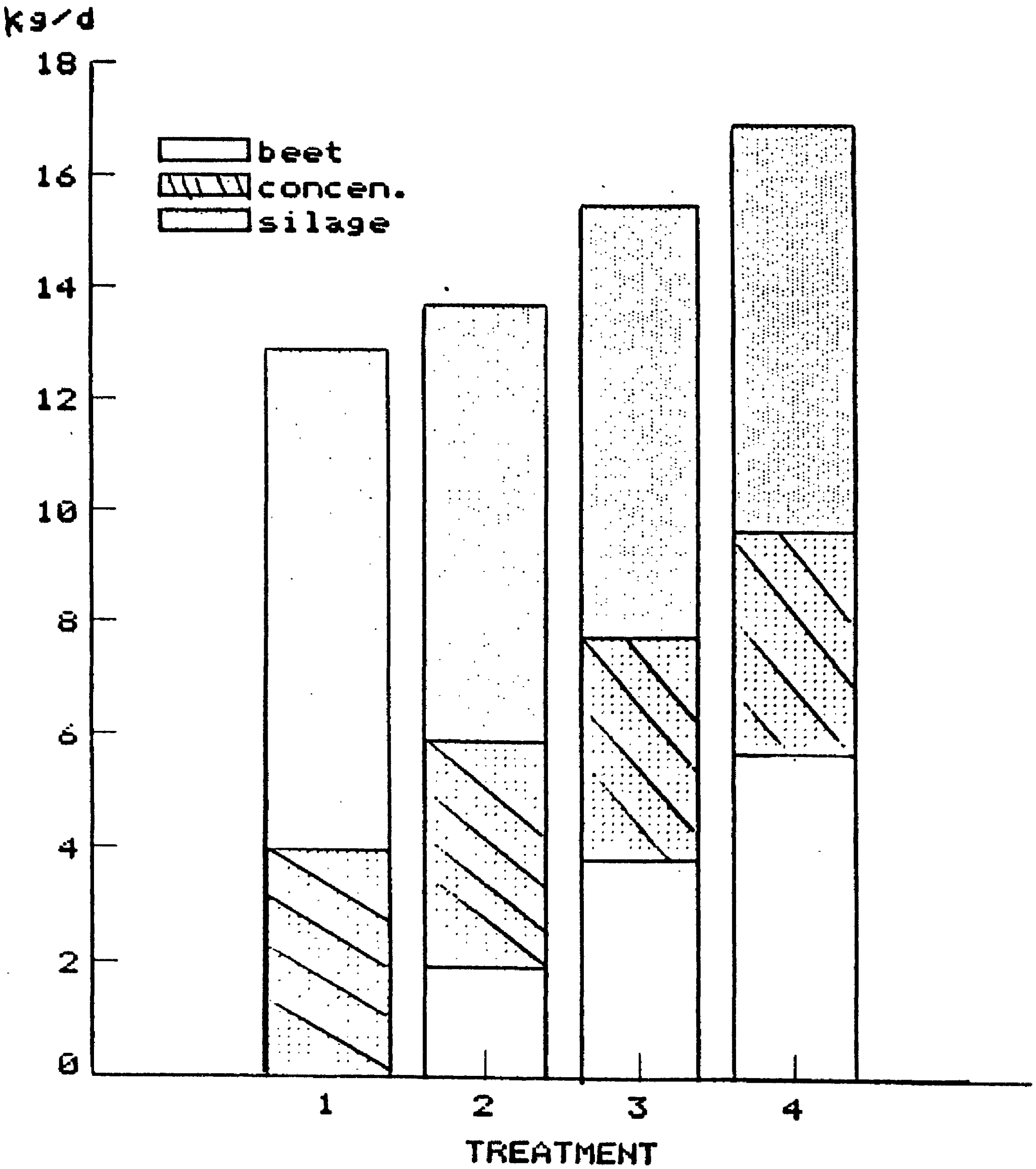
None of the levels of feeding fodder beet caused any digestive disorders and the general health of the cows was excellent.

5.4. Results

5.4.1. Feed intake

The mean daily DM intakes (kg DM d^{-1}), energy intake (MJ d^{-1}) and crude protein intake (kg d^{-1}) are given in Tables 35, 36 and 37. The silage intake in four treatments were decreased as

Figure 11 TOTAL DRY MATTER INTAKE



1 = Treatment A
2 = Treatment B
3 = Treatment C
4 = Treatment D

the fodder beet were increased, but no significant effects were observed between the four treatments. The total dry matter and ME intakes were increased as the fodder beet increased. The significant ($P<0.05$) differences in total dry matter intake were between treatment 4 and 6 kg DM fodder beet compared with zero and 2 kg DM beet (Figure 11). The mean substitution rates (r) were 0.58, 0.31 and 0.29 kg silage DM fodder beet DM kg^{-1} between treatments A/B, A/C and A/D respectively.

The significant ($P<0.05$) differences in total ME intake were between treatments 4 and 6 kg DM fodder beet compared with zero and 2 kg DM fodder beet.

There were no significant differences in total CP intake between treatments. The energy density of the total diets increased from 11.4 MJ kg^{-1} DM for treatment zero fodder beet to 11.7, 11.9 and 12.1 MJ kg DM^{-1} for treatments 2, 4 and 6 kg^{-1} DM fodder beet. The crude protein declined from 159 g kg DM^{-1} for treatment zero beet to 149, 143 and 134 g kg^{-1} DM for treatment 2, 4 and 6 kg^{-1} DM fodder beet respectively. The relative intake of protein g d^{-1} of rumen degradable (RDP) and undegradable protein (UDP) were derived from the group intake of silage, fodder beet and concentrate using degradability values of 0.85 for silage and fodder beet, and 0.72 for concentrate (ARC, 1980) Table 37.

Table 35 The mean daily DM intakes (kg/d)

	A 0/4	B 2/4	C 4/4	D 6/4	SED
Fodder beet (kg/d)	0.0[a]	1.93[b]	3.82[c]	5.71[b]	0.042***
Concentrate (kg/d)	3.96	3.96	3.96	3.96	0.0 NS
Silage (kg/d)	8.90	7.78	7.70	7.25	0.817 NS
Total (kg/d)	12.86[a]	13.66[a]	15.47[b]	16.92[c]	0.827 *

Table 36 The mean daily ME intake (MJ/d)

	A	B	C	D	SED
Fodder beet (MJ/d)	0.0[a]	25.57[b]	51.30[c]	76.33[d]	1.581***
Concentrate (MJ/d)	53.5	53.5	53.51	53.51	0.0 NS
Silage (MJ/d)	92.77	81.18	80.26	75.53	8.467 NS
Total (MJ/d)	146.32[a]	160.25[a]	185.07[b]	205.37[c]	9.267 *

Table 37 The mean daily CP intake and calculated RDP, UDP

	A	B	C	D	SED
Fodder beet (kg/d)	0.0[a]	0.14[b]	0.29[c]	0.43[d]	0.015***
Concentrate (kg/d)	0.80	0.80	0.80	0.80	0.0 NS
Silage (kg/d)	1.22	1.11	1.12	1.03	0.136 NS
Total (kg/d)	2.05	2.04	2.21	2.26	0.118 NS
RDP (g/d)	1612	1638.1	1775	1817	
UDP (g/d)	407	402	436	443	

5.4.2. Refusals

Some refusals of fodder beet was recorded during the first period and no refusals were recorded during the period 2, 3 and 4 (Appendix 9). The mean refusal was (2%) of the total fresh weight of fodder beet offered during period 1.

5.4.3. Milk yield and milk composition

The mean daily milk yield and milk composition was given in Table 38. There were no significant treatment effects observed for milk yields and milk composition, but the mean daily yield increased from 23.3 kg day^{-1} for treatment zero fodder beet to 25.4 kg day^{-1} for treatment 6 kg fodder beet.

Milk fat content, milk protein content and milk lactose content were slightly higher from 41.72, 29.93, 47.65 g kg^{-1} for treatment zero beet to 45.22, 31.60, 48.35 g kg^{-1} for treatment 6 kg fodder beet.

The significant ($P<0.05$) differences in milk fat yield were between treatments 2 and 6 kg DM d^{-1} fodder beet compared with zero and 4 kg DM beet. There were no significant differences in milk protein yield and milk lactose yield, at the four levels of fodder beet feeding but there were increased in milk protein yield and milk lactose yield as the fodder beet increased for each of the 4 treatments.

5.4.4. Liveweight and liveweight change

There were no significant differences in liveweight and liveweight change at the four levels of fodder beet, but there were increased in liveweight change and liveweight as the fodder beet increased for each of the 4 treatments (Table 38).

5.5. Discussion

5.5.1. Design

A small scale experiment with only 4 cows is unlikely to detect differences in milk yield of less than 3 kg (Steel and Torrie, 1960). However, such experiments are useful to provide an indication on the effects of feeding high levels of fodder beet. Similar limited experiments aimed at providing information on the feeding of fodder beet have been carried out eg. Bailey *et al* (1953).

5.5.2. Feed composition and feed intake

The feed composition of fodder beet and silage were similar to Experiment 1. The feeding of fodder beet decreased silage dry matter intake as the fodder beet level increased. The total dry matter intake was significantly ($P<0.05$) increased when fodder beet were used, from 12.86 kg DM d^{-1} for zero fodder beet to 16.92 kg DM d^{-1} for treatment 6 kg DM fodder beet, this agreed well with the previous study by Castle *et al* (1961).

Table 38 The mean milk yield, milk composition, liveweight and liveweight change

	A	B	C	D	SED
Milk yield (kg/d)	23.32	24.42	22.94	25.41	1.988 NS
Milk composition (g/kg)					
Fat content	41.72	44.56	44.05	45.22	3.033 NS
Protein content	29.93	30.83	32.75	31.60	1.310 NS
Lactose content	47.65	48.43	48.35	48.35	0.207 NS
Yields of solids (g/d)					
Fat yield	953.6[a]	1084.6[bc]	1019.1[ab]	1146.9[c]	32.852*
Protein yield	700.6	752.8	752.1	802.8	41.761 NS
Lactose yield	1111.5	1181.2	1108.4	1225.4	98.372
Liveweight change (kg/d)	-0.2	-0.01	0.41	0.17	0.773
Liveweight (kg)	563.11	564.65	565.33	566.19	4.176

Each 1 kg DM of fodder beet only decreased silage intake by 0.58, 0.31 and 0.29 kg DM when offered fodder beet at levels 2, 4 and 6 kg DM respectively and this results agrees with Castle et al (1961) who found the substitution rate was 0.34 and 0.35 when fed fodder beet at levels 2.9 and 5.2 kg DM respectively. But it is lower than that reported by other workers (Brabander et al 1976 and 1978). Krohn and Andersen (1980), cited by Larsen (1985) reported that the reduction in silage intake was 0.5-0.6 kg for each one kg DM of fodder beet when fodder beet was fed at levels of 3 and 6 kg DM.

The reasons for the different substitution rates could be related to the silage quality or ration composition, Brabander et al (1978) showed that the substitution rates of fodder beet for forage decreased with a lower quality basal forage and increased with a higher quality basal forage.

5.5.3. Refusal and Animal Health

There were no refusals of fodder beet even at the highest level fodder beet (up to 36 kg fresh weight) and no digestive disturbances were recorded with feeding 36 kg fresh weight fodder beet (6 kg DM). This result disagreed with Brabander et al (1981) who recommended a limit of 4.5 kg DM fodder beet to avoid digestive problems. The fodder beet was fed individually in this experiment, if the cattle had been group fed intakes of individual cows may have been higher than 6 kg DM. Other factors which may effect animal digestion are whether the fodder beet is chopped, clean and frequency of feeding. However, the bulk of experimental data would suggest that 6 kg DM d^{-1} can be included in daily cow rations (Larsen, 1985).

5.5.4. Milk yield and milk composition

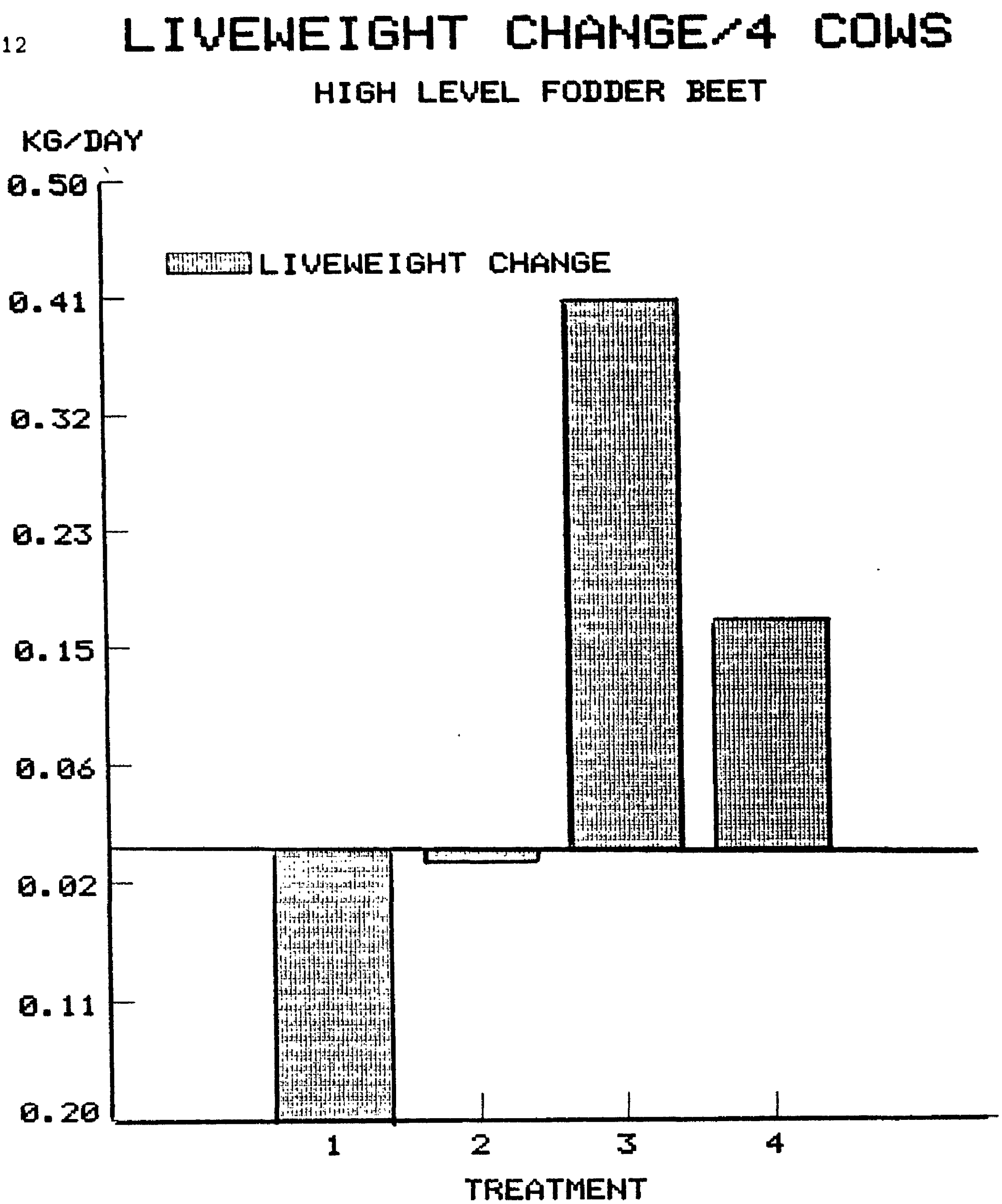
In this experiment there were no significant differences in milk yield and milk composition with feeding fodder beet at higher level (up to 6 kg DM d^{-1}), but the milk yield increased from 23.3 kg d^{-1} for treatment zero fodder beet to 25.4 kg day for treatment 6 kg fodder beet DM. Milk composition and milk yield content increased as the fodder beet increased and this result agrees with previous experiment Chapter 4.

Milk fat yield increased significantly ($P<0.05$) with the feeding fodder beet at higher level (up to 6 kg DM) and this result agrees well with the previous study by Brabander et al (1981) who found a positive influence on milk fat content with feeding fodder beet. Recently Roberts (1985) reported increases in milk fat yield ($P<0.05$) when fed dairy cows fodder beet at levels 4 kg DM.

5.5.5. Liveweight and liveweight change

There were no significant effects observed with feeding fodder beet on liveweight and liveweight change at three levels of fodder beet but there were increases in liveweight and liveweight gain with feeding fodder beet (Figure 12) and this result agrees well with previous study by Castle et al (1963), Izumi et al (1976) and Roberts (1985).

Figure 12



1 = Treatment A
2 = Treatment B
3 = Treatment C
4 = Treatment D

5.6. Summary

In 4 x 4 balanced changes over design experiment 4 treatment:

A - 4 kg DM concentrate with *ad libitum* silage

B - 4 kg DM concentrate + 2 kg DM fodder beet and *ad libitum* silage

C - 4 kg DM concentrate + 4 kg DM fodder beet and *ad libitum* silage

D - 4 kg DM concentrate + 6 kg DM fodder beet and *ad libitum* silage

were offered to four British Friesian cows housed in cubicles with access to individual feeding boxes, the experiment lasted for 12 weeks with four 3 week periods.

The effects of feeding high levels of fodder beet (up to 6 kg DM d^{-1}) on feed intake and cow performance were examined. Feeding fodder beet at higher level (up to 6 kg DM d^{-1})

- increased total dry matter intake from 12.86 kg d^{-1}, treatment A zero fodder beet to 16.92 kg d^{-1} treatment D 6 kg DM fodder beet.
- decreased silage intake from 8.90 kg d^{-1} zero fodder beet to 7.25 treatment D 6 kg DM fodder beet.
- improved milk fat yield, but there were no significant effects on milk yield or milk composition although they tend to be higher with feeding fodder beet.
- higher liveweight and liveweight gain were achieved with

fodder beet.

- no digestive disturbances were recorded with the feeding high level fodder beet (6 kg DM fodder beet).
- no refusals of fodder beet even at the highest level (up to 6 kg DM d^{-1}).

CHAPTER 6

Experiment Three

THE EFFECT OF FEEDING FODDER BEET WITH TWO LEVELS OF PROTEIN ON FEED INTAKE AND COW PERFORMANCE

6.1. Introduction

The result from Experiment 1 did not show the response in milk yield and milk composition, particularly milk fat content that were reported by Roberts (1985). Other workers have shown variable responses in milk fat content of feeding fodder beet (Section 3.3). One reason for the differences may be the level of protein supplementation, Roberts (1985) fed extra soya bean meal with fodder beet and this is the accepted commercial practice (Pearce, 1983).

This experiment had the objective of examining the effects of feeding fodder beet roots with two different levels of crude protein and *ad libitum* silage on feed intake and animal performance.

6.2. Materials and Methods

6.2.1. Design

Sixteen British Friesian cows in late lactation were allocated to the following 4 treatments in a cyclic changeover design (Davis and Hall, 1969) with three 3-week periods (Appendix 10), the treatments involved 2 levels of protein in the concentrate (low 129 and high 229 g kg^{-1} DM) and 2 levels of fodder beet (0, 4 kg DM). The experiment started on 3 October 1986 and ended on 5 December 1986.

6.2.2. Dairy cow and feed management

Cows were housed with access to individual feeding boxes fitted with transponder-operated gates (Broadbent et al, 1970). The cows changed gradually from one diet to another over a period of one week (first week of each period). Details of the changeover diets are given in Appendix 11).

All cows were offered grass silage in sufficient quantities to ensure that 5-10% of the original weight was available as a residue. The silage was not available to the cows when either the concentrate or fodder beet was being fed. The silage was weighed and any refusals weighed before the cows were fed again.

Silage made from first cut of a perennial ryegrass sward was harvested in June 1986. The grass was cut with a drum mower and wilted for 4-8 hours, before harvesting with a precision chop forage harvester applying formic acid (Add-F, BP Nutrition International Limited, 850 g formic acid l^{-1}) at 2.5 litres $tonnes^{-1}$.

The silage was ensiled in an unroofed silage bunker and sheeted with black polythene. All animals were offered this silage during the 12 week experiment. In addition to silage the cows received the following four treatments:

Treatment A: 4 kg concentrate DM d^{-1} low crude protein

(129 g kg^{-1} DM) with ad libitum silage.

Treatment B: 4 kg concentrate DM d^{-1} low crude protein (129), 4 kg fodder beet DM d^{-1} and ad libitum silage.

Treatment C: 4 kg concentrate DM d^{-1} high crude protein (229 g kg^{-1} DM) and ad libitum silage.

Treatment D: 4 kg concentrate DM day^{-1} high crude protein (229 g kg^{-1} DM), 4 kg fodder beet DM d^{-1} and ad libitum silage.

Concentrate was given in two out of parlour feeds daily at 08:30 and 13:00 hrs in a separate feed container, the feed container was removed as soon as the cows had finished eating and after 30 minutes any refusal was weighed and discarded.

Fodder beet was given in two feeds at 09:00 and 13:30 hrs in a separate feed container, the feed container was removed as soon as the cows had finished eating and any refusal after 60 minutes was weighed and discarded. During this time the cows on the zero fodder beet treatment had access to silage.

Fodder beet was chopped with a spade and a special machine (Herborg fodder beet feeder). After being chopped, the fodder beet was mixed well to avoid variation in DM between beets.

The variety of fodder beet was Trestel (Plate No. 6) which harvested in October and November 1986, stored in an unroofed clamp.

Plate 6 Fodder beet variety Trestel

Water was freely available to all cows in the feeding area. Cows were milked twice daily at 07:00 and 16:30 hrs.

6.2.3. Dairy cow and feed measurements

Milk yields of individual animals were recorded on the last four days of each 3-week period and samples were taken for fat, protein and lactose content analysis. The machine used to determine the milk composition was a 1st Electric Milkoscan 203 (Biggs, 1979).

Liveweight was recorded at 08:00 hrs before feeding on Monday, Wednesday and Friday in each week for every period to nearest 2 kg and liveweight change was calculated for each cow by linear regression. Liveweight change was also estimated from an energy balance equation as in Experiment 1.

An oven dry matter determination of silage, fodder beet and concentrates was made on five days per week, for the calculation of dry matter intake by using forced draught oven (Unitherm Drying Oven) at 100^{o}C for approximately 24 hours.

Silage, fodder beet and concentrate (low and high crude protein) samples were taken each week for the determination of chemical composition. The techniques used for the chemical analysis of the feed stuffs were those described by Alexander and McGowan (1966, 1969).

The silage, fodder beet and concentrate (low and high crude protein) ME concentration (MJ kg DM^{-1}) were estimated using the equations in Appendix 2. The calculated ME requirement for maintenance, milk yield production and liveweight change were estimated using the equations in Appendix 3.

6.2.4. Statistical analysis

Liveweight, liveweight change, milk yield and milk composition were calculated and analysed as in Section 4.3.

6.3. Animal Health

None of the rations fed during the experiment caused any digestive disorders and the general health of the cows was excellent.

6.4. Results

6.4.1. Feed composition

The fodder beet (Trestel) had a dry matter between 198 g kg^{-1} for period 1 to 231 and 222 for period 2 and 3 respectively. The crude content was low (44-58 g kg^{-1} DM), but ME content was high (12.9-13.5 MJ kg^{-1} DM). The silage was moderate quality with an average ME of 10.5 MJ kg^{-1} DM, and a moderate ammonia nitrogen content 107 g kg, with an average dry matter of 157 g kg^{-1}. Two concentrates were offered to the cows with low crude protein level 129 g kg^{-1} DM with ME 13.1 MJ kg^{-1} DM and high crude protein level 229 g kg^{-1} DM with ME 13.2 MJ kg^{-1} DM).

The average chemical composition of the feeds are given in Table 39. Appendix 12 contains the chemical composition for each period. The physical ingredients of concentrate (low and high crude protein) are given in Table 40.

6.4.2. Feed Intake

The mean dry matter intake (kg DM d^{-1}), the mean energy intake (MJ d^{-1}) and the mean crude protein intake (g d^{-1}) are given in Tables 41, 42 and 43. The silage in both the low and high levels crude protein treatments were significantly ($P<0.001$) decreased when fodder beet was fed.

The mean substitution rate (r) was 0.51 kg silage DM kg^{-1}. Fodder beet DM between treatments A and B at the low crude protein level. With high level crude protein the mean substitution rate (r) was 0.59 kg silage DM kg^{-1} fodder beet DM between treatments C and D.

The total dry matter intake (kg DM d^{-1}) and total energy intake at both the low and high crude protein level were increased when fodder beet was fed (Figures 13 and 14). The significant ($P<0.001$) difference in total dry matter intake and the total energy intake were between treatment 4 kg DM fodder beet compared with the zero beet at low and high level crude protein.

Table 39 The average of the chemical composition of the silage, concentrate (low and high crude protein) and fodder beet.

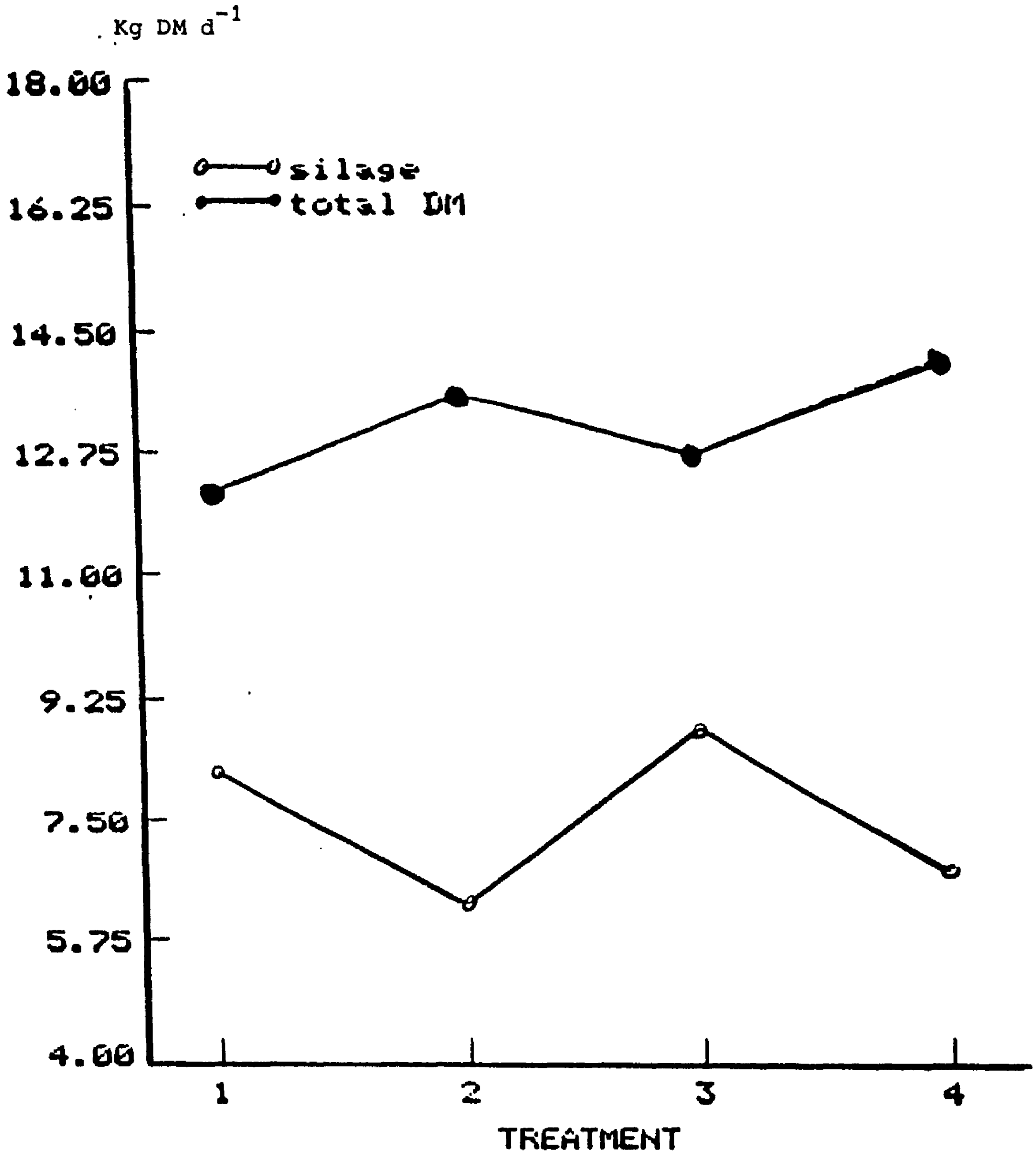
	Fodder beet	Silage	Concentrate Low	Concentrate High
Oven dry matter (g/kg)	217	156	839	845
Crude protein (g/kg DM)	51.5	134.5	129	229
Organic matter (g/kg DM)	897	909	954	930
DOMD (in vitro) (g/kg DM)	901	727	856	873
Ammonia N as g/kg of total N	-	107	-	-
Predicted ME (MJ/kg DM)	13.2	10.5	13.1	13.2
Calcium (g/kg DM)	1.12	5.25	5.53	8.02
Phosphorous (g/kg DM)	1.91	3.12	5.67	7.05
Magnesium (g/kg DM)	1.67	1.96	2.80	3.88
pH	-	4.1	-	-

Table 40 Physical ingredients of concentrate (low and high crude protein)

	Concentrate	
	Low crude protein	High crude protein
Ground Barley (kg)	900	650
Soya bean meal (kg)	80	330
Minerals* (kg)	20	20

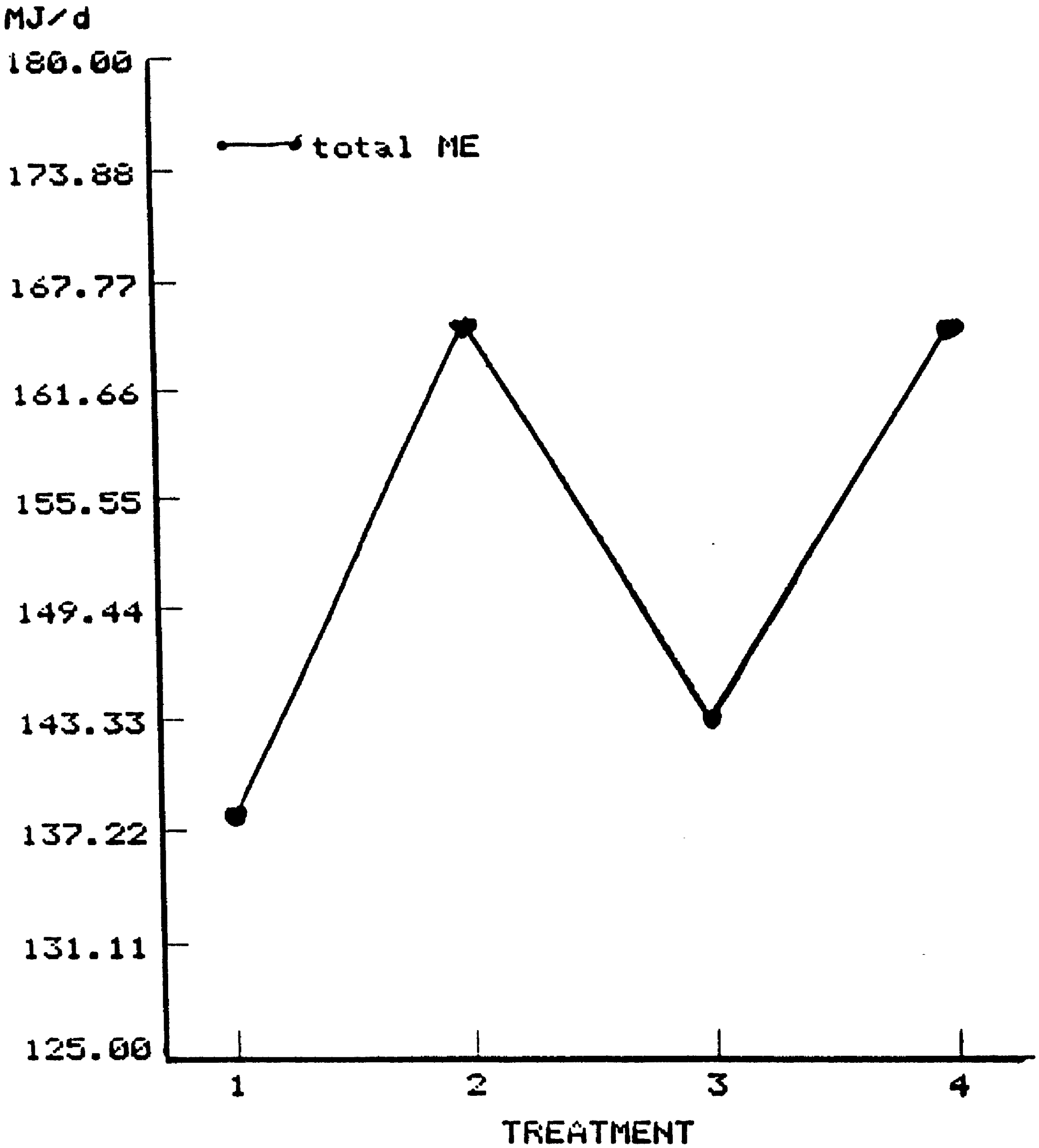
*physical ingredients of minerals:

calcium	165 g/kg
phosphorus	60 g/kg
magnesium	50 g/kg
sodium	95 g/kg
copper	1000 mg/kg
selenium	8 mg/kg
Vit A	320000 lU/kg
D	60000 lU/kg
E	300 lU/kg



1 = Treatment A
2 = Treatment B
3 = Treatment C
4 = Treatment D

Figure 14 Total ME intake



1 = Treatment A
2 = Treatment B
3 = Treatment C
4 = Treatment D

Table 41 Mean daily dry matter intake (kg/d)

	A	B	C	D	SED
Fodder beet (kg/d)	0.0[a]	3.82[c]	0.0[a]	3.51[b]	0.12***
Concentrate (kg/d)	3.81	3.86	3.88	3.86	0.011 NS
Silage (kg/d)	8.22[c]	6.26[a]	8.83[d]	6.77[b]	0.242***
Total (kg/d)	12.18[a]	13.57[b]	12.70[a]	14.09[b]	0.319***

Table 42 Mean daily intakes of metabolizable energy (MJ/d) and calculated ME density

	A	B	C	D	SED
Fodder beet (MJ/d)	0.0[a]	50.70[c]	0.0[a]	46.53[b]	1.594***
Concentrate (MJ/d)	50.49	50.41	51.08	50.84	0.182 NS
Silage (MJ/d)	96.60[c]	65.51[a]	92.81[d]	71.05[b]	2.595***
Total (MJ/d)	137.86[a]	165.46[b]	143.33[a]	165.28[b]	3.969***
Energy density (MJ/kg)	11.32	12.19	11.29	11.73	

Table 43 Mean daily intakes of crude protein and the calculated crude protein density, RDP and UDP intakes

	A 0/4	B 4/4	C 0/4	D 4/4	SED
Fodder beet (g/d)	0.0^{a}	192.60^{b}	0.0^{a}	182.96^{b}	8.072***
Concentrate (g/d)	502.59^{a}	498.17^{a}	888.99^{b}	882.00^{b}	5.593**
Silage (g/d)	1112.54^{b}	844.80^{a}	1183.29^{c}	910.58^{a}	32.313***
Total (g/d)	1612.94^{b}	1534.96^{a}	2070.11^{d}	1975.33^{c}	32.278**
Crude protein density (g/kg DM)	132.43	113.11	163.0	140.19	
RDP (g/d)	1332.65	1265.38	1654.76	1573.37	
UDP (g/d)	280.29	269.58	415.35	401.96	

The total crude protein intake was significantly lower ($P<0.01$) when fodder beet was included in the diet at both levels of protein supplementation (Figure 15).

There were no significant interactions between the level of protein and fodder beet for silage intake, total dry matter intake, ME intake and crude protein intake.

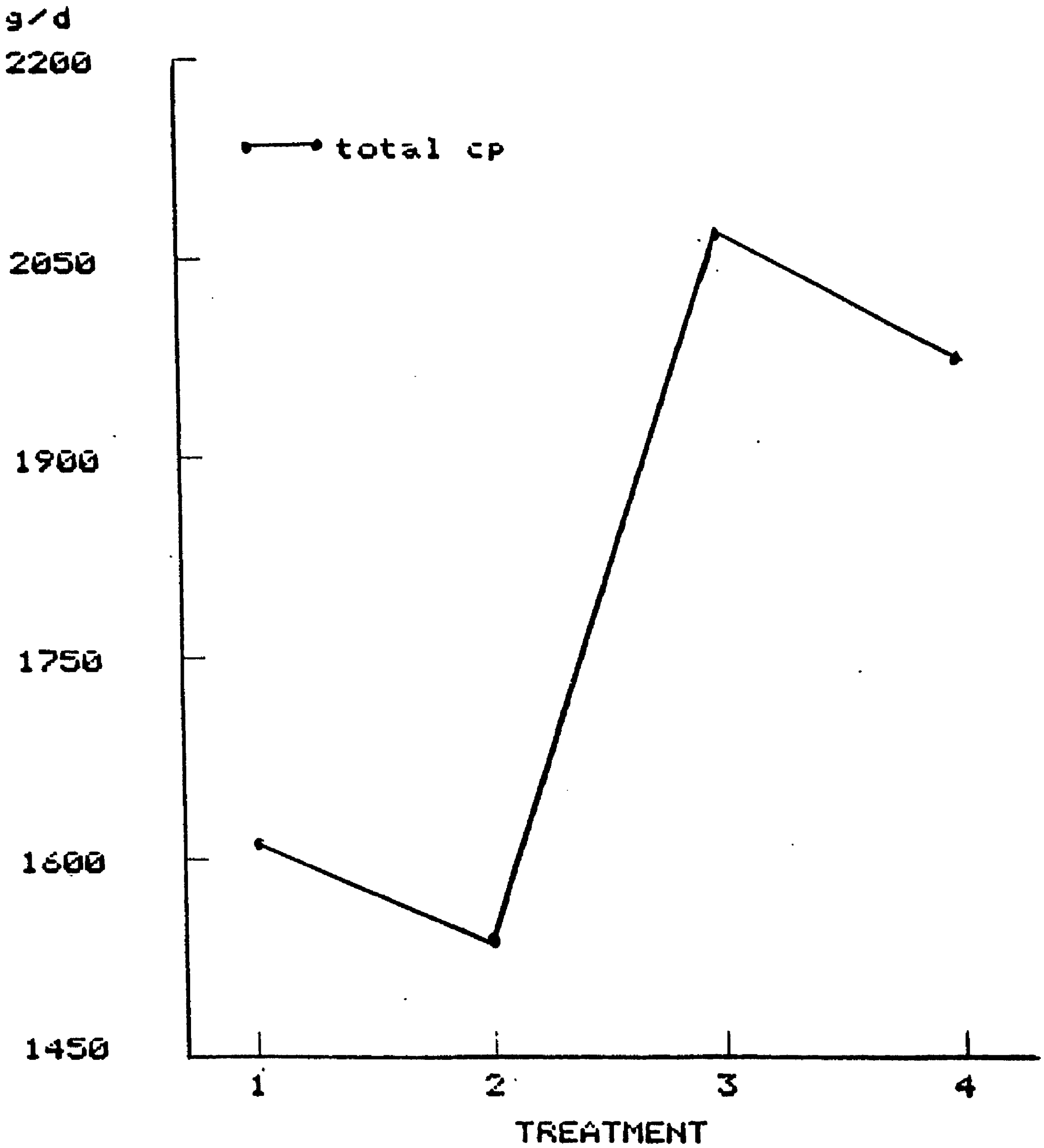
The energy density of the total diets increased from 11.3 MJ kg DM^{-1} for treatment zero fodder beet to 12.2 and 11.7 MJ kg DM^{-1} for treatments 4 kg DM beet in low and high crude protein respectively. The crude protein content declined from 132 and 163 g kg DM^{-1} for treatment zero fodder beet to 113 and 140 g kg DM^{-1} for treatment 4 kg beet with the low and high crude protein respectively.

The relative intake of protein (g day^{-1}) of rumen degradable (RDP) and undegradable protein (UDP) were derived from the mean intake of silage, fodder beet and concentrate low and high level protein using degradability values of 0.85 for silage and fodder beet, 0.73 for concentrate with high protein and (0.77) for concentrate with low crude protein (Table 43).

6.4.3. Refusals

Some refusals of fodder beet were recorded during the experiment. The mean refusals % in periods 1, 2 and 3 were

Figure 15 Total crude protein intake



1 = Treatment A
2 = Treatment B
3 = Treatment C
4 = Treatment D

11.1, 25.6 and 10% respectively of the total fresh weight of fodder beet offered and the mean refusal for the experiment was 15.6%.

6.4.4. Milk yield and milk composition

The mean daily yields and milk composition and milk yield of constituents are given in Table 44, Figures 16, 17 and 18 respectively.

There was a significant ($P<0.05$) increase in milk yield between the low crude protein/no fodder beet treatment and high protein/fodder beet treatment. There was no significant difference between fodder beet treatments within the crude protein levels (Table 44). There were highly significant ($P<0.001$) increases in milk fat contents and milk protein content when fodder beet was fed with low and high crude protein levels compared with treatments without fodder beet Table 44 and Figure 17.

No significant effects were observed for milk lactose content with all the treatments. There were highly significant ($P<0.001$) increases in milk fat yield and milk protein yield when fodder beet was fed with low and high levels crude protein Table 44 and Figure 18. No significant effects were observed for milk lactose yield with feeding fodder beet at low and high levels of crude protein.

There were no significant interactions between crude protein levels and fodder beet for milk yield and milk composition.

6.4.5. Livewieght and liveweight change

There were no significant treatment effects observed for liveweight and liveweight change when fodder beet was fed with low and high levels crude protein (Table 44) but the mean liveweight and daily liveweight change were slightly higher with feeding fodder beet at low and high crude protein levels (Figure 19).

The estimate of liveweight change from an ME balance at +0.53, +1.18, +0.63 and +1.11 for treatments A, B, C and D respectively was higher than that calculated by regression.

6.5. Discussion

6.5.1. Fodder beet chemical composition

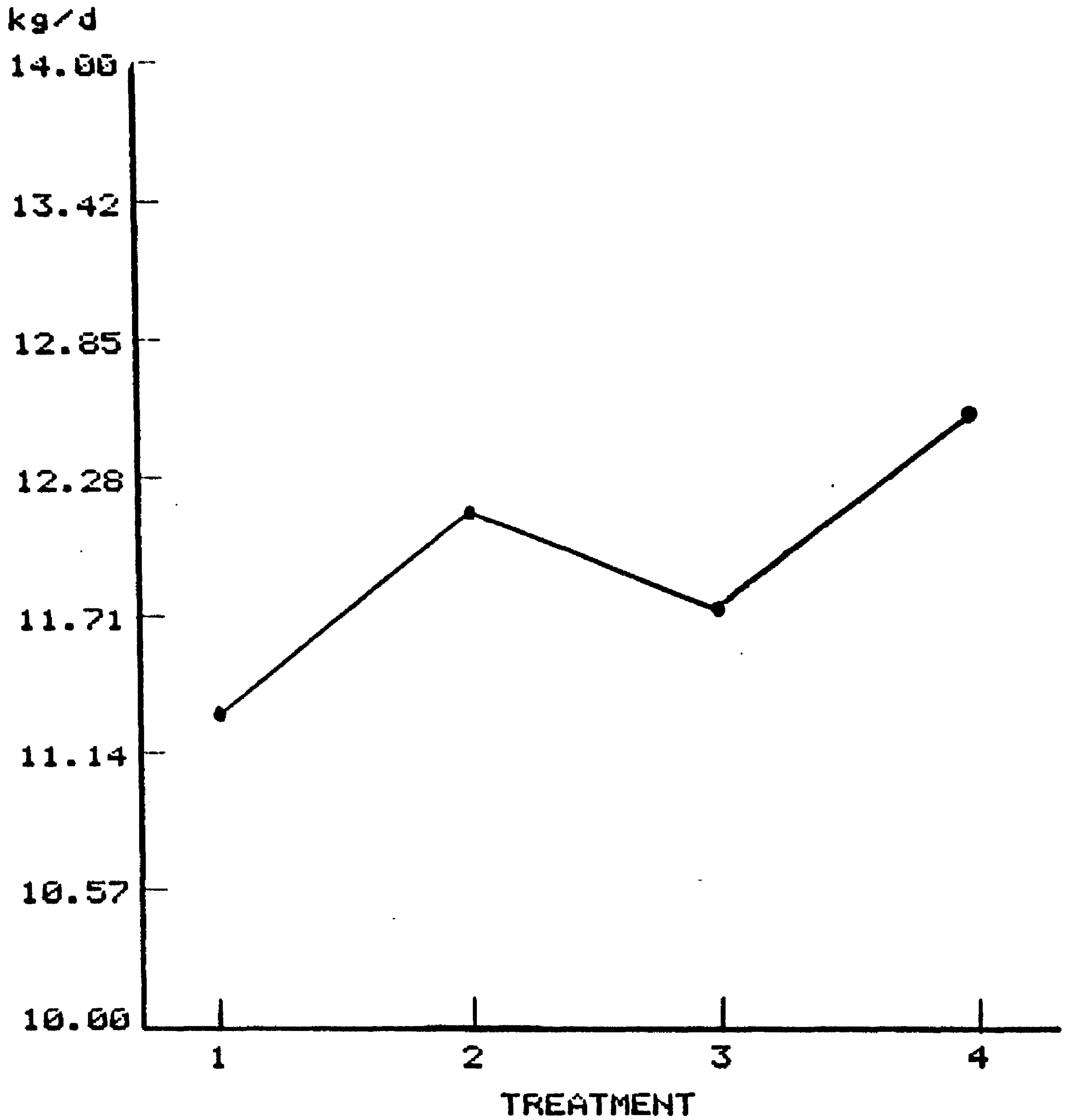
The composition of fodder beet (Trestel) with high dry matter content which was used in this experiment was summarised in Table 39.

The average dry matter at 217 g kg^{-1} was similar to the value given by MAFF (1985) who reported the dry matter for fodder beet (Trestel) was 203 g kg^{-1}, but higher than the value reported by Heppel (1985) which was 174 g kg^{-1}.

Table 44 The mean daily milk yield, milk composition, milk yield constituents, liveweight and liveweight gain

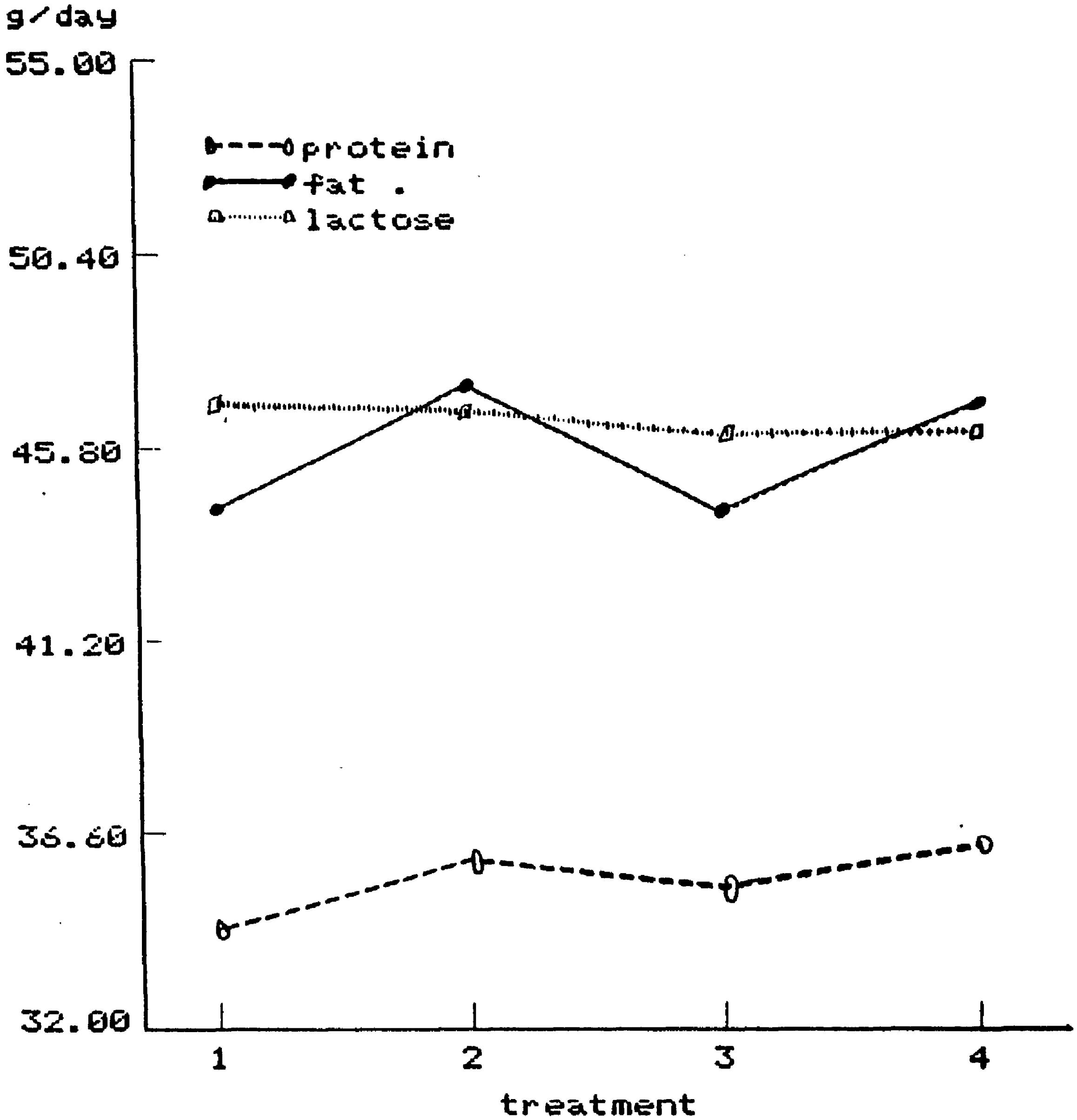
	A	B	C	D	SED
Milk yield (kg/d)	11.3 [a]	12.1 [ab]	11.7 [ab]	12.5 [b]	0.43*
Milk fat content (g/kg)	44.4 [a]	47.3 [b]	44.3 [a]	46.8 [b]	0.73***
Milk protein content (g/kg)	34.3 [a]	35.6 [b]	35.3 [b]	36.2 [c]	0.28***
Milk lactose content (g/kg)	46.8	46.7	46.1	46.2	0.34 NS
Milk fat yield (g/d)	493.5 [a]	574.4 [b]	511.5 [a]	578.9 [b]	20.039***
Milk protein yield (g/d)	385.0 [a]	426.1 [c]	406.9 [b]	442.3 [c]	12.869***
Milk lactose yield (g/d)	531.8	568.0	544.8	579.0	18.55 NS
Liveweight (kg)	612.0	611.7	605.8	612.3	3.21 NS
Liveweight gain (kg/d)	0.15	0.35	0.58	0.61	0.221 NS

Figure 16 Daily milk yield
Low and High Protein



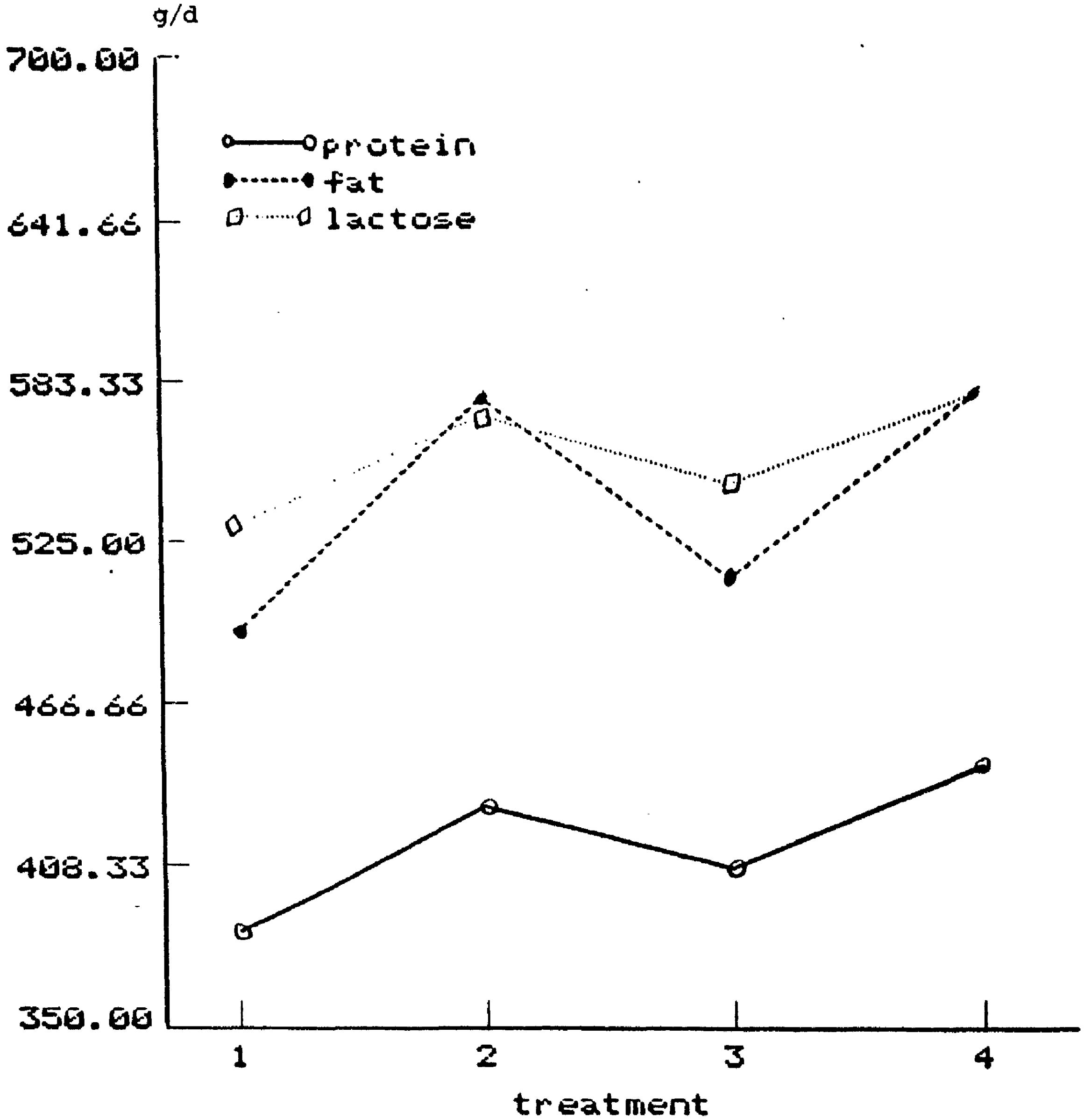
1 = Treatment A
2 = Treatment B
3 = Treatment C
4 = Treatment D

Figure 17 Milk composition
Low and high protein



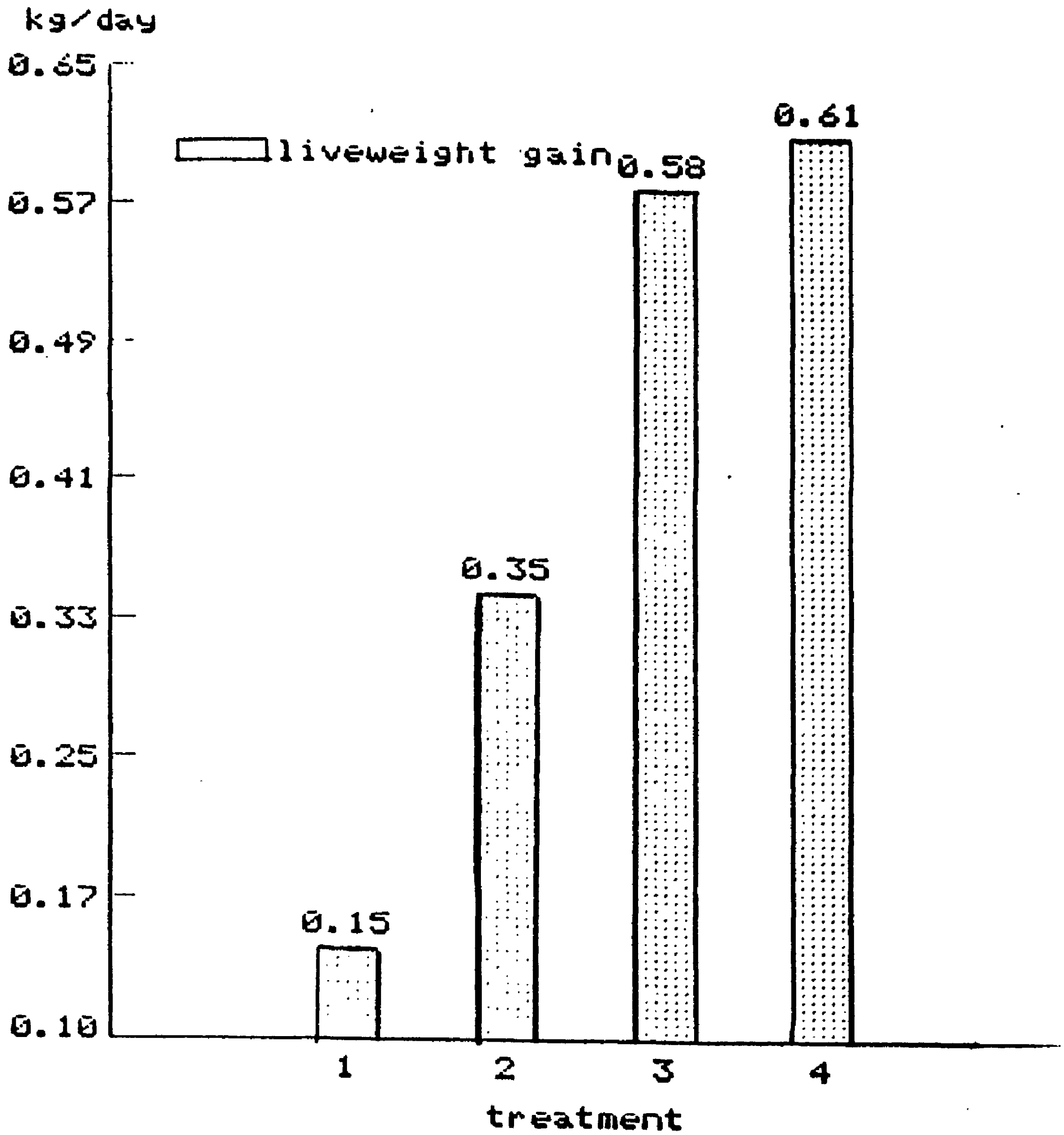
1 = Treatment A
2 = Treatment B
3 = Treatment C
4 = Treatment D

Figure 18 Milk yield composition
Low and high protein



1 = Treatment A
2 = Treatment B
3 = Treatment C
4 = Treatment D

Figure 19 Liveweight gain
Low and high protein



1 = Treatment A
2 = Treatment B
3 = Treatment C
4 = Treatment D

In this experiment the average of the organic matter content was 897 g kg^{-1} DM for three periods. This value was lower than 948 g kg^{-1} DM which was reported by MAFF (1985), and was due to the high soil contamination of 10%.

6.5.2. Dry matter intake

Silage dry matter intake was decreased from 8.22 kg DM d^{-1} for treatment A to 6.26 kg DM d^{-1} for treatment B and from 8.83 kg DM d^{-1} for treatment C to 6.77 kg DM d^{-1} for treatment D.

This result agreed with previous studies by Castle et al (1961) and Roberts (1985) who reported a decrease in silage intake when fodder beet was fed.

There was an increase in silage DM intake at the high protein content from 6.26 kg DM d^{-1} for treatment B to 6.77 kg DM d^{-1} for treatment D, and from 8.22 kg DM d^{-1} for treatment A to 8.83 kg DM d^{-1} for treatment C. This result agreed with many workers who found including high level protein in the concentrate increased silage intake (eg Laird et al, 1979 and 1981).

The total dry matter intake increased significantly ($P<0.001$) with feeding fodder beet at low and high crude protein. This agreed well with Roberts (1985) who reported the total dry matter intake increased with feeding fodder beet with extra soya bean. However, it has been shown that feeding of extra protein will improve feed intake (Castle *et al*, 1977 and Murphy *et al*, 1985).

The substitution rates reported here are similar to those of Brabander *et al* 1976, 1978, Krohn and Andersen, 1979 and Roberts, 1985).

6.5.3. Refusals

There were refusals of fodder beet during all 3 periods, the mean refusal of fodder was 10%. This was due to the soil contamination which was high during the experiment especially in period 2 due to very wet weather. The cows ate the fodder beet well and most of the soil was left behind.

6.5.4. Milk yield, milk composition, liveweight and liveweight change

Roberts and Dickson (1985) recommend that extra protein is necessary at high levels of fodder beet especially when the protein content of the silage is low. Previous work by Laird *et al*, 1979 showed that increasing the protein level of the concentrate resulted in higher milk production. The increase in the consumption of crude protein from (1612.9 g d^{-1}) for treatment A to 1975.3 g d^{-1} for treatment D were accompanied by increases in milk from 11.3 kg d^{-1} for treatment A to 12.5 kg d^{-1} for treatment D.

Milk composition and milk component yield were increased significantly with feeding fodder beet at both low and high levels protein contents compared with treatments without fodder beet and this result agreed well with a previous study by Roberts (1985) who showed improved in milk quality with feeding fodder beet with extra soya bean meal. The result also agreed with many workers who have shown an improvement in milk yield or milk quality with extra protein in the ration (Castle and Watson, 1976; Gordon 1977a and 1979 and Laird et al, 1981).

Many workers showed no significant effect on liveweight and liveweight change with feeding fodder beet (Izumi, 1976 and Roberts, 1985). In this experiment no significant effect was observed with feeding fodder beet at low and high levels of protein on liveweight and liveweight change and this result agrees well with results of experiments 1 and 2.

6.6. Summary

The effects of feeding fodder beet with two levels of protein (low 129 g kg^{-1} DM) and high (229 g kg^{-1} DM) with *ad libitum* silage were examined in a cyclic changeover experiment using 16 British Friesian cows in late lactation. The experiment lasted for 9 weeks with three periods each of 21 days.

The mean values for silage, fodder beet and concentrate with low and high level protein content analyses were respectively DM: 217, 156, 839 and 845 g kg^{-1}, crude protein 134.5, 51.5, 129 and 229 g kg^{-1} DM; metabolizable energy 10.5,

12.2, 13.1 and 13.2 MJ kg^{-1} DM mean values for treatments D and 4 kg DM d^{-1} fodder beet at low and high level protein content were as follows, total feed intake (kg DM d^{-1}) L 12.18 and 13.57; H 12.7 and 14.09.

Silage intake (kg DM d^{-1}) L 8.22 and 6.26, H 8.83 and 6.77; milk yield (kg d^{-1}) L 11.3 and 12.1; H 11.7 and 12.5; milk fat content (g kg^{-1}) L 44.4 and 47.3; H 44/3 and 46.8; milk protein contents (g kg^{-1}) L 34.3 and 35.6; H 35.3 and 36.2.

Feeding fodder beet with a high level protein concentrate significantly increased milk yield, milk composition, milk yield constituents and total dry matter intake. Silage intake was decreased with feeding fodder beet at low and high level protein content. There were no significant effects on liveweight or liveweight change.

CHAPTER 7

Experiment 4

THE DIGESTIBILITY OF FODDER BEET ROOTS MEASURED *IN VIVO*

7.1. Objective

Very little information is available on the nutritive value of modern fodder beet roots. The variety Kyros with a medium dry matter content was examined in the laboratory and evaluated *in vivo* using sheep.

7.2. Experimental Details

7.2.1. Animals, Housing and Management

Six Suffolk x Greyface wethers sheep (average live weight 55 kg) born spring 1984, were individually housed in metabolism crates. Each crate was fitted with a slatted floor and provided with a detachable feed box at the front, together with a removable plastic bucket.

Fresh drinking water was provided *ad libitum* throughout the duration of the trial.

During the trial period, each animal was fitted with a faecal collection harness to which a polythene faeces collection bag was attached. The harness was adjusted by four metal clips, and elastic bands. This experimental system allowed accurate measurement of feed intake and faecal output.

7.2.2. Statistical analysis

The design as shown in Table 45 was a two treatment change over, with two 3-week periods using 6 sheep.

Organic matter and gross energy digestibilities (OMD and GED respectively) were analysed using the EDEX statistical package (Hunter and Mann, 1979).

Table 45 Change over design for 6 sheep allocated to 2 treatments

Sheep No.	77	78	80	69	71	72
Period 1	L	L	L	H	H	H
Period 2	H	H	H	L	L	L

7.2.3. Experimental diets

A standard complete diet Ruminant A was fed in two rations. Ration H (high level fodder beet) contained fodder beet and Diet A in the ratio 61.1:38.9 on a DM basis. Ration L (low level fodder beet) contained fodder beet and diet A in the ratio 48.5:51.5 on a DM basis. The composition of the ration is shown in Table 46, and the composition and analyses of diet A is shown in Appendix 13 and the composition of fodder beet is shown in Table 19. The quantities were estimated to provide the maintenance energy requirement plus 10%.

7.2.4. Feed preparation routine

Feed preparation routine was as follows:

1. Enough fodder beet for 6 sheep for 3 days were washed and weighed.
2. Fodder beets were roughly chopped with spade then sliced to 5 mm thickness by using a Hobart A2oo Mixer with vegetable slicer attachement (Hobart Manufacturing Company Limited, Hobart Corner, New South Gate, London, NI1 1QW).
3. Sliced fodder beet were then mixed in a feed mixer to avoid variation in DM between individual fodder beets.
4. Appropriate weights of sliced fodder beet and diet A were weighed into separate feed bags (low and high diet).
5. Bags of fodder beet were stored in a refridgerator at $4^{o}C$ before use.
6. Urea and minerals were pre-weighed into plastic containers for daily feeding.

Table 46 Composition of the experimental rations (g/day)

	High level H FW	High level H DM	Low level L FW	Low level L DM
Fodder beet (g/d)	2804	479.5	2242	383.4
Diet 'A' (g/d)	354	305.1	472	406.9
Minerals (g/d)	10		10	
Urea solution (g/d)	8		8	

7.2.5. Feeding Routine

A pre-trial equilibration period of 13 days was used to accustom the sheep to fodder beet. Thereafter the two diets (H and L) were fed in two 3 week periods. Total faecal collection were made during the last 9 days of each period. The daily ration was offered in two equal feeds at 08.30 and 16.30 hours. Feed consumption was recorded daily. There were no refusal during the course of the experiment.

7.2.6. Faeces

Faeces were removed from the collection bags daily at 09.00 hours and the fresh weight of faeces was recorded. Faeces were accumulated for each sheep in a sealed plastic bucket at 4^{oC}. At the end of each 3 days collection the total faeces was weighed and thoroughly mixed using a food mixer.

7.3. Analytical Technique

All feed and faeces samples were dried in pre-weighed metal trays for 24 hours at 100°C in a forced draught oven to provide an estimate of dry matter. Duplicate 50 g sub-samples of dried samples were then placed in pre-weighed crucibles and ashed in an electric muffle furnace at 460°C for 17 hrs. The crucibles were then cooled in a desiccater for 30 minutes and weighed. The ash was then moistened with distilled water and dried at 100°C for 30-45 min. Ashing was continued at 460°C for a further 5-6 hrs to obtain ash free of carbon. The crucibles were then cooled and re-weighed and the organic matter content calculated.

7.4. Results

The fodder beet (Kyros) which was used in this experiment had a high dry matter content (171 g kg) the root had an metabolisable energy content of (13.1 MJ kg DM^{-1}) but a low crude protein content (75.7 g kg^{-1} DM). The sheep readily accepted the fodder beet and there were no refusals recorded.

The mean values obtained for the dry matter, organic matter, gross energy and metabolisable energy are given below:

Dry matter g/kg	171 ± 2.8
Organic matter g/kg DM	929 ± 4.7
Organic matter digestibility	0.962 ± 0.0086
Gross energy MJ/kg DM	16.8 ± 0.13
Metabolisable energy MJ/kg DM	13.1 ± 0.11

The digestibility values for organic matter and gross energy were calculated by difference assuming values of 0.659 $\pm$ 0.005 and 0.640 $\pm$ 0.007. For OMD and GED for Diet A. These values had been measured in a previous trial using 9 sheep fed Diet A alone (Offer N W, personal communication).

The ME values were calculated from the following equation ME (MJ kg^{-1} DM) = GED x GE x 0.82 (ARC 1980).

where

GED = gross energy digestibility

GE = gross energy

There were significant differences ($P<0.05$) between the calculated digestibility of the energy for the high and low rations. The mean gross energy digestibility increased from 0.939 for treatment high fodder beet to 0.967 for treatment low fodder beet. There were however no significant differences between the calculated organic matter digestibility between high and low fodder beet rations. There were no significant differences observed due to period or animal for the low and high ration.

7.5. Discussion

The dry matter of fodder beet depends on the variety but, generally the dry matter varies between 140 and 220 g kg^{-1}. Drayton Feed Evaluation Unit (MAFF, 1985) had shown that the dry matter of fodder beet (Kyros) ranged between 159 and 173 g kg^{-1} and the average was 166 g kg^{-1}. The dry matter of fodder beet (Kyros) in this experiment was 171 g kg^{-1} which is higher than the figure of 154 g kg^{-1} reported by Evans (1986). The variation between the results may be due to the weather and the conditions of storage.

The organic matter content reported here (929 g kg^{-1} DM) was slightly higher than the previously reported figure of 912 g kg^{-1} DM (MAFF, 1985). However the organic matter content depends on the amount of soil contamination, which is reflected by the ash content of the dry matter.

The values for the organic matter digestibility ranged from 0.955 to 0.969 for high and low diet respectively. The mean value for low and high diets was 0.962 which is higher than that in the previous work by MAFF (1985(who reported that the organic matter digestibility ranged between 0.930 and 0.950. The metabolizable energy contents reported here ranged from 12.7-13.5 MJ kg^{-1} DM and are higher than the previous study by MAFF (1985) who reported the metabolisable energy contents ranged from 11.6 - 12.1 MJ kg^{-1} DM.

It is interesting to examine the sources of the difference in ME values for fodder beet calculated by MAFF (1985) and those from the present study. MAFF (1985) showed a mean ME of 11.8 MJ kg^{-1} DM compared to 13.1 for the present trial. The discrepancy arises mainly in two ways: firstly MAFF (1985) found a lower GE value (15.8 compared to 16.8); secondly MAFF found a lower GED 0.88 compared to 0.953). The difference in GE may partly be due to the higher ash content found by MAFF (89 g kg^{-1} compared to 71 g kg^{-1}) perhaps due to different degrees of soil contamination. The difference between the values for GED between the two trials is more difficult to explain especially as the OMD values were similar.

7.6. Summary

The digestibility of organic matter and gross energy of fodder beet were measured using six sheep (average weight 55 kg).

Fodder beet was fed at two levels with a standard complete diet containing 400 g kg of straw, Ration (H) consisted of 305.1 g DM complete diet + 479.5 g DM fodder beet; Ration (L) consisted of 406.9 g DM complete diet + 383.4 g DM fodder beet. They were both supplemented with urea and mineral supplement to meet requirements.

Measurements of feed intake and faecal output were taken over the last nine days of a 21 day period on each experimental

diet. The mean digestibility was calculated by difference assuming values for Diet A fed alone which had been measured in a previous trial. The calculated values were:

Organic matter digestibility	=	0.962 $\pm$ 0.0086
Organic matter digestibility	=	924 $\pm$ 4.7 g kg
Gross energy digestibility	=	0.953 $\pm$ 0.0090
ME ^{x}	=	13.1 $\pm$ 0.11 MJ/kg DM

x using ME = 0.82 x DE x GED

(ARC, 1980)

CHAPTER 8

Experiment 5

RUMEN METABOLISM MEASUREMENTS

8.1. Introduction

Fodder beet can be used as a supplement in dairy cow rations to replace either forage (Brabander et al, 1976, 1978 and Roberts, 1985) or concentrate (Jans, 1983). It is necessary to be able to predict the substitution rates which will give the optimum animal response. Thus it is important that production trials as well as considering whole animal responses, the effect of supplementation at the rumen level must also be considered. Although the digestibility of fodder beet has been measured, the rumen effects should also be investigated.

8.2. Aims

To characterise fodder beet as supplement:

a) by comparing the effects of dietary fodder beet inclusion with other supplements on:

   i) rumen pH

   ii) VFA concentrations

   iii) hay dry matter digestion *in sacco*

   when fed to sheep in a 50:50 ratio (DM basis) with chopped hay.

b) To measure *in sacco* digestion rates for fodder beet and other supplements in sheep fed a standard high forage diet.

8.3. Experiment A

8.3.1. Materials and Methods

8.3.1.1. Animals

Three mature Suffolk cross wether sheep of approximately 80 kg liveweight were used. Each animal was fitted with a permanent rumen cannula with a screw top. Plate 7. The animals were kept indoors in loose pens and fed individually.

8.3.1.2. Experimental Diets

Three different rations were offered to the sheep during the experimental periods. The daily rations are given in Table 47.

Table 47 The composition of rations (g d^{-1} DM)

Treatment	Hay	Supplement
SBP	500	500 Molassed sugar beet shreds
BM	500	250 Rolled barley + 250 flaked maize
FB	500	500 fodder beet

The composition of the hay, fodder beet, barley, maize and molasses sugar beet shreds are given in Table 48. All sheep received daily 25 g minerals and 14 g urea. The diets were given in two equal feeds at 09:00 and 17:00 hrs. The experiment started on 8 January 1987 and ended on 16 March 1987.

Plate 7 Sheep fitted with a permanent rumen cannula

Table 48 Feed composition

	Fodder beet	Flaked maize	Rolled barley	Hay	Molassed . sugar beet shreds
Dry matter (g/kg)	198	852	821	820	869
CP (g/kg DM)	42	90	90	82	105
OM (g/kg DM)	896	980	973	930	900
*IVOMD %	89.8	92.0	82.5	57.2	88.2
In vitro D	80.5	90.2	80.3	53.2	79.4
ME (MJ/kg DM)	12.9	14.4	12.8	8.2	12.7

*IVOMD% Organic matter digestibility measured _in vitro_

The quantities were estimated to provide the maintenance and energy requirement of sheep plus 10%. Fresh drinking water was provided *ad libitum* throughout the duration of the trial.

8.3.1.3. Experimental Design

Three sheep were allocated at random to the 3 treatments in a cyclic changeover design (Davis and Hall, 1969) with three periods each of 21 days (Table 49).

8.3.1.4. Feed preparation routine

Feed preparation routine was as follows:

i) Fodder beet (Trestel) was washed and chopped using a spade and then sliced to 5 mm thickness using 'Hobart A200' mixer with vegetable slicer attachment. Sliced fodder beet was mixed well to avoid variation in DM between the fodder beet.

ii) Hay was chopped and mixed well to avoid variation in DM between the hay.

iii) The hay was well mixed before weighing to avoid variation in composition.

iv) The rolled barley/flaked maize and the molassed beet shreds were each well mixed before weighing to avoid variation in composition.

Table 49 Changeover for 3 sheep, 3 diets and 3 periods.

	Diet		
Sheep	Period 1	Period 2	Period 3
89	BM	SBP	FB
83	FB	BM	SBP
90	SBP	FB	BM

8.3.1.5. Determination of dry matter

Dry matter estimates of all feed stuffs were carried out by heating triplicate samples in preweighed dry crucibles in an oven at 60°C for at least 48 hrs. The crucibles were then transfered to a desiccator to cool then reweighed and the dry matter content calculated.

8.4. In sacco measurements

8.4.1. Preparation of bags

The nylon bags were made of HSO 13 cloth supplied by "Henry Simons, PO Box 31, Stockport, Cheshire". The bags were 20 cm x 7.5 cm in size with approximately (45 μ) pore diameter and about 2.75 g weight. The seams were double stitched to prevent any leakage of sample and the bottom of the bags were curved to prevent the samples collecting in the corners. The bags were clearly labelled in numerical sequence and were weighed to three decimal places. The sample was weighed approximately 5 g airdry of hay into each bag, which then was tied tightly with a nylon thread to prevent spillage of the contents.

8.4.2. Preparation of samples

In advance of the trial, a sufficient amount of Timothy hay was prepared. The hay was first chopped twice to a length of 5-6 cm in 'GHL' straw chopper and then put through a 'Hobart Mixer Slicer Attachment' 4 times to give an average chop length of 0.5 - 1.0 cm. It was then sieved by using 45 μ mesh to remove fines.

8.4.3. Incubation of bags in the rumen

The bags were incubated in groups of three in the rumen of each sheep. The bags were attached to a rubber bung by three strings which passed through a polythene tube (Plate 8) to prevent tangling of strings and to spread the bags out in the rumen, the bungs were selected to fit the cannulae of the three sheep.

8.4.4. Incubation time

Three incubation times were used 8, 24 and 48 hours. The bags were incubated immediately prior to feeding since it was easier to introduce them to the rumen at that stage.

8.4.5. Washing

After removing the bags from the rumen, the bags were washed in cold running tap-water and were further cold washed in a present automatic washing machine (Zannusi, Program B). Zero time bags received the same treatment except they were not incubated in the rumen. After washing, all bags were oven-dried

Plate 8 Photograph showing method of attachment of nylon bags

at 60°C for 48 hours. The bags were allowed to cool in a desiccator and weighed again to three decimal places.

8.5. Measurements and collection of rumen liquor

The apparatus described by Alexander and McGowan (1966) was used to collect the rumen liquor. The apparatus (see Plates 9 and 9a) consisted of a 50 cm^3 syringe attached by polythene tubing to a non-return valve system, this enters a 100 cm^3 thermos flask through a rubber bung. The tube which enters in the flask by the same route is inserted into the rumen via the cannula. The end of this tube is sealed, but several holes are cut near the end to filter the rumen fluid. The minimum vacuum to induce the liquor to flow into the flask is created by operating the syringe.

8.5.1. Rumen liquor sampling

Rumen liquor samples were taken every week day at 13.45 hrs. During the last week of each period, rumen liquor was taken just before feeding in the morning at 8.45 and at one hourly intervals until 16:45 hrs.

8.5.2. Determination of pH

The pH was measured on freshly taken rumen liquor using Cranwell pH Meter UK (Cranwell, Brentwood, Essex, CM14 4XT, UK). The meter was calibrated using standard buffer solution of pH 7.0 at 25°C.

Plate 9 Apparatus used to collect rumen liquor

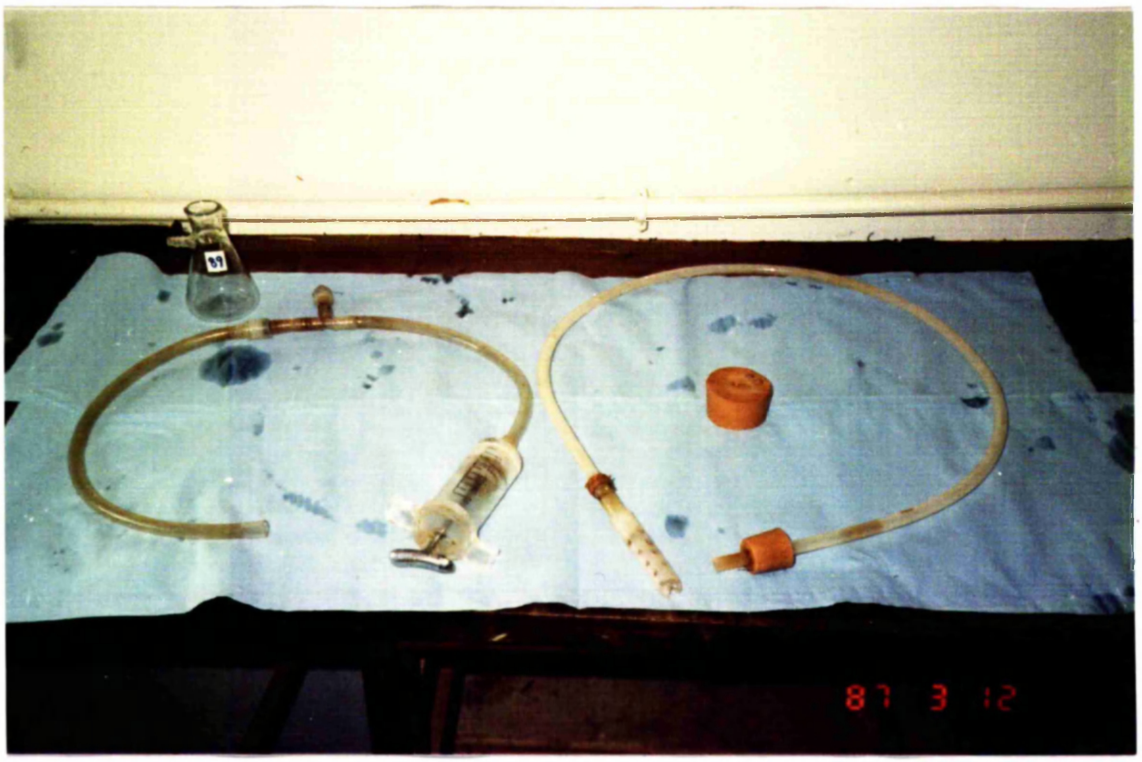


Plate 9A Apparatus used to collect rumen liquor

8.5.3. VFA analysis

The sample of rumen liquor for each sheep at each recording time was analysed in duplicate. 8cm^3 of rumen liquor was placed in a test tube using a wide mouthed 10cm^3 graduated pipette, and 2 ml of preservative (25% w/v metaphosphoric acid) was added, and the sample was well mixed. The samples were then centrifuged at 4^{o}C and 3000 rpm for 10 minutes. 2cm^3 of 0.02 n-hexanoic acid was then added to 3 cm^3 of supernatant and mixed well, and spun for 15 minutes at 4^{0}C and 2000 rpm in Amicon cones. 2-3 cm^3 of filtrate was removed and frozen until analysed by GLC.

8.5.4. Gas Liquid Chromatography (GLC)

The sample (1μL) was injected into a glass column (2m x 2mm) packed with Chromasorb W-AW (mesh 100-120)* containing 10% SP1200 + 1% H_3PO_4. Chromatography was carried out isothermally at 125^{o}C using N_2 carrier gas at a flowrate of ~~40~~ 20ml/min. An electronic integator was used to quantify peak areas and results were calculated by reference to an internal standard (~~hexanoic acid~~).

*Supelco Inc., Supelco park, Bellefonte, PA. 16823-0048.

8.6. Feed intake and refusals

The sheep readily accepted all the diets and no refusals were recorded.

8.7. Experiment B

8.7.1. Materials and Methods

8.7.1.1. Animals

Three mature Suffolk-cross wether sheep were used. All had been fitted with rumen cannulae and weighed on average about 80 kg.

8.7.1.2. Feeding

The sheep were penned and fed individually. The diets was offered about 900 g DM of hay + 200 g DM of compound feed (BOCM Ewebol pencils) with the following composition (g kg^{-1} FW); oil 4.5; fibre 9.5; protein 160; ash 100; DM 870 g kg^{-1}). The composition of the hay was the same as for Experiment A (Table 46). Fresh drinking water was provided *ad libitum* throughout the duration of trial.

8.7.1.3. Preparation of samples

Fodder beet was chopped to small pieces (approximately 3mm cubes) using a knife and were then mixed well to avoid variation in composition. Hay was chopped and sieved as described in Section 8.4.2. Rolled barley and flaked maize and the molassed sugar beet shreds were crushed using a mortar and pestle and mixed well before use.

8.7.1.4. Preparation of bags

The method was as described in Section 8.4.1.

8.7.1.5. Incubation bags in the rumen

Four incubation times were used 3, 5, 8 and 16 hours. The bags were incubated in groups of four in the rumen (Plate 8) using the method described in Section 8.4.3.

8.7.1.6. Washing

The procedures for washing and dry matter were the same as in Experiment A sections 8.3.1.5 and 8.4.5. The procedure for determination of organic matter was the same as Experiment 4 Section 7.3.

8.8. Statistical analysis

The EDEX statistical package (Hunter and Mann, 1979) was used for both Experiments A and B.

8.9. Results

8.10. Experiment A

8.10.1. Hay dry matter disappearance from nylon bags

Highly significant effects ($P<0.001$) due to sheep, diet and time were observed. No significant period effect was observed. Sheep No. 90 had the lowest mean dry matter disappearance % (43.81) and sheep 89 and 83 the highest values (47.95 and 48.60) respectively.

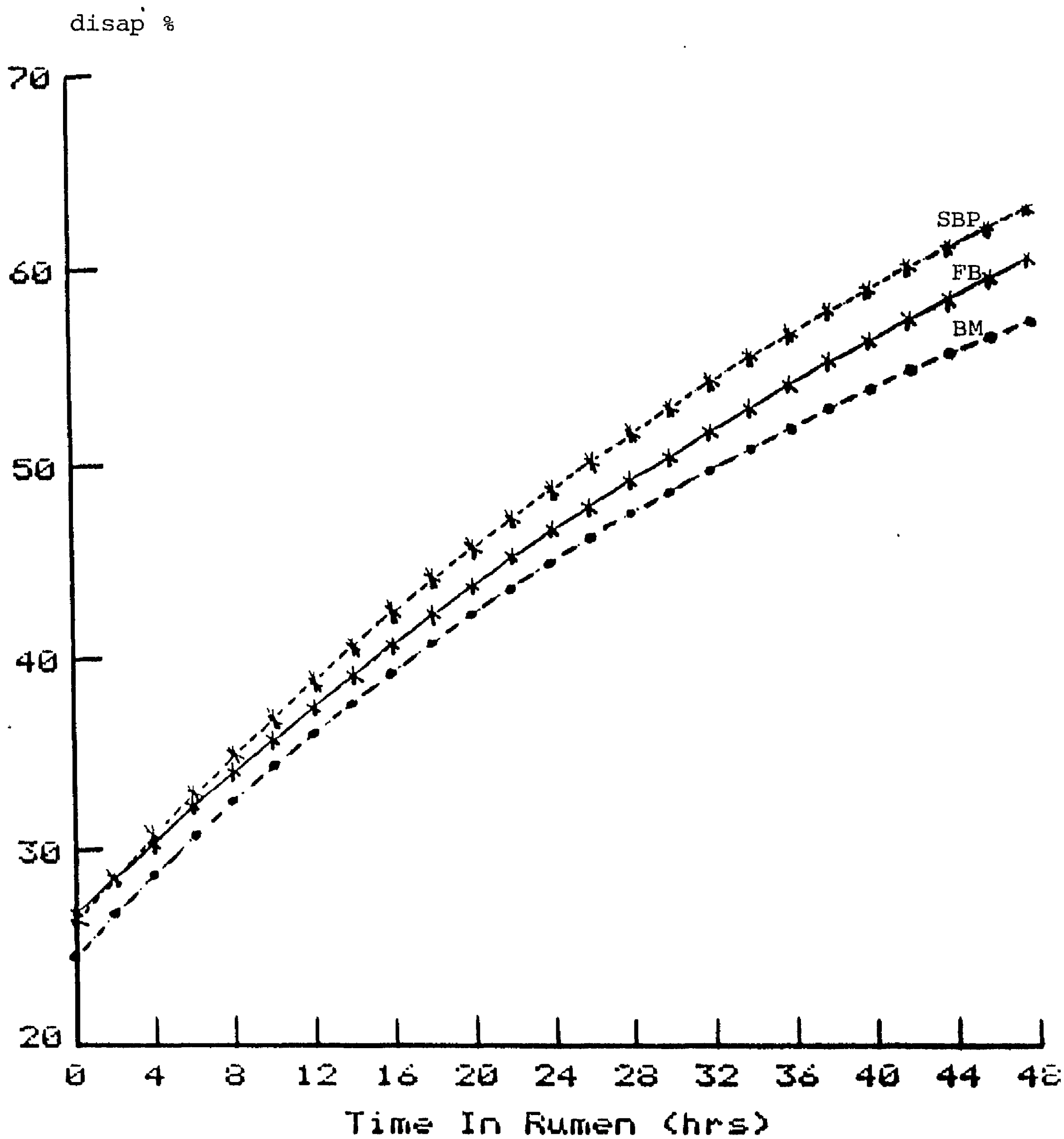
There were highlysignificant increases in hay dry matter disappearance associated with increasing time of incubation in the rumen. The mean hay dry matter disappearance % at 0, 8, 24 and 48 hours were 26.04, 32.91, 46.71 and 60.74 respectively Figure 20. There were also highly significant differences in hay disappearance due to diets FB, SBP and BM Table 50 and Figure 20. The mean hay dry matter disappearance was significantly higher for diet SBP (48.6) than for diet BM (44.7). For diet FB an intermediate value was recorded (47.1). There was a significant interaction ($P<0.05$) between the time and three different diets (FB, SBP and BM) for dry matter disappearance % from nylon bags as presented in Table 50. There were no significant interactions ($P<0.05$) between sheep/diet, period/diet and week/diet.

8.10.2. Rumen pH

The effect of feeding three different diets (FB, SBP and BM) on rumen pH at different times from 08:45 until 16:45 are presented in Figure 21 and Appendix 14.

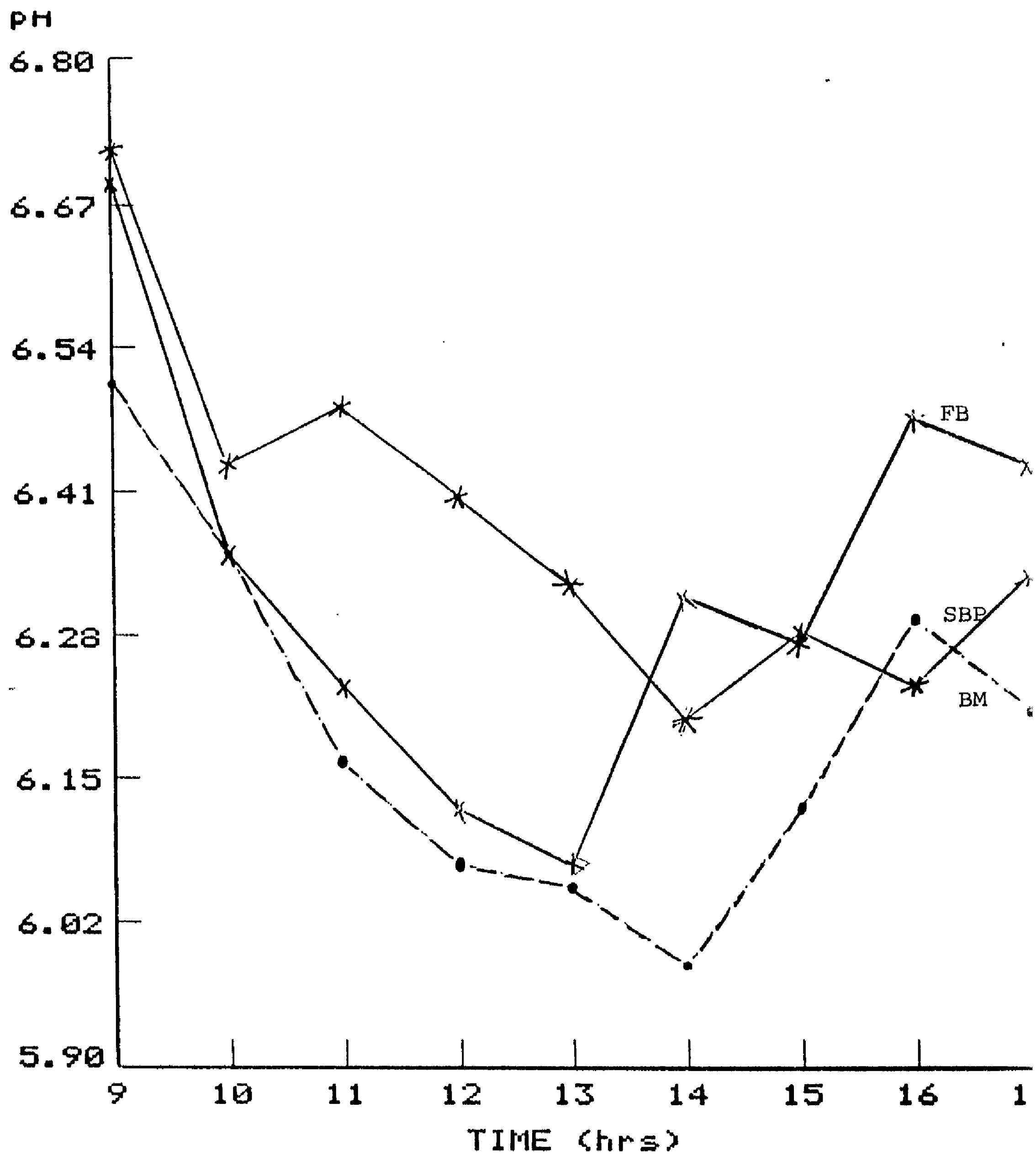
The lowest rumen pH occured for diet BM (5.99) five hours after feeding. For diet FB the lowest rumen pH recorded was 6.21 also five hours after feeding. However, the lowest value for diet SBP was 6.08 recorded four hours after feeding. There was a highly significant effect ($P<0.001$) on rumen pH due to diet. The mean rumen pH was lowest for diet BM (6.20) and the highest for diet SBP (6.38).

Figure 20 Hay DM Disappearance from nylon bags



The disappearance of dry matter of hay from nylon bags incubated in the rumen for three different diets fed to sheep, 1) *---*-- SBP; (2) *____*____ FB; (3) .-.-. BM

Figure 21   Diurnal pattern of rumen pH



Average rumen fluid pH as influenced by time and type of supplements, (1) x——x FB (2) *——* SBP; (3) ·----· BM

Table 50 Hay dry matter disappearance (%) from nylon bags incubated in the rumen of sheep fed on 3 different diets.

Incubation time in rumen (hrs)	Diet FB	SBP	BM	SED
8	33.00^{a}	33.45^{a}	33.27^{a}	1.196
24	46.65^{ab}	48.81^{b}	44.68^{a}	1.196*
48	61.52^{ab}	63.58^{b}	60.78^{a}	1.196*
Mean	47.1^{b}	48.6^{c}	44.7^{a}	0.69***

Fodder beet gave an intermediate mean rumen pH (6.34) which was not significantly different from that for diet SBP. There was no significant interaction (P>0.05) between time/ and diet on rumen pH. (Appendix 14)

8.10.3. Volatile fatty acid concentration

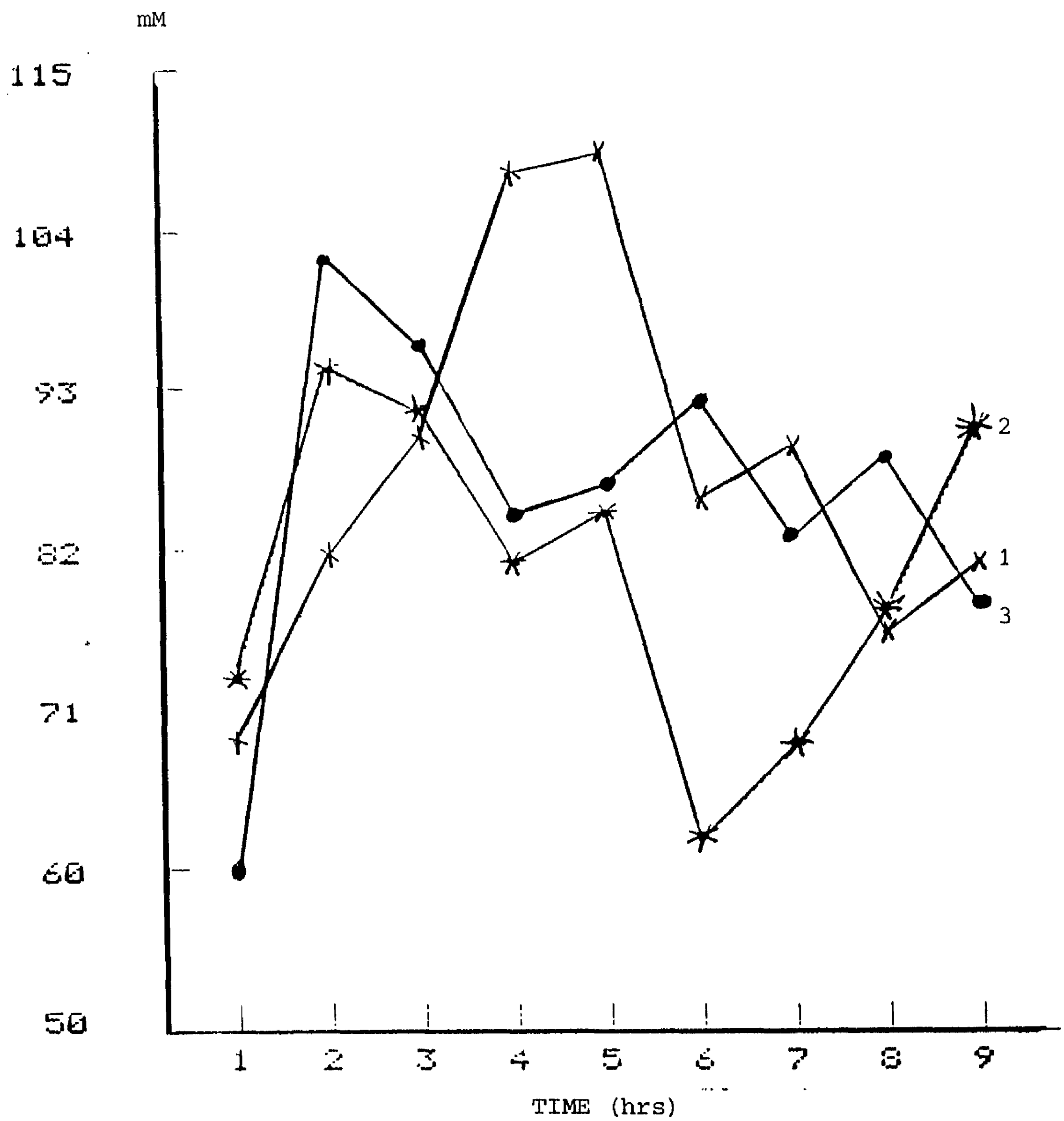
The effect of diets and sampling time on total fatty acid concentration (TVFA mM) and percentages of molar acetic acid (AC%), propionic acid (P %) and butyric acid (Bu%) are presented in Figure 22, 23, 24 and 25 and Table 51. Mean TVFA was not significantly affected by diet but there were differences in the diurnal pattern of concentration. Peak TVFA occured only one hour after feeding for diets DM and SBP. For diet FB TVFA increased more slowly following feeding to give a peak between three and four hours. The mean was significantly (P<0.001) higher for (AC%) diet SBP than for diet (BM). The value for diet FB being intermediate, (Table 51).

The values for PR% were the opposite of those for AC%, pr% was highly significantly affected by diet, the values for pr% were lowest with feeding SBP and highest with BM. For diet FB an intermediate value was recorded. No significant effect due to diet was observed for the mean Bu%, values were very variable different samples taken at different times.

Table 51 The mean TVFA (mM), acetic acid %, propionic acid % and butyric acid % produced in the rumen with the feeding of FB, SBP and BM.

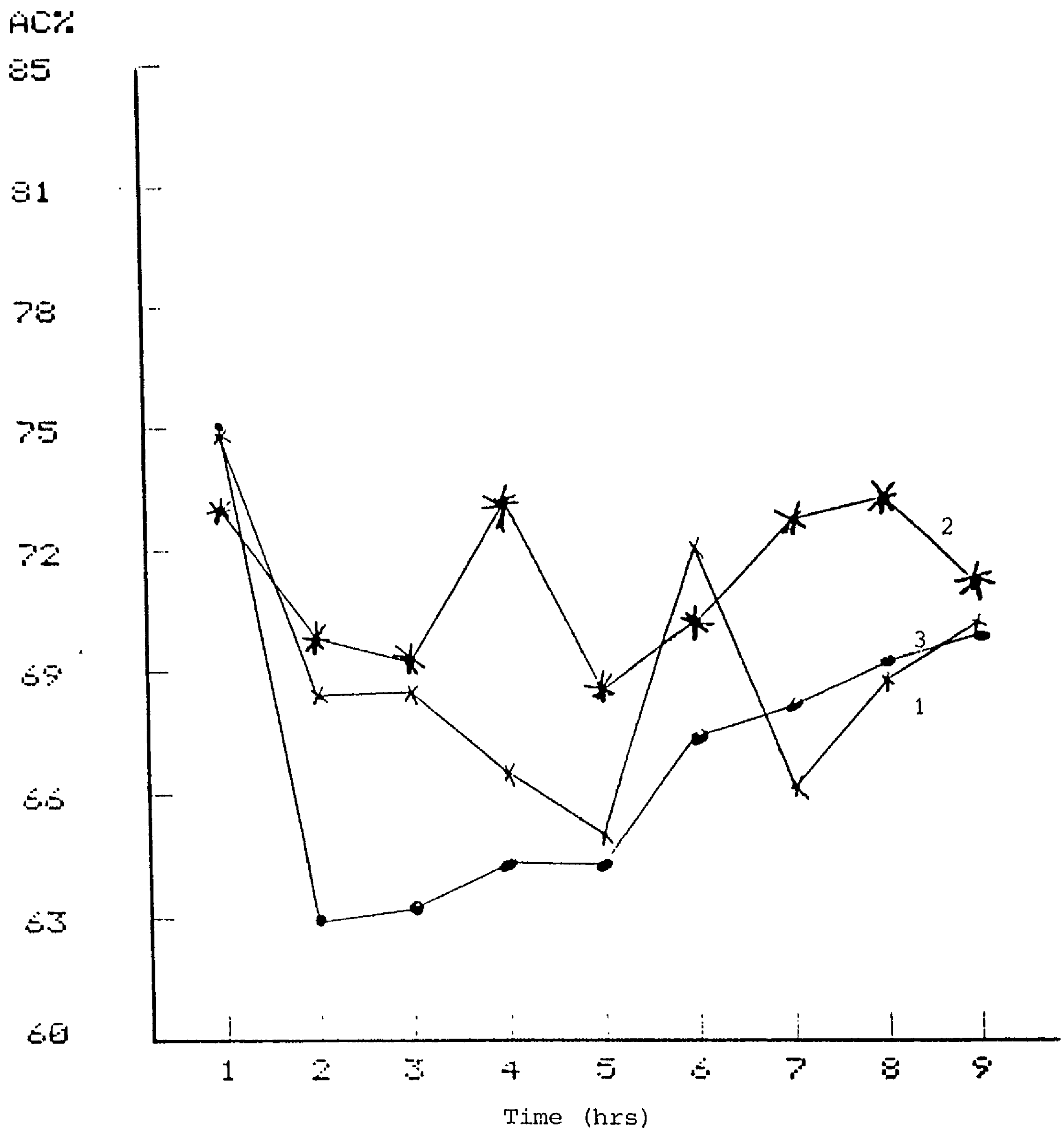
	Diet			
	FB	SBP	BM	SED
Volatile fatty acid (mM)	88.00	80.78	85.96	3.798 NS
Acetic acid (%)	69.29[a]	71.69[b]	69.46[a]	0.828***
Propionic acid (%)	20.64[b]	18.80[a]	22.21[c]	0.436**
Butyric acid (%)	10.07	9.50	10.32	0.762 NS

Figure 22 TVFA concentrations in the rumen



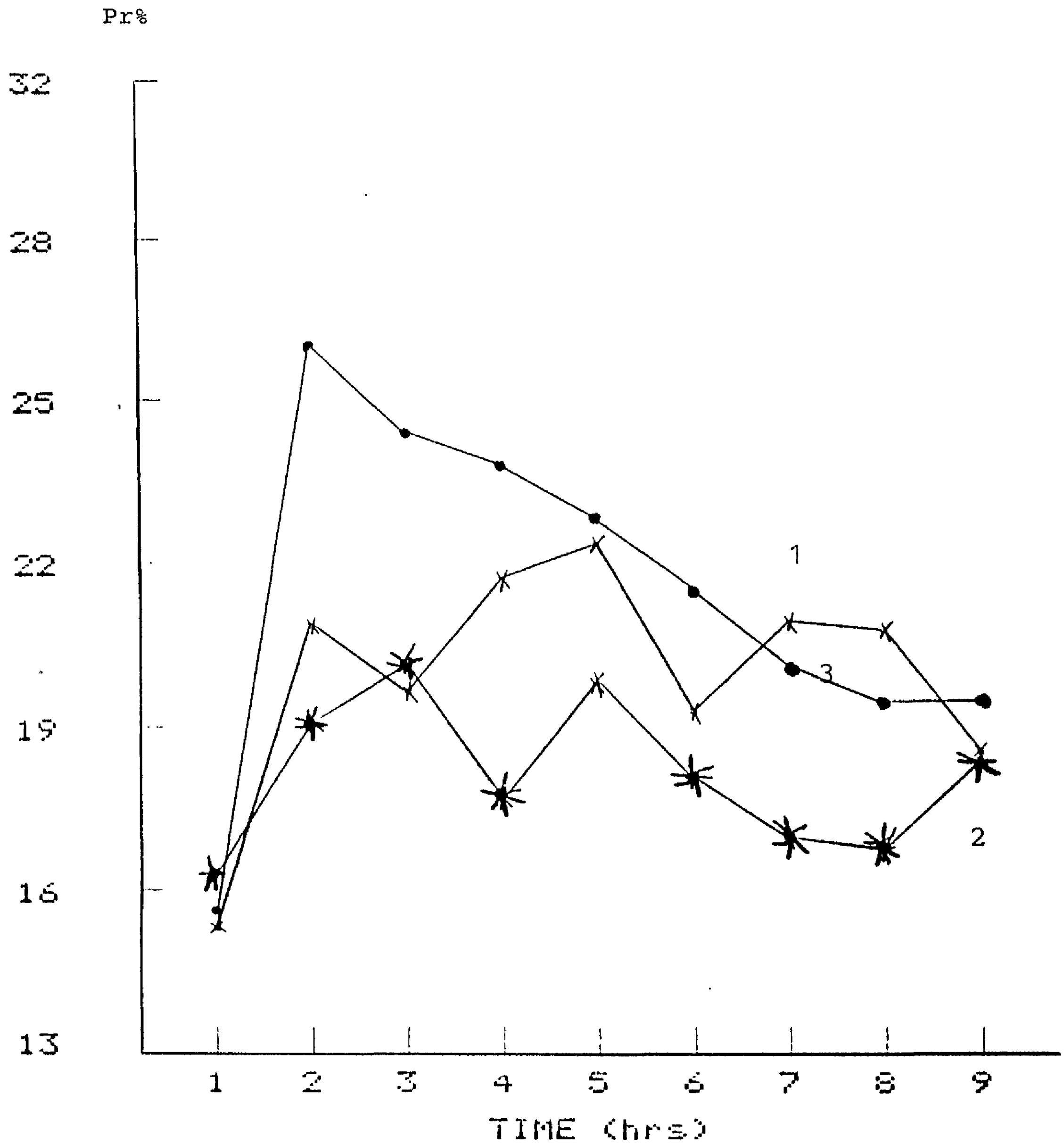
Total volatile fatty acids (TVFA) produced in the rumen as influenced by time and type of supplement, (1) x——x FB; (2) SBP *——* ; (3) .——. BM.

Figure 23 Acetic acid % in the rumen



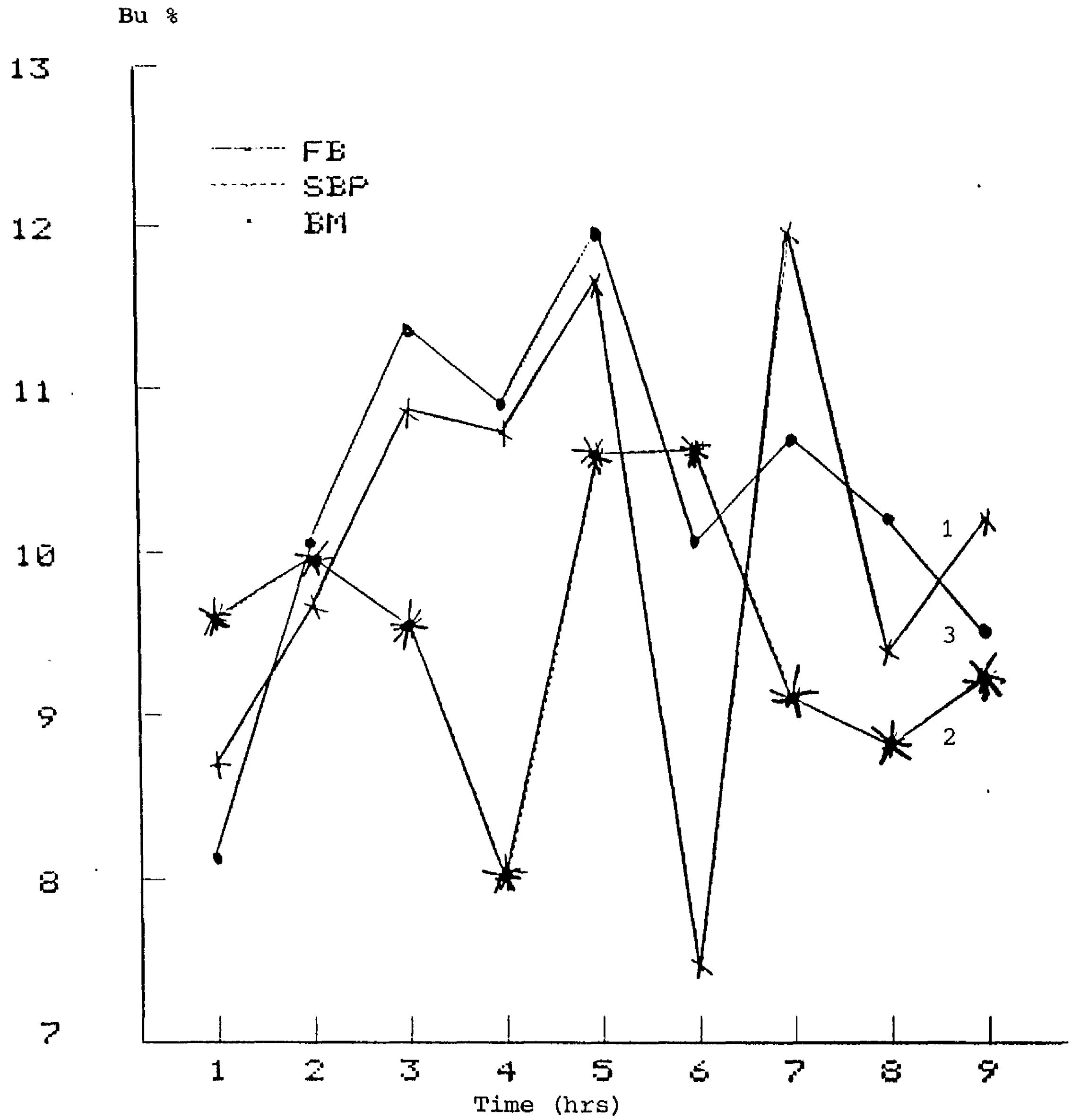
Proportion of acetic acid of TVFA produced in the rumen as influenced by time and type of supplement (1) x——x FB; (2) *——* SBP; (3) .——. BM.

Figure 24 Propionic acid % in the rumen as % of total VFA in the rumen



Propionic acid % produced in the rumen as influenced by the different time and different supplement, (1) x——x FB; (2) *——* SBP; (3) .——. BM.

Figure 25 Butyric acid % produced in the rumen



Butyric acid % produced in the rumen as influenced by the different time and different supplement, (1) x——x FB; (2) *——* SBP; (3) .——. BM.

There was significant interaction (P<0.01) observed between diet and time on propionic acid % . in the rumen (Appendix 15). Reference (Figure 24) shows that for diet BM there was a bigger increase in pr% following feeding than was found for the other diets. Although not significant the converse was found for AC% with diet BM resulting in the greatest decrease. There were no significant interactions (P>0.05) observed between diet and time on TVFA, AC% and BU%. (Appendix 16, 17 and 18)

8.11 Results of Experiment B

8.11.1. Organic matter disappearance

There were highly significant (P<0.001) differences in both rate and extent of organic matter disappearance between fodder beet, sugar beet shreds, barley/maize and hay when incubated in the sheeps rumen (figure 26).

The mean organic matter disappearance of fodder beet for (3, 5, 8 and 16 hours) was higher (79.3%) compared with that for hay (28.1%). Sugar beet shreds and barley maize were intermediate between fodder beet and hay (44.5% and 70.0% respectively). There was a significant interaction (P<0.01) between feed and incubation time.

After 3 hours incubation in rumen the organic matter disappearance from fodder beet was 76.7% compared with the value of 23.6, 37.8 and 60.8% for hay, sugar beet shreds and barley maize respectively. After 16 hours the organic matter disappearance of fodder beet increased to 83.1% and this was higher than the value for sugar beet shreds, barley maize or hay (Tables 52 and Figure 26).

8.12. Discussion

In this study the nylon bag methods described by Ørskov and Mehrez (1977) was used to estimate the rate of dry matter disappearance of hay in the rumen when the sheep were fed three different rations (FB, SBP and BM) (Experiment A). The technique was also used to estimate the organic matter disappearance of fodder beet, molassed sugar beet shreds, barley/maize and hay for sheep fed the same standard diet (Experiment B).

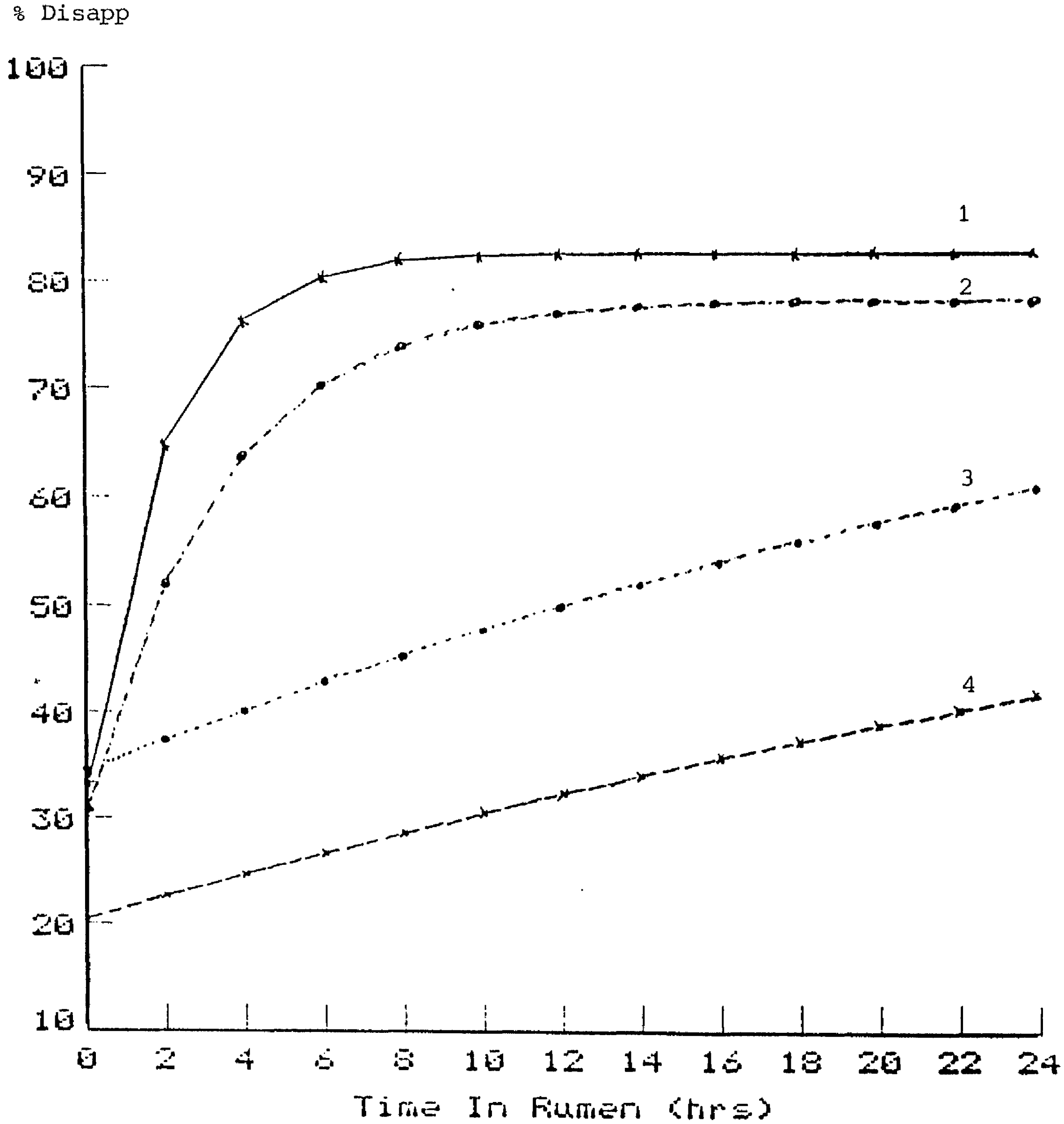
Three sheep were used to estimate the dry matter and organic matter disappearances from nylon bags,Mehrez and Ørskov (1977) considered this the minimum number acceptable to obtain repeatable results. The aim of feeding energy rich feed such as fodder beet is either to increase total metabolisable energy intake or to replace forage or concentrate in the diet whilst maintaining ME intake. A problem with the feeding of very rapidly digested materials is that microbial activity in the rumen may be inhibited as rumen pH falls due toarapid VFA production.

Table 52 Organic matter disappearance from different feeds at different times

Time	Fodder beet	Sugar beet shreds	Barley/ Maize	Hay	SED
3	76.7 [d]	37.8 [b]	60.8 [c]	23.6 [a]	2.08**
5	77.8 [d]	40.5 [b]	64.5 [c]	24.1 [a]	2.08**
8	79.5 [c]	45.8 [b]	76.2 [c]	27.9 [a]	2.08**
16	83.1 [d]	54.1 [b]	78.6 [c]	36.7 [a]	2.08**
Mean	79.3 [d]	44.5 [b]	70.0 [c]	28.1 [a]	1.04***

*means in each line not sharing a common subscript different significantly ($P<0.01$)

Figure 26 OM Disappearance from nylon bags



The organic matter % disappearance of (1) Fodder beet; (2) Barley/Maize; (3) Molassed sugar beet shreds; (4) Hay from nylon bags incubated in the rumen of sheep.

Chimwano *et al* (1976) found that supplementation with readily fermented source of energy such as barley or molasses inhibited rumen cellulolysis and dry matter. Mould and Ørskov (1983) reported the reduction of rumen pH (to 6.0-6.1) in sheep given roughage led to the inhibition of cellulolysis and partial destruction of the rumen micro flora.

An additional danger of feeding very rapidily fermented supplements is that the rumen environment may be so disturbed that forage intake may be reduced. The overall consequence of reduced forage intake and digestibility may be that total metabolisable energy intake is reduced or only slightly increased even though expensive concentrate have been included in the diet. Thus it is important to characterise an energy feedstuff in terms of the effect that it has on rumen digestion. The high water soluble carbohydrate content of fodder beet suggests that it could have a harmful effect on the rumen.

This experiment aimed to examine the effects of fodder by measuring rumen pH and rate of hay digestion in sheep, sheep fed 50% fodder beet + 50% hay were compared with two control diets which contained 50% barley/maize + 50% hay and 50% molassed sugar beet shreds + 50% hay. There were no significatn effect observed between the 3 diets (FB, SBP and BM) after eight hours incubation on hay dry matter disappearance from nylon bags, but there were significant effectsbetween 3 diets after 24 hours on hay dry matter disappearance.

The mean dry matter disappearance of hay from nylon bags was 47.1% when sheep were fed FB which was less than values of 48.5% when the sheep were fed SBP, but was higher than the value of 44.7% for diet BM. These differences may be due to the different sources of carboyhdrate in the three supplements. In fodder beet the main source of carbohydrate is sugar but with the BM the main source is starch. For molassed sugar beet shreds approximately 20% of the dry matter is sugar but in addition there is a high content of digestible fibre.

The mean rumen pH was intermediate when fodder beet was fed (6.34) compared with SBP (6.38) and for diet BM (6.20). Furthermore diet BM caused the greatest depression in rumen pH following feeding. For samples taken 5 hours after feeds, the rumen pH values for diets BM, SBP and FB were 5.99, 6.21 and 6.32 respectively. This large pH reduction for diet BM would be expected to inhibit cellulose digestion and explain the observed effects on _in sacco_ digestion.

Terry _et al_ (1969) demonstrated that cellulolysis was markedly reduced below pH 6.0, while Halliwell (1957) found that cellulose powder was not degraded by rumen micro-organisms at pH 5.9 and Stewart (1977) demonstrated that titre of bacteria degrading filter paper was reduced on lowering the pH of rumen contents, being 10^6 micro-organisms/ML at pH 6.9, but only 10^3/ML after incubation at pH 6.0. The effect of supplement on rumen VFA pattern observed in this trial supports the view that diet BM caused the greatest disturbance to rumen fermentation. Propionate molar percentage were significantly higher for diet BM than for the other two diets. Again diet FB showed an intermediate response between diets B/M and SBP. A study by Ørskov et al (1969) with roots found that when only roots (swedes) and protein supplement were given there was an increase in the butyric acid proportion and a decrease in the acetic acid proportion. Izumi (1976) reported that when feeding 4 levels of fodder beet (0, 15, 30 and 45 kg FW d^{-1}) with hay to dairy cattle the total VFA increased linearly as levels of fodder beet intake increased and the acetic acid decreased as levels of fodder beet intake increased, however, the percentage of butyric acid was increased with levels of fodder beet.

Thus in term of disturbance to the rumen microflora the 3 supplements can be ranked as follows:

greatest

barley/maize
fodder beet
molassed sugar beet shreds

least

It is important to relate the effect of the 3 supplements on the rumen environment to their rates of digestion measured *in sacco* in sheep fed a standard diet (Experiment B).

8.12.1. Organic matter disappearance (Experiment B)

In this experiment the mean organic matter disappearance of fodder beet from nylon bags was 79.3% which was higher than values of 28.0%, 44.5% or 70.0% for hay, molassed sugar beet shreds or barley/maize respectively.

The zero time disappearance of OM (ie bags washed but not incubated in the rumen) was similar for fodder beet, barley maize and molassed sugar beet shreds. However, fodder beet and barley/maize OM disappeared at a much greater rate than the OM of sugar beet shreds (Figure 26). Most of the molasses in the beet shreds would be expected to disappear from the bag during the zero time washing. The rapid disappearance rate for fodder beet and barley/maize reflect the high rates of sugar and starch fermentation compared to the much lower rate of fibre digestion in the beet shreds.

On the basis of their rate of in sacco digestion fodder beet and barley/maize would be expected to disturb rumen microbial digestion to a greater extent than sugar beet. The results for rumen pH, VFA and in sacco hay digestion when the supplements were fed in Experiment A support this view. However, the initial rate of fermentation of fodder beet (Experiment B) was significant greater than for barley/maize, yet fodder beet, when fed caused less rumen disturbance than barley/maize. This discrepancy is probably due to the rate at which the two supplements were eaten by the sheep, fodder beet is extremely bulky and was eaten over a period of several hours. The barley/maize mixture however was eaten within 30 minutes of feeding. Thus the rate of VFA production in the rumen would be expected to be lower for fodder beet than barley/maize even though theinherent rate of fermentation of fodder beet OM is greater.

The change in rumen pH following feeds support this view although no significant differences in total VFA concentration were recorded. The observation that fodder beet is very rapidly fermented in the rumen has important implications for the choice of feeding systems.

The dairy cows consumed fodder beet much more rapidly than the sheep. Up to 3 kg of fodder beet DM was eaten within 45 minutes. Thus the conclusion with regard to the effect on the rumen environment observed in the sheep trials may not apply to cattle.

It may be beneficial to feed fodder beet to cattle as though it were a concentrate. At high levels of feeding frequent small meals should be proved rather than a simple large meal (eg in a complete diet). Also attention should be given to the method of processing prior to feeding. Whole fodder beet are eaten more slowly than chopped and/ this may then reduce rumen disturbance.

8.13. Summary

Two experiments were carried out with sheep, to characterise fodder beet in terms of effects on rumen function.

In Experiment A, a study was made of the effects of feeding fodder beet on rumen pH and VFA concentration compared with two control diets barley/maize (BM) and molassed sugar beet shreds (SBP). Hay was fed with all three supplements in a 50:50 ratio (DM basis). Three wether sheep were used, each fitted with a permanent rumen cannula.

The nylon bag technique was used to measure the effect of feeding the 3 different diets (FB, SBP and BM) on hay dry matter disappearance (Experiment A). In Experiment B the rate of *in sacco* OM disappearance of the 3 supplements were compared in sheep fed a concentrate high forage diet (900 g DM hay + 200 g DM compound feed (BOCM Ewebol pencils).

The mean rumen pH for the fodder beet diet was 6.34 intermediate between two controls (BM 6.20 and SBP 6.38). There was no significant different observed in TVFA for the 3 different diets (FB, SBP and BM) but there were highly significant ($P<0.001$) effects due to diet for Acetic and propionic acid molar percentages. Molar % of propionic acid for diets FB, SBP and BM were 20.64, 18.80 and 22.21 respectively.

The mean hay dry matter disappearance from nylon bags was 44.7%, 47.1% and 48.6% for diets BM, FB and SBP respectively.

In Experiment B there were highly significant ($P<0.001$) differences between the _in sacco_ OM disappearances of the feedstuffs. The initial rate % OM disappreance was 79.3 greater for fodder beet followed by barley/maize, molassed sugar beet shreds and hay 70.0, 44.5 and 28.1 respectively.

CHAPTER 9

GENERAL DISCUSSION

9.1. Growing fodder beet

The future for the growing of fodder beet on farms in Great Britain will depend on the ability of farmers to control the weeds in the crop and the reliability of the crop in terms of high yields of DM/ha. The use of slurry as the only fertiliser (Heppel, 1985) has advantages in terms of cost and being able to spread slurry during wet weather in the winter. However, there may be environmental pressures to limit the use of large amounts of slurry because of nutrient losses and subsequent pollution.

The harvest date needs careful consideration, for although the yield increases up to November (Taunton, 1985, Evans, 1986) there is a greater risk of wet weather at harvesting and soil contamination. Within the whole farm context, the harvesting date has to be evaluated in terms of the next crop as well as the fodder beet. On an arable system, the fodder beet could be harvested in early October and be followed by a winter wheat crop. Whilst on an all grass farm, the fodder beet would have to be followed by a spring reseed.

9.2. Chemical composition of fodder beet

The results of both the *in vitro* and *in vivo* estimates of ME content in these experiments are similar with a mean value of 13.1 MJ/kg DM. The growth rates from a recent experiment with young stock(Roberts and Bax, 1986) are consistent with an ME value for fodder beet of 13.4 MJ/kg DM. The discrepancy between these values and those of MAFF (1985a) may be due to differences in the ME calculation equation or seasonal differences the energy value of fodder beet needs further investigation.

There is general agreement between the results from this work and other reports on the protein content of fodder beet. At such a low value (50 g/kg DM) the inclusion of fodder beet at high levels in a ration may lead to a shortage of protein unless other high protein supplements are fed.

9.3. Feed intake and rumen digestion

In all three dairy cow experiments the feeding of fodder beet decreased silage DM intake but increased total DM intake (Table 53).

The increase in total intake and decrease in silage intake may be due to the palatability of the fodder beet, but it also indicates that beet is similar to concentrate in its effect on feed intake. The substitution rates (Table 54) in these experiments are similar to those reported for fodder beet by Brabander *et al*, (1974, 1981)and Roberts,(1985)and are similar to the substitution rates commonly found with concentrates (Taylor, 1983).

Table 53 Silage DM intake (kg/day)

		Level of fodder beet (kg DM/d)			
		0	2	4	6
Experiment 1	LC	9.09	7.89	7.83	
	HC	7.94	7.74	7.78	-
Experiment 2	LC	8.90	7.78	7.70	7.25
Experiment 3	LP	8.22	-	6.26	-
	HP	8.83	-	6.77	-

Total DM intake (kg/day)

		Level of fodder beet (kg DM/d)			
		0	2	4	6
Experiment 1	LC	13.00	13.78	15.60	-
	HC	16.23	16.65	18.29	-
Experiment 2		12.86	13.7	15.5	16.9
Experiment 3	LP	12.18	-	13.57	-
	HP	12.70	-	14.10	-

LC - low concentrate
HC - high concentrate
LP - low protein
HP - high protein

Table 54 Substitution rate

		Level of fodder beet (kg DM)		
		0 to 2	0 to 4	0 to 6
Experiment 1	LC	0.62	0.33	-
	HC	0.68	0.40	-
Experiment 2	LC	0.58	0.31	0.29
Experiment 3	LP	-	0.51	-
	HP	-	0.59	-

Experiment 5 showed that fodder beet organic matter is very rapidly digested in the rumen which can be expected from the low fibre content but high content (65%) of water soluble carbohydrates. Thus it is not surprising that the substitution rates observed in the dairy cow trials indicate that fodder beet behaves as a concentrate. However, Experiment 5 also showed that when fodder beet is fed to sheep the degree of rumen disturbance (as measured by rumen pH, VFA concentration and *in sacco* hay disappearance) is less than that found, when supplement barley/flaked maize was fed. However, fodder beet did have a greater effect on rumen fermentation than molassed sugar beet shreds.

An additional factor is the rate at which the fodder beet is eaten. The sheep consumed the beets over a number of hours which would be expected to slow down the rate of VFA production in the rumen. However, the cows consumed the fodder beet more quickly than sheep. The digestion characteristic of fodder beet suggests that rumen disturbance with reduced forage digestion and intake, could be possible if higher levels of fodder beet were fed to cows than used in the present trial. It may well be necessary if higher levels are to be fed, to take steps to ensure that the fodder beet is eaten slowly. The beets could be offered in a number of small meals during the day as in a complete mix for example. Also attention should be given to the effects of processing fodder beet (chopped or fed whole) on the rate of consumption.

At the levels used in this work, fodder beet does not have the same limitation on bulk intake as has been reported for silage (Lewis, 1981). It behaved as a bulky concentrate feed. The results from Experiment 2, where the cows readily ate 6 kg DM fodder beet (36 kg fresh weight/day) would support the concept that beet is an easily digested feed.

9.4. Animal Performance

The effects of supplementary feeding fodder beet with silage fed *ad libitum* on dairy cow performance are to increase milk yield and with a tendency to improve milk quality. The results from the dairy cow experiments reported here do not all show a significant improvement in fat and protein content. The improvement in milk yield and protein content can be explained by the increased energy intake.

The investigation into the effect of different protein levels (Experiment 3) was conducted with late lactation cows. Whereas Experiment 1 and the work of Roberts (1985) was with early lactation cows. The effect of feeding supplementary protein may be different for cows at different stages of lactation. The protein intakes at the high level of supplementation in Experiment 3 were 1535 and 1975 g d^{-1} for low and high level protein compared to 2220 and 2820 g d^{-1} for low and high level concentrate in Experiment 1. Roberts (1985) had protein intakes of up to 3238 g d^{-1} which was higher than the levels in either Experiment 1 or 3.

9.5. Experimental Technique

Changeover design experiments are useful for evaluating different feeds as in the expriments reported here. However, the long term effects of the rations over a winter feeding period are of more importance in a farming system. Experiment 1 is a good illustration as the silage only diets caused high liveweight losses and over a winter feeding period of 200 days these may have had serious effects on cow performance and fertility.

Liveweight change	A	B	C	D	E	F
9 weights/period	+0.20	+0.47	+0.35	+0.69	+0.26	+0.75
6 weights/period	-0.69	+0.42	+1.01	+0.12	+0.22	+1.62
Estimated	-0.30	+0.32	+0.76	+0.56	+1.02	+1.51

The use of cyclic changeover designs in Experiments 1 and 3 allows a greater number of diets to be evaluated, compared to conventional latin square designs. It is important in cyclic changeover designs to ensure that the cows within replicates are as similar as possible. The estimation of weight change in cyclic changeover experiments is subject to large errors because of the length of the periods are not long enough for a steady state to be achieved.

The estimation of liveweight change by regression using 3 liveweight measurements per week has to be questioned. The comparison of the estimated liveweight change in Experiment 1 showed that the use of measurments in the last 2 weeks may be more satisfactory. However, it is difficult to estimate which method is the most accurate, the use of the ME balance equation also has errors associated with it (Alderman et al, 1982).

9.6. Future Work

There has been very little work on the feeding of fodder beet to dairy cows under British conditions since the research of Castle et al in the 1950's. The experiments reported here confirm the effects of fodder beet on feed intake and animal performance. Other areas of research which should be considered include:

a) a direct estimate of the ME content of fodder beet using dairy cattle.

b) a study of the effects of feeding different levels of fodder beet to cattle on rumen function.

c) further work with fodder beet fed with different types of forage, eg straw.

d) the effect of soil contamination and chopping on feed intake and rate of consumption.

e) the maximum amount which can safely be fed to dairy cows and methods of limiting adverse effects on rumen metabolism.

f) the importance of protein level and type in the ration, especially with early lactation cows.

g) Long term lactation trials with dairy cows to study the effects of fodder beet supplementation on lactation performance and weight change.

APPENDIX I

Experiment 1, Week 1 changeover diets (kg fresh wieght)

		Concentrates	Fodder Beet		
Decreasing	Increasing	4 - 8	0 - 2	0 - 4	2- 4
Day 0	7	9.3	12.0	24.0	24.0
1	6	8.7	10.2	21.0	22.2
2	5	8.1	9.0	17.4	21.0
3	4	7.5	7.2	13.8	19.2
4	3	6.7	5.4	10.2	17.4
5	2	6.0	3.6	7.2	15.6
6	1	5.3	1.8	3.6	13.8
7	0	4.6	0.0	0.0	12.0

APPENDIX 2

Estimated ME concentration in the silage, fodder beet and concentrate using the following equations (M McGowan, personal communication):

Silage ME = (IVD x 0.907 +6.03) x 0.16

Fodder beet and concentrate ME = IVD x 0.16

where IVD = *in vitro* digestible organic matter in the dry matter g/kg.

ME = metabolizable energy (MJ kg/DM).

APPENDIX 3

Estimated ME requirements for maintenance, milk production and liveweight change using the following equations (MAFF 1975):

Maintenance $Mm = 7.9 + 0.086W$

Milk production $EV_1 = 0.0623\ BF + 0.0331\ SNF - 0.381$

BF and SNF in g kg^{-1}

$M_1 = EVI \times Y$

SNF = protein + lactose + ash (7.5)

Liveweight change

1. Mg = 26.5 MJ/kg loss
2. Mg = 32.3 MJ/kg gain

Mm = ME required for maintenance (MJ/day)

W = Liveweight (kg)

EV_1 = Energy value of milk (MJ/kg)

BF = Butter fat content (g/kg)

SNF = Solids-not-fat content of milk (g/kg)

M_1 = ME required for milk production (MJ/day)

Y = Milk yield (kg/day)

Mg = ME required for body gain or loss (MJ/day)

APPENDIX 4

Examples of statistical analyses

Mean 891.6

Min 633.4

Max 1170.4

Analysis of variance table

Source of variation	DF	SS	MS	F	Prob
F = groups	1	18902.972	18902.972	3.051	
S = cows	10(1)	399477.568	39947.756	6.447	***
P = period	3	23645.854	7881.951	1.272	
R = treatment	5(1)	12485.938	2497.187	0.403	
C = concent	1	136369.120	136369.120	22.009	***
B = fodder beet	2	19370.828	9685.415	1.563	
CB = concen + beet	2	12012.024	6006.012	0.969	
Error	23	142511.296	6196.144		
Total	47	764775.648			

CV = 8.83 per cent

CB Table

C	B 0	B 2	B 4	Mean
4	827.1	792.9	884.5	834.8
8	954.3	936.4	954.3	948.3
Mean	890.7	864.7	919.4	891.6

Appendix 4 cont.

AV SE = 27.83
AV SE = 16.07
AV SE = 19.68

SED = 2 x AV SE

DF = Degrees of Freedom

SS = Sum of squares

MS = mean of square

F = F ratio

Pro = significance

REGRESS 'WT1' 1 'DAYS'

Column	Coefficient	St.Dev of Coef	T-Ratio= Coeff/S.D
	505.8232	9.1694	55.16
XI days	505.5918	9.6575	55.90

The ST.Dev of Y about regression is S = 5.637

With (6-2) = 4 degrees of freedom

R - squared = 16.8 percent

R - squared = -3.9 percent, adjusted for DF

Analysis of variance

Due to	DF	SS	MS=SS/DF
Regression	1	25.75	25.75
Residual	4	127.09	31.77
Total	5	152.83	

APPENDIX 5

Experiment 1 - Chemical composition of feeds for periods 1 and 2 ($g\ kg^{-1}$ DM unless otherwise stated).

	Period 1			Period 2		
	Silage	Beet	Conc	Silage	Beet	Conc
Oven DM (g/kg)	175	178	860	181	156	860
Crude protein	143	65	216	147	84	206
Organic matter	908	917	920	917	877	916
DOMD g/kg DM	655	860	736	653	801	840
ME (MJ/kg DM)	10.3	13.8	13.5	10.4	12.8	13.6
NH (g/kg total N)	145	-	-	103	-	-
pH	4.0	-	-	4.0	-	-
Ca	5.7	1.3	7.2	5.4	1.9	9.4
P	2.8	2.0	7.9	3.0	2.4	7.2
Mg	1.8	1.5	6.3	1.9	1.8	6.3

APPENDIX 6

Chemical composition of feeds for periods 3 and 4
(g/kg DM unless otherwise stated)

	Period 3			Period 4		
	Silage	Beet	Conc	Silage	Beet	Conc
Oven dry (g/kg)	189	159	860	208	159	860
CP Protein	140	71	186	140	83	196
OM g/kg	919	920	920	908	923	917
DOMD g/kg DM	667	826	832	655	859	804
ME (MJ kg DM)	10.6	13.2	13.7	10.4	13.7	13.3
NH (g kg total N)	118	-	-	145	-	-
pH	4.2	-	-	4.0	-	-
Ca	5.8	0.9	9.2	5.7	2.4	9.9
p	2.8	2.5	7.5	2.8	2.5	7.1
Mg	1.9	1.4	6.0	1.8	1.6	5.8

APPENDIX 7

Fodder beet refusal for four periods

(kg d FW)

Cow No.	Period 1 Feed	Period 1 Ref	Period 2 Feed	Period 2 Ref	Period 3 Feed	Period 3 Ref	Period 4 Feed	Period 4 Ref
471	0	-	12	-	-	-	24	2.06
473	12	3.77	24	1.01	12	4.98	-	-
801	24	2.73	-	-	24	-	12	-
922	0	-	12	-	-	-	24	0.77
962	12	2.38	24	0.08	12	-	-	-
414	0	-	-	-	12	-	12	0.04
982	24	5.80	-	-	24	1.06	12	-
625	12	0.00	12	0.06	24	0.07	24	0.46
810	24	0.54	24	0.87	-	-	-	-
911	0	-	-	-	12	1.7	12	-
998	12	0.00	12	-	24	0.06	24	-
970	24	0.14	24	-	-	-	-	-

FW - fresh weight

APPENDIX 8

Experiment 2, week 1, changeover diets (kg fresh weight)

Fodder Beet

Day	0 to 6 kg DM	2 to 6 kg DM	4 to 6 kg DM
Friday	5.4 FW	15.6 FW	25.8 FW
Saturday	10.8 FW	19.2 FW	27.6 FW
Sunday	16.2 FW	22.2 FW	29.4 FW
Monday	21.6 FW	25.8 FW	31.2 FW
Tuesday	27.0 FW	29.4 FW	33.0 FW
Wednesday	30.6 FW	33.0 FW	34.2 FW
Thursday	36.0 FW	36.0 FW	36.0 FW

Experiment 2, week 1, changeover diets (kg fresh weight)

Day	6 to 0 kg DM	6 to 2 kg DM	6 to 4 kg DM
Friday	30.6 FW	33.0 FW	34.2 FW
Saturday	27.0 FW	29.4 FW	33.0 FW
Sunday	21.6 FW	25.8 FW	31.2 FW
Monday	16.2 FW	22.2 FW	29.4 FW
Tuesday	10.8 FW	19.2 FW	27.6 FW
Wednesday	5.4 FW	15.6 FW	25.8 FW
Thursday	0.0 FW	12.0 FW	24.0 FW

FW - fresh weight

APPENDIX 9

Mean refusal of fodder beet for four period (kg/d fresh weight)

Cow No.	Period 1 Feed	Period 1 Ref	Period 2 Feed	Period 2 Ref	Period 3 Feed	Period 3 Ref	Period 4 Feed	Period 4 Ref
1	0	-	12	-	24	-	36	-
2	12	-	36	-	0	-	24	-
3	24	0.8	0	-	36	-	12	-
4	36	0.7	24	-	12	-	0	-

Ref - refusal

APPENDIX 10

Changeover design for 16 cows allocated in four treatments

	kg DM/d					
	Period 1		Period 2		Period 3	
Cow No.	F	C	F	C	F	C
832	0	L	4	L	0	H
410	4	L	4	H	0	L
407	0	H	0	L	4	H
890	4	H	0	H	4	L
461	0	L	0	H	4	H
404	4	L	0	L	0	H
737	0	H	4	H	4	L
995	4	H	4	L	0	L
518	0	L	4	H	0	H
873	4	L	0	H	0	L
600	0	H	4	L	4	H
708	4	H	0	L	4	L
849	0	L	4	L	4	H
615	4	L	0	L	0	H
844	0	H	4	H	4	L
646	4	H	0	H	0	L

F - fodder beet

C - concentrate

L - low level protein

H - high level protein

APPENDIX 11

Week 1, Changeover (kg fresh weight)

Day	Fodder beet 0 to 4 kg DM	Fodder beet 4 to 0 kg DM
Friday	4 kg FW	16 kg FW
Saturday	8 kg FW	14 kg FW
Sunday	10 kg FW	12 kg FW
Monday	12 kg FW	10 kg FW
Tuesday	14 kg FW	8 kg FW
Wednesday	16 kg FW	4 kg FW
Thursday	20 kg FW	0 kg FW

FW - fresh weight

APPENDIX 12

Experiment 3

Chemical composition of feeds (g kg^{-1} DM)

Period 1

	Fodder beet	Silage	Concentrate L Protein	H Protein
Oven dry matter (g/kg)	197.7	164.0	848.0	864.0
Crude protein (g/kg DM)	58	140.5	131.5	231.5
Organic matter (g/kg DM)	922.5	902.0	951.0	923.0
IVOMD (g/kg)	911.5	725.0	861.0	888.5
Predicted ME (MJ/kg DM)	13.5	10.4	13.1	13.1
Ammonia N as g/kg of total N	-	94.5	-	-
calcium	0.95	5.05	5.85	9.55
phosphorus	2.3	3.3	5.8	7.5
magnesium	1.7	2.1	3.0	4.5
pH	-	3.9	-	-

Appendix 12 cont.

Period 2

	Fodder beet	Silage	Concentrate L Protein	H Protein
Oven dry matter (g/kg)	230.9	149.6	833.0	840.0
Crude protein (g/kg DM)	53.0	139.0	13.2	239.5
Organic matter (g/kg DM)	891.0	902.6	955.5	931.0
IVOMD (g/kg)	888.0	721.7	854.5	858.0
Predicted ME (MJ/kg DM)	12.9	10.3	13.1	13.4
Ammonia N as g/kg of total N	-	122.3	-	-
calcium	1.27	5.4	5.3	7.3
phosphorus	2.27	3.3	5.7	6.95
magnesium	1.60	2.03	2.65	3.55
pH	-	4.46	-	-

Appendix 12 cont

Chemical composition of silage, fodder beet and concentrate (low and high protein)

Period 3

	Fodder beet	Silage	Concentrate Low	Concentrate High
Oven dry matter (g/kg)	221.5	155.8	836.0	831.0
Crude protein (g/kg DM)	43.5	124.0	123.5	216.0
Organic matter (g/kg DM)	877.6	923.0	954.5	937.0
IVOMD (in vitro) (g/kg DM)	902.5	735.0	851.0	871.5
Ammonia N as g/kg of total N	-	104.0	-	-
Predicted ME (MJ kg/d DM)	13.35	10.68	13.0	13.05
calcium (g/kg DM)	1.15	5.3	5.5	7.2
phosphorus (g/kg DM)	2.2	2.75	5.5	6.7
magnesium (g/kg DM)	1.7	1.8	2.75	3.65
pH	-	3.95	-	-

l- low

h- high

APPENDIX 13

Physical ingredients of diet 'A'

	kg
Barley straw	400
Soya Bean Meal	70
Barley	125
Wheat Feed	220
Molasses	100
50% Fat	25
College B	60

College B[x] Analysis

Vitamin A M.I.U.	10.0
Vitamin D_3 M.I.U.	2.0
Vitamin E g	10.5
Ferrous sulphate g	36.0
Manganese sulphate g	18.0
Zinx oxide g	20.0
Cabalt sulphate g	17.0
Calcium Iodate g	2.3
Salt kg	15.0
Sodium Bicarbonate kg	20.0
Dicalcium phosphate kg	15.0
Urea kg	10.0

Chemical composition of diet 'A' g kg^{-1}

Dry matter	862
Organic matter	894
Crude protein	126
IVOMD	688
ME in vivo MJ/kg	9.9
GE MJ/kg	18.9
OMD	659

APPENDIX 14

The rumen pH of sheep fed on 3 different diets at different times

	Diet			
Time	FB	SBP	BM	SED
08:45	6.69	6.72	6.51	0.120 NS
09:45	6.36	6.44	6.36	0.120 NS
10:45	6.24	6.49	6.17	0.120 NS
11:45	6.13	6.41	6.08	0.120 NS
12:45	6.08	6.33	6.06	0.120 NS
13:45	6.32	6.21	5.99	0.120 NS
14:45	6.28	6.29	6.13	0.120 NS
15:45	6.48	6.24	6.30	0.120 NS
16:45	6.44	6.34	6.22.	0.120 NS
Mean	6.34[b]	6.38[b]	6.20[a]	0.039***

APPENDIX 15

Propionic acid % produced in the rumen with feeding different diets (FB, SBP and BM) at different times.

	Diet			
Time	FB	SBP	BM	Mean
08:45	15.87[a]	16.90[a]	16.17[a]	1.311**
09:45	21.63[a]	19.77[a]	26.90[a]	1.311**
10:45	20.33[a]	20.83[a]	25.23[b]	1.311**
11:45	22.47[b]	18.30[a]	24.60[b]	1.311**
12:45	23.10[ab]	20.57[a]	23.60[b]	1.311**
13:45	19.97[ab]	18.73[a]	22.27[b]	1.311**
14:45	21.67[b]	17.60[a]	20.83[b]	1.311**
15:45	21.50[b]	17.40[a]	20.17[b]	1.311**
16:45	19.23[a]	19.10[a]	20.17[a]	1.311**
Mean	20.64[b]	18.80[a]	22.21[c]	0.436***

APPENDIX 16

TVFA produced in the rumen with feeding different diets (FB, SBP and BM) at different times.

	Diet			
Time	FB	SBP	BM	SED
08:45	69.33	73.67	60.67	11.397 NS
09:45	82.00	94.67	102.33	11.39 NS
10:45	90.00	91.67	96.33	11.39 NS
11:45	108.00	81.67	84.67	11.39 NS
12:45	109.33	85.00	86.67	11.39 NS
13:45	85.67	62.67	92.33	11.39 NS
14:45	89.33	69.00	83.33	11.39 NS
15:45	76.67	78.00	88.67	11.39 NS
16:45	81.70	90.70	78.70	11.39 NS
Mean	88.00	80.78	85.96	3.798 NS

APPENDIX 17

Acetic acid % produced in the rumen feeding different diets (FB, SBP and BM) at different times.

		Diets		
Time	FB	SBP	BM	SED
08:45	75.40	73.53	75.67	2.486 NS
09:45	68.73	70.23	63.03	2.486 NS
10:45	68.83	69.60	63.40	2.486 NS
11:45	66.80	73.70	64.50	2.486 NS
12:45	65.23	68.83	64.50	2.486 NS
13:45	72.53	70.60	67.70	2.486 NS
14:45	66.40	73.23	68.43	2.486 NS
15:45	69.10	73.80	69.60	2.486 NS
16:45	70.57	71.67	70.30	2.486 NS
Mean	69.3^{b}	71.7^{c}	67.5^{a}	0.83***

APPENDIX 18

Butyric acids % produced in the rumen with feeding diets (FB, SBP and BM) at different times.

	Diet			
Time	FB	SBP	BM	Mean
08:45	8.70	9.60	8.13	2.286 NS
09:45	9.67	9.97	10.07	2.286 NS
10:45	10.87	9.57	11.37	2.286 NS
11:45	10.73	8.00	10.90	2.286 NS
12:45	11.67	10.60	11.79	2.286 NS
13:45	7.47	10.63	10.07	2.286 NS
14:45	11.97	9.10	10.70	2.286 NS
15:45	9.40	8.83	10.20	2.286 NS
16.45	10.20	9.23	9.50	2.286 NS
Mean	10.1	9.5	10.3	10.76 NS

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