PATTERN OF CONCENTRATE ALLOCATION FOR DAIRY COWS OFFERED SILAGE *AD LIBITUM*

by

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SUMMARY

1. The literature review studies the effects which concentrates have on silage intake, milk yield, milk composition and partition of energy. The inter-relationships with forage quality, concentrate type, stage of lactation and milk yield potential are also discussed. Some of the main effects are quantified. The final review chapter discusses experiments where different patterns of concentrate allocation have been compared using the same total quantity of concentrate.

2. Five experiments were carried out: The first three were of continuous design and 20 to 25 weeks duration beginning 3 weeks post-calving. They compared different patterns of concentrate allocation to autumn-calving dairy cows offered silage *ad libitum*. The effects of forage quality and total level of concentrate were included within this framework. Two changeover experiments studied silage and milk yield responses, to different levels of concentrate supplementation with autumn-calving dairy cows in mid-lactation offered moderate quality silage *ad libitum*.

3. In Experiment 1: Three groups of cows and heifers were offered high quality grass silage *ad libitum* and an average of 1.26 tonnes cow^{-1} of concentrate from weeks 3-22 of lactation. Concentrates were either offered: at a flat rate to all animals, in steps to all animals, or a flat rate per cow based on milk yield potential. Feeding proportionately more concentrates in early lactation or to higher yielding cows gave similar levels of performance to where concentrates were offered at a flat rate to all cows.

4. Experiment 2. From weeks 3-27 of lactation silages of 65 and 59 DOMD were offered *ad libitum* to two groups of dairy cows. Within each group two patterns of concentrate allocation were compared: a flat rate for all cows or a variable rate for individuals. The total quantity of concentrate given to each group averaged 1.58 tonnes cow^{-1}. With both high and low DOMD silages, feeding proportionately more concentrates in early lactation and to individuals of higher milk yield did not result in any better performance than a simple flat rate to all cows.

5. Experiment 3. From weeks 3-27 of lactation two levels of concentrate 1.925 tonnes cow^{-1} or 1.225 tonnes cow^{-1} were fed to two groups of cows offered high quality silage *ad libitum*. Within each group two patterns of concentrate allocation were compared: a flat rate to all cows or a variable rate for individuals. Pattern of concentrate allocation had no effects on average performance within the low level of concentrate. Within the high level of concentrate over the first 25 weeks the flat rate pattern had significantly better average milk fat yields and solids-corrected milk yields and a non-significant increase in 305-day yield of 570 kg compared with the variable pattern to individuals.

6. Moderate quality silage was offered *ad libitum* and either 8, 7, 6 or 5 kg day^{-1} (fresh weight) in experiment 4 and 11, 9, 7 or 5 kg day^{-1} of concentrate in experiment 5, to dairy cows in mid-lactation using changeover experiments with 3 week periods. Silage intakes were only increased by an average of 0.17 and 0.22 kg DM kg^{-1} decrease in concentrate DM and milk yields were decreased by an average of 0.84 and 0.76 kg kg^{-1} reduction in concentrate DM in experiments 4 and 5 respectively. These results indicate that

reducing concentrate levels between 5 and 9 kg day^{-1} (fresh weight) with moderate quality silage offered *ad libitum* will lead to accelerated declines in milk yield and composition in mid-lactation.

7. Considerable attention has been given in the past to feeding proportionately more concentrates in early lactation and to higher yielding individuals. This series of experiments and others reviewed from the literature have failed to show any significant advantages of complex individual feeding to yield patterns of concentrate allocation, compared with a simple flat rate to all cows.

ABBREVIATIONS

A	*Ad libitum*
ARC	Agricultural Research Council
d	Day
d.f.	Degrees of Freedom
D, D-value, DOMD	Digestibility of the Organic Matter in the Dry Matter
DCP	Digestible Crude Protein
DM	Dry Matter Content
DMD	Dry Matter Digestibility
g	Grams
h	Hours
ha	Hectare
hd	Head
kg	Kilogram
KLo	Efficiency of Utilisation of ME for Milk Production
LW	Liveweight
MAFF	Ministry of Agriculture, Fisheries and Food
M/D	ME Concentration in the Dry Matter
ME	Metabolisable Energy
MJ	Megajoule
N	Nitrogen
NA	Not Available
NS	Not Significant
r or r-value	Substitution Rate
R	Restricted
RDP	Rumen Degradable Protein
SFU	Scandinavian Fodder Unit
UDP	Undegradable Protein
VFA	Volatile Fatty Acids

REVIEW OF LITERATURE

CHAPTER 1 - THE INFLUENCE OF CONCENTRATES ON FORAGE INTAKE

Introduction

Forage is normally supplemented with concentrates, as the amount of forage eaten when offered alone, will only supply energy and protein sufficient for maintenance plus 10-18 kg milk day^{-1} with high liveweight losses which vary with breed and forage quality (Ekern and MacLeod, 1978; Castle *et al.* 1980; Blair *et al.* 1982). For milk yields of around 6000 litres, approximately 70% of the diet dry matter can be forage and the remainder a concentrate supplement (Skovbourg and Anderson, 1973, Ekern and MacLeod, 1978). At higher levels of production diets with a greater proportion of concentrates are required.

When forage is offered *ad libitum* additional concentrates generally reduce forage intake but increase total feed intake (Østergaard, 1979 Figure 1.1). Concentrates, therefore act to some extent as substitutes for, as well as supplements to forages. This is an important factor to consider when quantifying milk production responses to additional concentrates (Broster, 1980; Thomas, 1980; Broster and Thomas, 1981).

Factors affecting the depression in forage intake include: forage quality, the type and level of concentrate fed, stage of lactation and the milk yield potential of the animal (Wernli, 1972; Thomas, 1980, Wilkins, 1981; Bertilsson, 1983).

1.1 Forage type and quality

The unit decrease in forage dry matter intake per unit increase in concentrate dry matter intake is known as the substitution rate (r) (Forbes, 1983). It is positively correlated with the intake character-

Daily intake of a cow (550 kg)

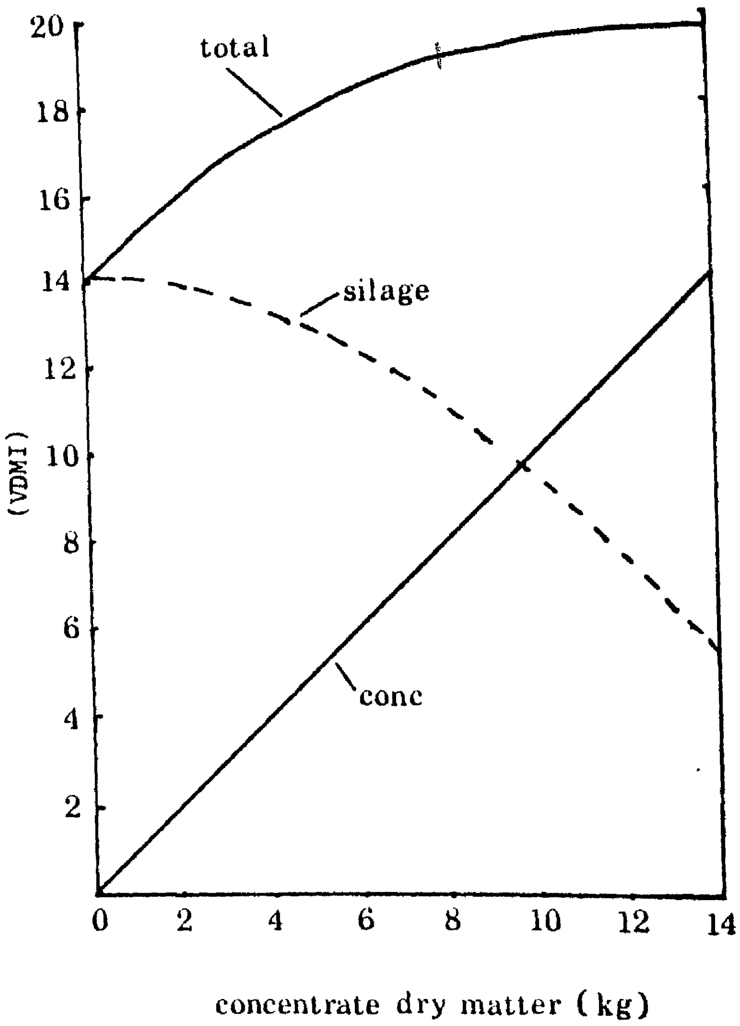


Fig. 1.1 Functions for voluntary dry matter intake (VDMI) for increased level of concentrates

(Østergaard 1979)

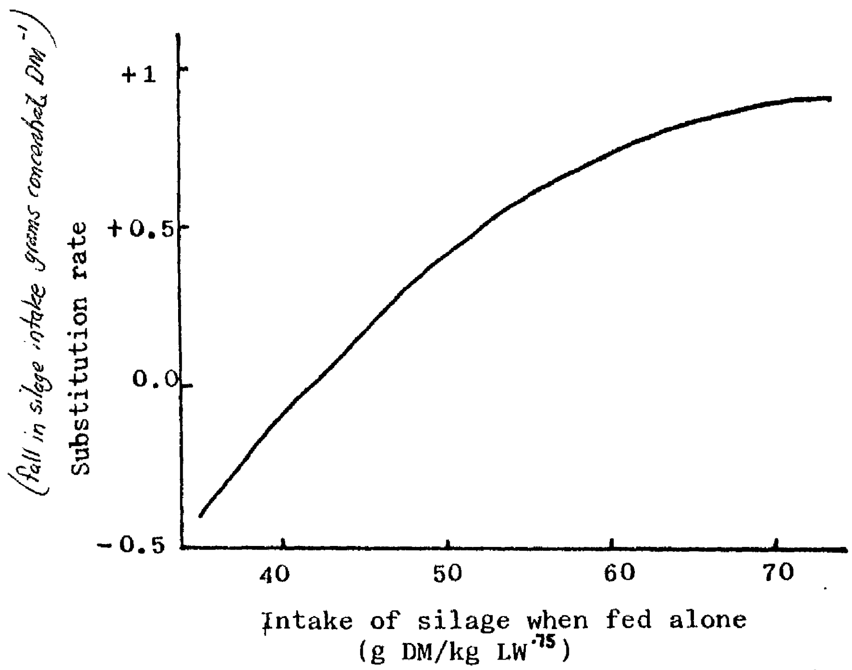


Fig.1.2 Substitution rates when sheep are fed silage without supplement or with a barley based concentrate at 17-25 g DM/kg LW$^{.75}$

(Wilkins,1981)

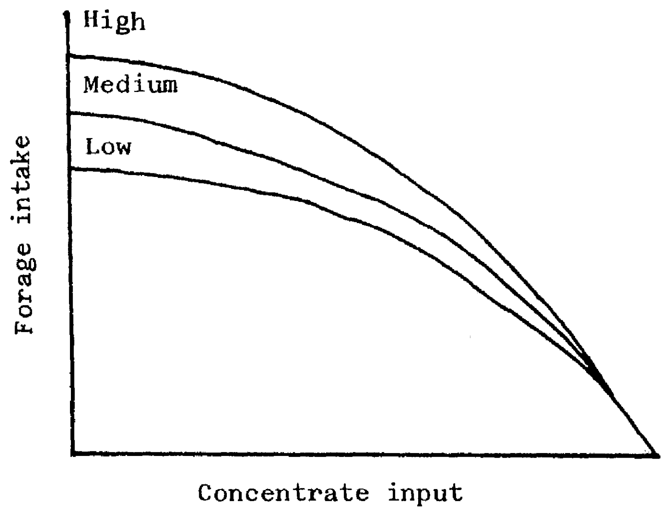


Fig.1.3 The effect of concentrate input on the intake of forage of various qualities

(Broster & Thomas,1981)

Table 1.1 EFFECT OF CONCENTRATE DRY MATTER INTAKE ON SILAGE DRY MATTER INTAKE

Range of concentrate intake (kg DM day)	Stage of lactation	Forage type and quality	Type of concentrate	r value	Reference
1.8 - 7.2	84 - 161 days post partum	hay and silage 61D	43% barley 32% sugar beet pulp 10% flaked maize	0.18	Holmes et al.,1960 (1)
2.0 - 7.2		62D		0.21	
3.7 - 7.8	1 - 140 days	hay and 1957/58 silage 1958/59	40% oats 20% barley	0.38 0.18	Castle and Watson,1961 (2)
2.3 - 6.4	9 - 20 wks	hay and silage	NA	0.34	Foot and Line,1964 (3)
0 - 3.9	NA	silage	NA	0.55	Campling,1966 (4)
0 - 4.5	none lactating	silage	NA	0.23	Campling and Murdoch,1966 (5)
5.1 - 8.3	56 - 161 days	silage 65D	50% sugar beet pulp	0.47	Castle et al.,1966 (6)
1 - 4.7	early - mid	silage	NA	0.26	Gleeson , 1970 (7)
NA	3 - 6 wks 7 - 12 wks 13 - 18 wks 19 - 26 wks	92% silage	NA	0.93 0.73 0.53 0.34	Ekern , 1972a (8)
3.5 - 10.5	NA	fresh silage wilted silage	NA	0.35 0.37	Rohr et al., 1974 (9)
6.0 - 6.8	6 - 22 wks	silage	100% barley	0.26	Tayler and Aston , 1976 (10)
	early - mid	silage 69D	100% groundnut cake	0.10	Castle et al., 1977 (11)
0.9 - 5.0	early	silage 70D	35% barley 35% maize	0.59	Gordon , 1977 (12)
3.5 - 9.6	98 - 170 days	silage 70+ 66D	35% barley 35% oil cake	0.51 0.39	Kristensen et al., 1979 (13)

Continued over..

Table 1.1 continued

Range of concentrate intake (kg DM day)	Stage of lactation	Forage type and quality	Type of concentrate	r value	Reference
8– 16	7 – 14 wks	hay good quality	NA	0.6	Oldenbroek, 1979 (14)
4 – 8	early – mid	silage	35% barley 35% oil cake	0.4	Ostergaard, 1979 (15)
3.5 – 7.0	49 – 161 days	silage 65D 62D	40% barley 20% maize	0.34 0.28	Castle *et al.*, 1980 (16)
4.9 – 8.9	6 – 18 wks	silage 69D 66D	NA	0.55 0.34	Moisy and Leaver, 1980 (17)
3.5 – 7.1	early	silage 70D	30% barley	0.44	Steen and Gordon, 1980a (18)
6.4 – 9.6	7 – 80 days	silage 72D 68D	52% barley 21% maize	0.60 0.56	Steen and Gordon, 1980b (19)
3.7 – 7.3	early – mid	silage 61D	NA	0.40	Blair *et al.*, 1981 (20)
0 – 5.6	early – mid	silage 66D 66D 62D 62D	barley beet pulp barley beet pulp	0.44 0.45 0.43 0.35	Castle *et al.*, 1981 (21)
3.3 – 8.1	early – mid	silage	NA	0.25	Gordon, 1981b (22)
2.2 – 7.6	early – mid	silage 62D	50% barley	0.57	Laird *et al.*, 1981 (23)
5.1 – 9.6	1st 10 wks	silage 62D	NA	0.35	Blair *et al.*, 1982a (24)
3.4 – 6.9	1 – 158 days	silage 62D poor fermentation	NA	0.17	Blair *et al.*, 1982b (25)
4.9 – 8.8 5.3 – 10.2	early –mid	silage 64D	32% maize 15% barley	0.46 0.72	Moisey and Leaver, 1982 (26)
6.0 – 8.6	early – mid	silage 67D	31% barley 50% barley	0.40 0.36	Mayne and Gordon, 1982 (27)
2.6 – 7.0	11 –26 wks	silage 67D hay 62D	80% grain	0.40 0.60	Bertilsson, 1983 (28)
			Mean	0.41	

istics of the silage, i.e. silages with high intakes when fed alone have a higher r value than those with low intakes (Wernli, 1972; Wilkins, 1981; Steen and MacIlmoyle, 1982 a, b). Figures 1.2 and 1.3 illustrate the relationship between the intake characteristics of forages and r value.

Silages have various types of fermentations, (Wilkins *et al.* 1971; Demarquilly, 1973; Thomas and Chamberlain, 1982), and surveys of large numbers of individual silages have shown poor correlations between digestibility and silage intake (Wilkins *et al.* 1971; Demarquilly, 1973). The fermentation characteristics may therefore affect r values to a greater degree than digestibility *per se*.

For hay based diets the correlation between digestibility and voluntary feed intake is higher than for silages (Blaxter and Wilson, 1962; Reid *et al.* 1962; Ekern and MacLeod, 1978) and high r values will tend to be associated with hays of high digestibility. Hay diets have been shown to have higher r values than silage diets of comparable digestibility (Campling, 1966 ; Campling and Murdoch, 1966; Bertilsson, 1983). This may be a result of the hay method of conservation or to the dry matter content of the material, as the r value for silages greater than 250 g kg^{-1} dry matter is greater than the r value for silages below 200 g kg^{-1} dry matter (Hermansen, 1980). In the study of Hermansen (1980) the relationship between r and digestibility was positive for silages greater than 260 g kg^{-1} dry matter but no relationship was apparent for silages of 180 g kg^{-1} dry matter.

Table 1.1 illustrates the large variation in r value observed with different forages and qualities.

1.2 Digestion of forage diets and forage intake

There is considerable evidence to show that forage intake is limited by the capacity of the reticulorumen and by the rate of disappearance of digesta from this organ (Balch and Campling, 1962; Campling, 1969, 1980; Jarrige *et al.* 1974). Rumen capacity is a function of animal size whereas the rate of disappearance of digesta depends on the rate of breakdown of forage particles in the reticulo-rumen by microbial and mechanical processes (Campling, 1969).

Introduction of concentrates into the rumen causes a depression in the digestibility of cellulose (Tayler and Aston, 1976; Thomas and Castle, 1978; Waldo and Jorgensen, 1981). The digestibility of the cell wall fraction of the forage is depressed much more than that of the soluble carbohydrate fraction (Osbourn, 1977; Østergaard, 1980; Van Soest, 1982; See Figure 1.4) and this affects the 'ingestibility' of the forage (Jarrige *et al.* 1974). Tayler and Aston (1976) produced the equation 1.1

$$y = 77.64 - 1.8x \quad \ldots\ldots\ldots\ldots \quad 1.1$$

y = cellulose digestibility x = kg barley supplement

to describe the decline in cellulose digestibility which occurred with increasing levels of barley fed to dairy cows.

The depression in cellulose digestibility can be explained in part by a lower pH and a change in the molar proportions of volatile fatty acids when high levels of concentrates are introduced into the rumen. This reduces the numbers of cellulolytic and fibre digesting bacteria and increases the number of lactic-acid and propionic-acid-producing bacteria (Terry *et al.* 1969; Rook, 1975; Thomas and Rook, 1981).

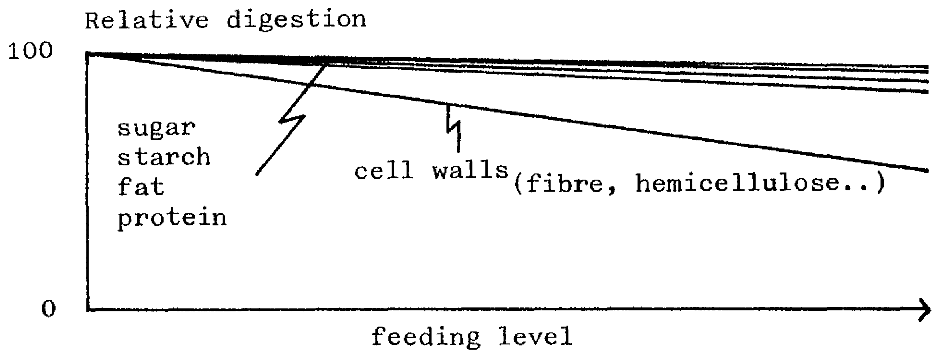


Fig 1.4 Digestion of nutrients at different feeding levels
100 = digestion at maintenance feeding level.

(Østergaard, 1980)

A curvilinear relationship exists between concentrate dry matter intake and forage dry matter intake (Figure 1.1) with substitution rates (r) being greater at higher levels of concentrate supplementation (Osbourn, 1980; Broster and Thomas, 1981; Forbes, 1983, Table 1.4). There is still incomplete agreement on the factors responsible for concentrates depressing forage intake, but a number of explanations have been discussed (Campling, 1966 ; Kesler and Spahr, 1964; Kaufman, 1972, Osbourn, 1980).

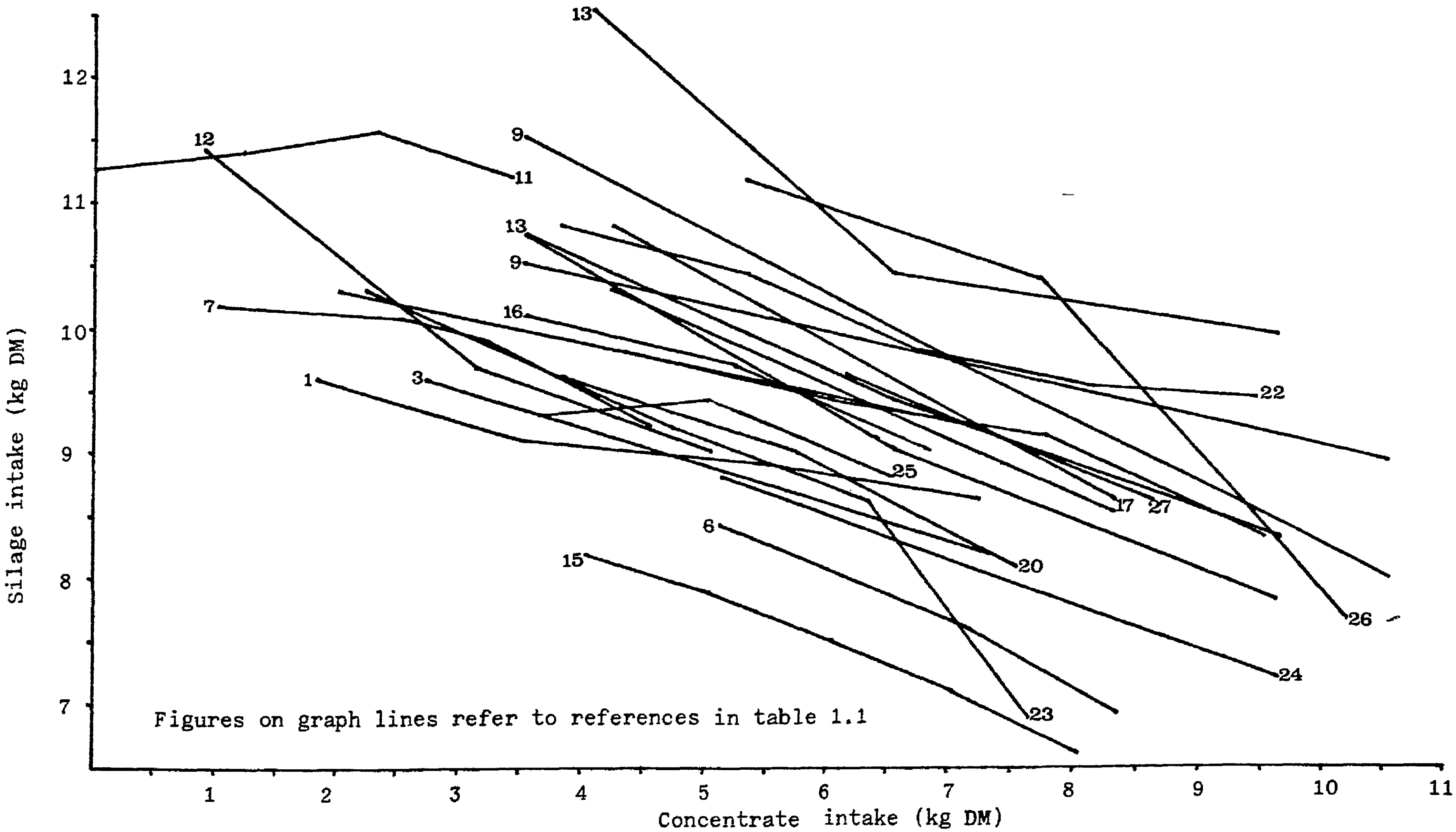
The effect of concentrates on the depression in cellulose digestibility is greater and more consistent with hay than with silage diets (Head, 1953; Campling, 1966 ; Kesler and Spahr, 1964; Lamb *et al.* 1976). With dry forages therefore, the simple theory of bulk limitation and rate of passage seems to be the most useful concept to explain variations in forage intake from additional concentrates (Osbourn, 1967, Wernli, 1972). Here cellulose digestibility is reduced by the unfavourable rumen environment for fibre digestion caused by additional concentrates. Forage retention time in the rumen is therefore greater and as satiety in ruminants is closely correlated with rumen fill (Balch and Campling, 1962; Farhan and Thomas, 1978; Campling, 1980); the animal will cease eating after a shorter period, if digestibility and hence throughput is reduced.

With ensiled forage crops more complicated mechanisms are involved. It has been observed that cows stop eating silage well before the reticulo-rumen contains amounts of digesta and digested dry matter equal to those found with hay fed animals (Campling, 1966 ; Lawlor and O'Shea, 1967; Wernli, 1972). Therefore silage dry matter intake is not strictly limited by the capacity of the reticulo-rumen (Campling, 1966 ; Wernli, 1972; Jarrige *et al.* 1974). In this circumstance any reduction in the rate of passage of silage, as a result of supplementation with concentrates would increase gut fill but would not necessarily result in a reduction in silage intake (Wernli, 1972). This may partly explain the higher r values with hay as opposed to silage diets previously discussed in Chapter 1:1.

Kaufman (1972) suggests that an additional mechanism for the regulation of intake is given by saliva production. Concentrates reduce saliva production through decreased rumination times (Campling and Morgan, 1981). Saliva influences the buffering system of the reticulo-rumen helping to maintain an optimum pH for cellulolytic bacteria and additional concentrates would restrict this process and depress forage intake.

The analysis of 28 experiments shown in Table 1.1 and Figure 1.5 illustrates the general trend of decreasing forage intake with additional concentrates. The average r value from Table 1.1 was 0.41. This

Fig.1.5 The effect of concentrate intake on silage intake



is slightly less than the value of 0.5 from an analysis of 16 trials (Thomas, 1980) and an average value of 0.46 from an analysis of 5 trials (Bertilsson, 1983).

1.3 Concentrate type

The composition of a concentrate has been shown to affect r values markedly (Wernli and Wilkins, 1971; Wernli, 1972; Thomas and Castle, 1978; Forbes, 1983). Dried grass cubes and ground nut cake have less of a depressing effect on silage intake than barley (Tayler and Aston, 1976; Thomas and Castle, 1978; Castle, 1982). Castle (1982) reported that up to approximately 4 kg day^{-1}, soya and ground nut cake improved silage intake by 0.13 kg kg^{-1} supplement. They state that the high nitrogen content of ground-nut, 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.

As ground-nut and dried grass have lower r values than barley, they result in greater responses in total energy intake and this results in higher partial efficiencies of utilisation of ME for lactation (Kl_O) than supplements of barley (Thomas and Castle, 1978, Table 1.2). Barley and sugar beet pulp have similar r values of 0.44 and 0.40 respectively when used as supplements for grass silage (Castle *et al.* 1981).

With medium quality forages of which 650 - 700 g kg^{-1} of the DM is digested, approximately all the cellulose digestion occurs within the rumen, together with a slightly smaller proportion of digestible hemicellulose. In contrast starch digestibility in cereal grains is high, 900 g kg^{-1} and there is considerable variation in the site of this digestion. The proportion of starch digestion occurring within the

Table 1.2 The effect of supplementary feeds on dry-matter intake, metabolisable energy intake, milk yield and the efficiency of utilization of metabolisable energy for lactation (klo)

Supplement	Dry matter intake (kg day) Silage	Concentrate	Total	ME intake (MJ day)	Milk yield (kg day)	Klo (%)	Reference
None	11.6	-	11.6	141	14.5	51	
Barley	9.7	3.3	13.0	163	15.7	48	
Barley	9.7	4.6	14.3	181	16.6	44	Castle and Watson (1975)
Ground-pelleted dried grass	10.1	3.4	13.5	158	17.8	61	
'' '' ''	10.3	4.6	14.9	174	20.2	64	
Barley	8.6	4.7	13.3	164	16.1	39	
Ground nut cake	11.1	1.5	12.6	146	17.6	54	Castle and Watson (1976)
Barley + groundnut cake	9.3	4.7	14.0	170	17.9	47	

(Thomas and Castle, 1978)

reticulo-rumen may vary from 40% to more than 90% depending on cereal source, variety, proportion of cereal grain in the diet and the degree of processing (Orskov *et al.* 1978; Sutton, 1981; Thomas and Rook, 1981).

It has been possible to slow down the rate at which certain cereals are digested in the rumen by physical and chemical processing (Orskov, 1981; Thomas and Rook, 1981) and by feeding the supplement more frequently in smaller quantities (Thomas and Castle, 1978). These factors all significantly improved silage intake compared with the controls.

Present commercial concentrate compounds through their processing, and a greater inclusion of by-products with much less straight cereal grains than formerly (Campling, 1980; Sutton, 1981; Wilson *et al.* 1981. See Table 3.20), do not have such a severe depressing effect on silage intake. It has been suggested that concentrates containing greater than half their dry matter as cereals will give rise to severe depressions in cellulose digestibility and should be avoided (Orskov, 1980).

1.4 Stage of lactation

Few experiments have been designed to specifically observe r values at different stages of lactation (Ekern, 1972a; Østergaard, 1979; Donker and Maclure, 1982). Where concentrates have been allocated according to yield the effects of stage of lactation and concentrate level have been confounded (Thomas, 1980; Forbes, 1983).

Ekern (1972a) reported that r values were greater in early lactation than in mid-lactation. However, the concentrates were fed according to yield and the higher r values in early lactation may be a result of higher levels of concentrates (Table 1.3).

Table 1.3 The effect of stage of lactation on r values

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

(Ekern, 1972 a)

Donker and Maclure (1982) reported that r values increased as lactation progressed. They suggest that in early lactation when forage intake is increasing rapidly, the r value was probably a function of rumen capacity, i.e. because concentrate dry matter occupies less space than forage per unit weight, less forage should be displaced per unit concentrate added. This agrees with equation 1.2 suggested by Forbes (1983) where r is related to volume of feeds in the rumen. In later lactation intake may be regulated in part by energy balance, and therefore concentrates would be expected to displace forage intake in proportion to their energy contents (Forbes, 1983, equation 1.3).

Where concentrates are offered at a flat rate it is possible to independently measure the effect of stage of lactation on r values.

$$\Delta \text{ roughage intake} = -\Delta \text{ concentrate intake} \times \frac{\text{concentrate cell wall constituents}}{\text{forage cell wall constituents}} \quad \ldots\ldots 1.2$$

r = 0.38 for a concentrate of cell wall constituent (CWC) 0.25 and forage CWC 0.65

$$\Delta \text{ roughage intake} = -\Delta \text{ concentrate intake} \times \frac{\text{concentrate ME}}{\text{forage ME}} \quad \ldots\ldots 1.3$$

r = 1.33 for a concentrate ME of 12 and a forage ME of 9.

When values for cows and heifers were combined, Østergaard (1979) reported no significant difference in r over the first 36 weeks of lactation agreeing with Raymond and Prescott (1980). However, when the data of Østergaard (1979) were separated for cows and heifers, it was observed that cow r values increased during lactation whereas heifer r values decreased over the same period (see Table 1.4). This agrees with Donker and Maclure (1982) for cows, where energy balance may be regulating intake in later lactation but not for heifers where it may be expected that energy balance would not be limiting as they are still growing.

Table 1.4 r value at different levels of concentrate and different stages of lactation

		Level of concentrate (kg DM)		
		8	9	10
Weeks of lactation				
1-12	Heifers	0.35	0.40	0.44
	Cows	0.21	0.23	0.26
1-36	Heifers	0.21	0.23	0.26
	Cows	0.42	0.47	0.52

(Østergaard, 1979)

1.5 Yield potential

Thomas (1980) suggested that there was a tendency for r to be higher for higher yielding animals. This, however, may have been a reflection of the higher level of concentrate input to these animals.

Until specific evidence is available from studies where animals have been separated into groups based on their yield potential and fed pre-determined levels of concentrate no firm conclusions can be made.

The hypothesis outlined by Broster and Thomas (1981) suggests that with *ad libitum* forage feeding, r values for high and low yielders would be similar. Johnson (1979) found no differences in response to concentrates for high and low yielders but no information was available on r values as all animals were fed forage in restricted amounts.

The available evidence suggests that when forage quality is high and/or concentrates (especially those with highly soluble starch contents), are being fed at above average levels one can expect high r values (greater than 0.5). Where forage is poor in quality and/or concentrates (especially those low in soluble starch contents) are being fed at low levels one can expect low r values (less than 0.5).

There is little information to suggest that r value changes markedly over early and mid-lactation and between cows of different yield potential when offered *ad libitum* forage. Further work is needed to clarify the relationship between r value, stage of lactation and the yield potential of the animal.

CHAPTER 2 - THE EFFECT OF CONCENTRATES ON MILK YIELD

2.1 Restricted and ad libitum forage

With restricted forage fed for maintenance the first increments of concentrate act as supplements and do not cause any substitution effects. Additional concentrates, therefore, contribute directly to total energy intake, which the cow partitions between milk output and body reserves (Wernli, 1972; Broster and Thomas, 1981; Johnson, 1982). Further increases in concentrates result in a curvilinear response in milk output and an increase in body weight gain or reduction in weight loss (Broster and Thomas, 1981).

With *ad libitum* forage, concentrates depress forage intake this depression being greater as the level of supplement increases (Chapter 1). The net increase in energy intake is the increased energy from concentrates minus the decrease in energy intake from silage (Wernli, 1972). This net increase in energy intake is then partitioned between milk and body tissues.

Larger milk yield responses have been reported with restricted forage diets, (Strickland and Broster, 1981; Johnson, 1977), compared with *ad libitum* forage diets (Thomas, 1980; Gordon, 1981a) although other factors can affect milk yield responses. Table 2.1 illustrates the large variation in responses which have been reported.

2.2 Quality of forage

The milk yield response to additional concentrates decreases as the digestibility of the forage increases (Kristensen *et al.* 1979; Moisey and Leaver, 1980; Steen and Gordon, 1980a). This effect is small and inconsistent at low levels of concentrate supplementation (Gleeson, 1970, 1972). At higher levels of concentrate supplementation this effect is more pronounced and the more extreme the difference in forage quality the greater will be these differences (Kristensen *et al.* 1979; Moisey and Leaver, 1980).

An explanation for milk yield responses to concentrates being lower for high D value forages is linked with substitution rates and partition of energy. It has been reported in Chapter 1 that r values are higher with higher D value forages. Also with high levels of concentrate feeding and high D value silage, ration M/D (energy density) is higher and proportionately more energy will be partitioned toward body tissue gain compared with milk output (see Chapter 4).

2.3 Range of concentrate levels

There is a declining response in milk yield to each incremental rise in concentrates (Østergaard, 1979; Gordon, 1981, 1981 a). Gordon (1981 a) using data from four experiments with spring calving cows offered silage *ad libitum* demonstrated such a curvilinear relationship represented by equation 2.1 and Figure 2.1. A similar curvilinear response to concentrates was reported for autumn-calving cows (Gordon, 1981 b).

$$y = 19.38 + 7.5 \log_e \log_e x \qquad 2.1$$

y = milk yield kg day^{-1} $\quad$ x = concentrate input kg fresh wt.

Large milk yield responses in the region of 1.0 to 1.5 kg milk per kg concentrate dry matter are likely to be obtained at low basal levels of concentrate feeding (Gleeson, 1972; Castle *et al.* 1977; Gordon, 1977) whereas at high levels of concentrate feeding, responses of less than

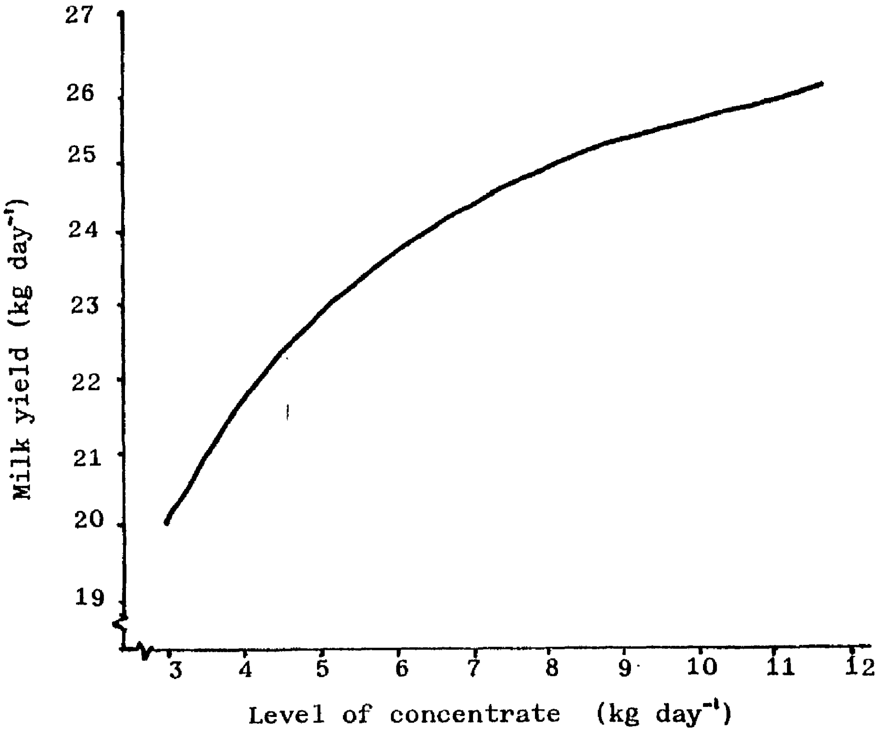


Fig. 2.1 The relationship between level of concentrate and milk yield for spring calving cows

(Gordon, 1981a)

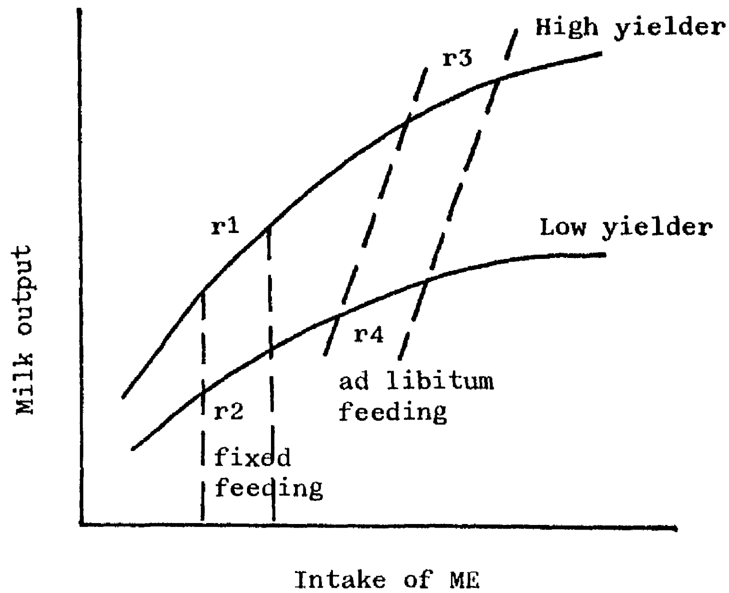


Fig. 2.2 The response of low and high yielding cows to an additional input of energy

(Broster and Thomas, 1981)

Fig. 2.3 **The effect of concentrate dry matter intake on milk yield**

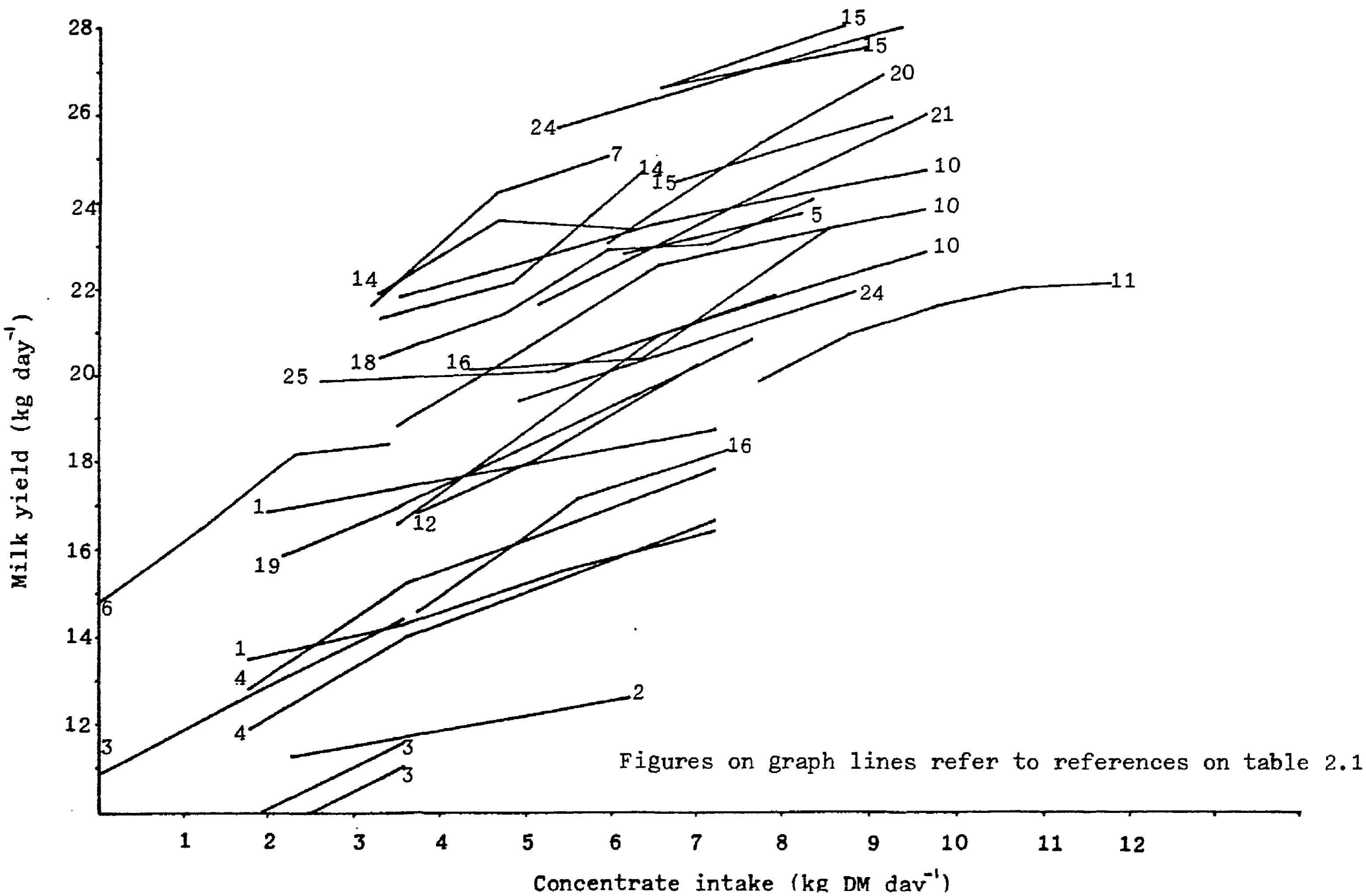


Table 2.1 MILK YIELD RESPONSE TO CONCENTRATES(kg milk kg conc. DM)

Range of concentrate intake (kg DM day)	Stage of lactation	Forage type and quality	Type of concentrate	Milk yield response	Reference
1.8 - 7.2 2.0 - 7.2	84 -161 days	hay and silage 61D 62D	43% barley 32% beet pulp 10% flaked maize	0.57 0.35	Holmes et al., 1960 (1)
2.3 - 6.4	9 - 20 wks	hay and silage	NA	0.33	Foot and Line, 1966 (2)
0 - 3.6 0 - 3.6 0 - 3.6	early	6 wk cutting 9 wk interval 12 wk silage	NA	0.92 1.00 1.00	Gleeson, 1972 (3)
1.8 - 7.2	1 - 8 wks	silage	NA	0.85 0.90	Gleeson, 1973 (4)
6.1 - 8.1	0 - 86 days	silage 70D	36% barley 36% maize 18% groundnut	0.43	Gordon, 1976 (5)
1.2 - 3.4	early - mid	silage 69D	groundnut only	1.10	Castle et al., 1977 (6)
0.9 - 5.0	0 -86 days	silage 70D	35% barley 35% maize	1.26	Gordon, 1977 (7)
3.5 - 5.8	1 - 20 wks	hay fixed	NA	1.70	Johnson, 1977 (8)
8.0 - 9.2 6.6 - 7.5	9 - 20 wks	hay fixed	high yielders low yielders	0.86 1.10	Johnson, 1979 (9)
3.5 - 9.6	98 - 170 days	high D medium silage low	35% barley 35% oil cakes	0.48 0.82 1.00	Kristensen et al., 1979(10)
4.0 - 8.0	1 - 24 wks	silage	35% barley 35% oil cakes	0.57	Ostergaard, 1979 (11)
3.5 - 7.0	49 - 161 days	silage 65D 62D	41% barley 20% maize	1.06 1.02	Castle et al., 1980 (12)

Continued over..

Table 2.1 continued

Range of concentrate intake (kg DM day)	Stage of lactation	Forage type and quality	Type of concentrate	Milk yield response	Reference
4.9 - 8.9	6 - 18 wks	silage 69D 66D	NA	0.58 0.71	Moisey and Leaver, 1980 (13)
3.5 - 7.1	early	silage 70D	30% barley	0.78	Steen and Gordon, 1980a (14)
6.4 - 9.6	7 - 80 days	early wilted 73D early unwilted 72D late unwilted 68D	52% barley 21% maize 18% soya	0.37 0.65 0.60	Steen and Gordon, 1980b (15)
3.7 - 7.3	early - mid	silage 61D	NA	0.76 1.00	Blair *et al.*, 1981 (16)
0 - 5.6	early - mid	silage 66D 66D 62D 62D	barley beet pulp barley beet pulp	0.51 0.56 0.37 0.50	Castle *et al.*, 1981 (17)
3.3 - 8.1	early - mid	silage 66D	NA	o.74	Gordon,1981 (18)
4.7 - 7.6	early - mid	silage 62D	50% barley	0.94	Laird *et al.*, 1981 (19)
5.9 - 9.1 4.2 - 8.0	3 - 10 wks	hay fixed	58% barley 20% maize	cows 1.20 heifers 0.72	Strickland and Broster,1981 (20)
5.1 - 9.6	1 - 10 wks	silage 62D	NA	0.98	Blair *et al.*, 1982a (21)
3.4 - 6.9	1 - 158 days	silage poor fermentation 62D	NA	1.35	Blair *et al.*, 1982b (22)
6.0 - 8.6	2 - 14 wks	silage 67D	varied	0.93	Mayne and Gordon,1982 (23)
5.3 - 10.2 4.9 - 8.8	early - mid	silage 64D	32% maize 15% barley	0.61 0.64	Moisey and Leaver, 1982 (24)
2.6 - 7.0	11 - 26 wks	hay 62D silage 67D	80% grain	0.36 0.42	Bertilsson, 1983 (25)
			Mean	0.80	

1.0 kg milk per kg concentrate dry matter are obtained (Østergaard, 1979; Steen and Gordon, 1980 b; Gordon, 1981 a).

Figure 2.3 containing some of the data from Table 2.1 illustrates the general milk yield response to additional concentrate dry matter intake. The mean pooled regression from Table 2.1 of milk yield response to concentrates in 25 experiments of 0.80 kg milk per kg concentrate dry matter, agrees well with the value of 0.79 obtained by Thomas (1980) from a survey of 16 experiments.

2.4 Type of concentrate

Greater milk yield responses from high protein feeds such as ground-nut, soya bean meal and dried grass compared with barley have been reported (Thomas and Castle, 1978; Castle, 1982). This may be due to effects on total energy intakes and/or to effects on the efficiency of utilisation of ME for lactation (Kl_o). Supplements of ground-nut cake and dried grass result in higher Kl_o values than supplements of barley (see Table 1.2).

Barley and sugar beet pulp give similar milk yield responses on a dry matter basis, with *ad libitum* forage, and are therefore interchangeable on a dry matter basis (Castle, 1972, Castle *et al.* 1981; Mayne and Gordon, 1982).

With restricted forage dried grass supplements give lower milk yield responses than supplements of cereal and protein (Gordon and Kormos, 1973) and Tayler and Aston (1976) argued that this was to be expected as dried grass has a lower ME value compared with barley and its benefit is through a lower depression in forage intake when forage is offered *ad libitum*.

2.5 Milk yield potential

There have been no reports that the milk yield response to additional concentrate feeding is greater for high compared with low yielding cows offered forage *ad libitum* (Østergaard, 1979; Thomas, 1980; Moisey and Leaver, 1982). With restricted forages it has been observed that the response to concentrates is positively related to current milk production (Blaxter, 1956; Broster, 1970; Broster *et al.* 1981).

Cows of higher initial yield (as measured with a standard fixed diet for the first 14 days post-calving) give greater milk yield responses, particularly at higher feeding levels than cows of lower initial yield when forage is restricted (Strickland and Lessells, 1971; Johnson, 1977; Altman, 1980).

When forage is offered *ad libitum* the milk yield response to concentrates is similar amongst cows of different current yields (Broster and Thomas, 1981). With fixed intakes high and low yielding cows by definition eat the same quantity of forage dry matter, whereas with *ad libitum* feeding the higher yielding animal has a higher intake of forage dry matter and consequently a higher ME intake from a given level of concentrate (Bines, 1976, 1977; Leaver, 1980, see Figure 2.2). As a result of this it is argued that high and low yielding animals produce similar milk yield responses (r_3 and r_4 in Figure 2.2) to a similar increment of concentrates.

2.6 Stage of lactation

Peak milk yield and/or the quantity of milk produced during early lactation is reported to be the major determinant of total lactation yield and plane of nutrition at this time is critical (Blaxter, 1956;

Broster, 1970; Broster, 1972). Every kg extra milk achieved at peak will increase total yield by approximately 219 kg (Broster and Thomas, 1981).

However, when the yields of groups of cows are alike, even at different stages of lactation, the milk yield responses to concentrates are similar, which indicates that response is linked more closely to current yield than to stage of lactation (Broster, 1970). Broster (1970) thus advocated feeding proportionately more concentrates in early lactation when yields were high, as the milk yield response to additional concentrates is greatest then and sugsequently falls as yields drop and lactation progresses.

Recent studies with *ad libitum* forage feeding have found no consistent relationship between peak milk yield and total lactation yield (Steen and Gordon, 1980 a; Thomas *et al.* 1981). Furthermore differences in peak yield can be compensated for completely by the pattern of concentrate allocation during mid-lactation (Østergaard, 1979; Steen and Gordon, 1980 a; Johnson, 1983, see Chapter 5).

2.7 Residual Effects

The impact of a change in yield response to a change in nutrient supply registers 66% of the full effect in week 1, 95% in week 2 and the full effect in 3 weeks (Blaxter, 1956). This short term or immediate response has been discussed in the previous sections of this chapter.

In certain circumstances however, direct milk yield responses may persist after the initial treatment period. These are known as residual effects and short changeover trials have the limitations of not being able to study these effects (Altman, 1980). Blaxter (1956) was not fully accurate in that nutritional effects on performance, especially liveweight change, may have prolonged effects which may influence the partition of energy after 3 weeks.

Experiments with restricted forage feeding have reported residual milk yield responses in mid-lactation from previous direct milk yield responses in early lactation (Broster *et al.* 1969; Broster *et al.* 1975; Johnson, 1977). The results of several trials (Broster, 1972) showed that the immediate effect of a variation in food intake in early lactation was quadrupled over the whole lactation, see Table 2.2

Table 2.2 Relationship between Immediate Effect (kg) on Milk Production of Additional Food in Early Lactation of Heifers and the Effect on Milk Production over the Full Lactation

Experiment	Period of extra feeding (week)	Immediate effect (A)	Total lactation effect (B)	Ratio: B/A
Broster *et al.* (1958)	12	128	645	5.0
Broster *et al.* (1964)*	9	45	177	3.9
Broster & Tuck (1967)	8	177	884	4.9
Broster *et al.* (1969)	9	161	533	3.3

* Result not presented in the original report.

(Broster, 1972)

Large residual responses can be expected if:

(a) cows are kept indoors for part or all the residual period with restricted quantities of forage, and/or

(b) cows are only offered restricted amounts of forage during the treatment period which may result in excessive weight losses in early lactation which must be replenished during the residual period (Gordon, 1976, 1977, Steen and Gordon, 1980 a, 1980 b.

Broster and Thomas (1981) concluded that residual effects were not likely to occur at high planes of nutrition when high quality forage is fed *ad libitum*.

Milk yield responses to additional feeding can therefore be misleading if recorded in the short-term, as large compensations in milk yield can occur subsequently, particularly during a residual period at grass. Such compensations can markedly reduce the overall impact of a specific treatment in early lactation, such that differences in 305 day milk yields may be greatly reduced (Gordon, 1977; Steen and Gordon, 1980 a; Chalmers *et al.* 1982).

CHAPTER 3 - THE EFFECT OF CONCENTRATES ON MILK COMPOSITION

3.1 Fat content and yield

In a study of 23 experiments (Table 3.1 and Figure 3.1) the general trend was a decrease in milk fat content as concentrate dry matter intake increased. The mean decrease in milk fat content from Table 3.1 was -0.41 g kg^{-1} per kg increase in concentrate dry matter intake.

When the 23 experiments were separated into those offering forage *ad libitum* and those feeding restricted amounts of forage, the average decrease in milk fat content was greater at -1.14 g kg^{-1} per kg increase in concentrate dry matter for the restricted forage experiments, compared with -0.10 g kg^{-1} per kg increase in concentrate dry matter with the *ad libitum* forage experiments. There may be confounding factors in these relationships as the mean concentrate:forage ratio at the highest concentrate level was greater for the restricted forage experiments (60:40) compared with the *ad libitum* forage experiments (49:51) and all the restricted forage experiments were based on hay.

Only 8 out of the 23 experiments reported significant depressions in milk fat content. Those that did observe significant depressions in milk fat content had large ranges in concentrate dry matter intake and/or restricted forage with exceptionally high concentrate:forage ratios.

Difficulties in achieving significant depressions in milk fat content are mainly attributed to the large coefficients of variation that have been reported for milk fat content and as a result observed differences are not significant (Rook, 1961; Clapperton *et al*, 1978; Malestein *et al*, 1981).

Table. 3.1 Change in fat content and yield per kg. increase in concentrate dry matter

Concentrate forage ratio at highest level	Forage type A. ad libitum R. restricted		Type of concentrate	Average change in fat content ($g\ kg^{-1}$) and significance	Average change in fat yield (g) and significance	Reference
45 : 55	hay and silage	A.	43% barley 32% beet pulp	+0.04	+23.9	Holmes *et al.*, 1960 (1)
44: 56	hay and silage	A.	NA	+0.61	+26.2	Foot and Line, 1964 (2)
83 : 17	hay	R.	NA	-1.35**	-27.0	Kesler and Spahr, 1964 (3)
80 : 20	Alfalfa hay	R.	75% maize 23% soya	-2.17*	-80.1**	Flätt *et al.*, 1969 (4)
61 : 39	hay beet pulp	R.	40% oats 40% barley	-1.28*	+26.8*	Wiktorsson, 1971 (5)
55 : 45	mean of all forages	A.	NA	-0.33	NA	Rohr *et al.*, 1974 (6)
43 : 57	silage	A.	barley dried grass	+0.42 -0.38	+25.8 +32.8	Castle and Watson, 1975 (7)
NA	silage	A.	36% barley 36% maize	-0.10	+13.3	Gordon, 1976 (8)
23 : 77	silage	A.	groundnut only	-0.76	+31.0	Castle *et al.*, 1977 (9)
40 : 60	silage	A.	35% barley 35% maize	+0.39	+55.0	Gordon, 1977 (10)
90 : 10	hay	R.	NA	-2.86	-22.7	Sutton *et al.*, 1977 (11)
53 : 47	mean of all silages	A.	35% barley 35% oil cakes	-0.39**	+20.4	Kristensen *et al.*, 1979 (12)

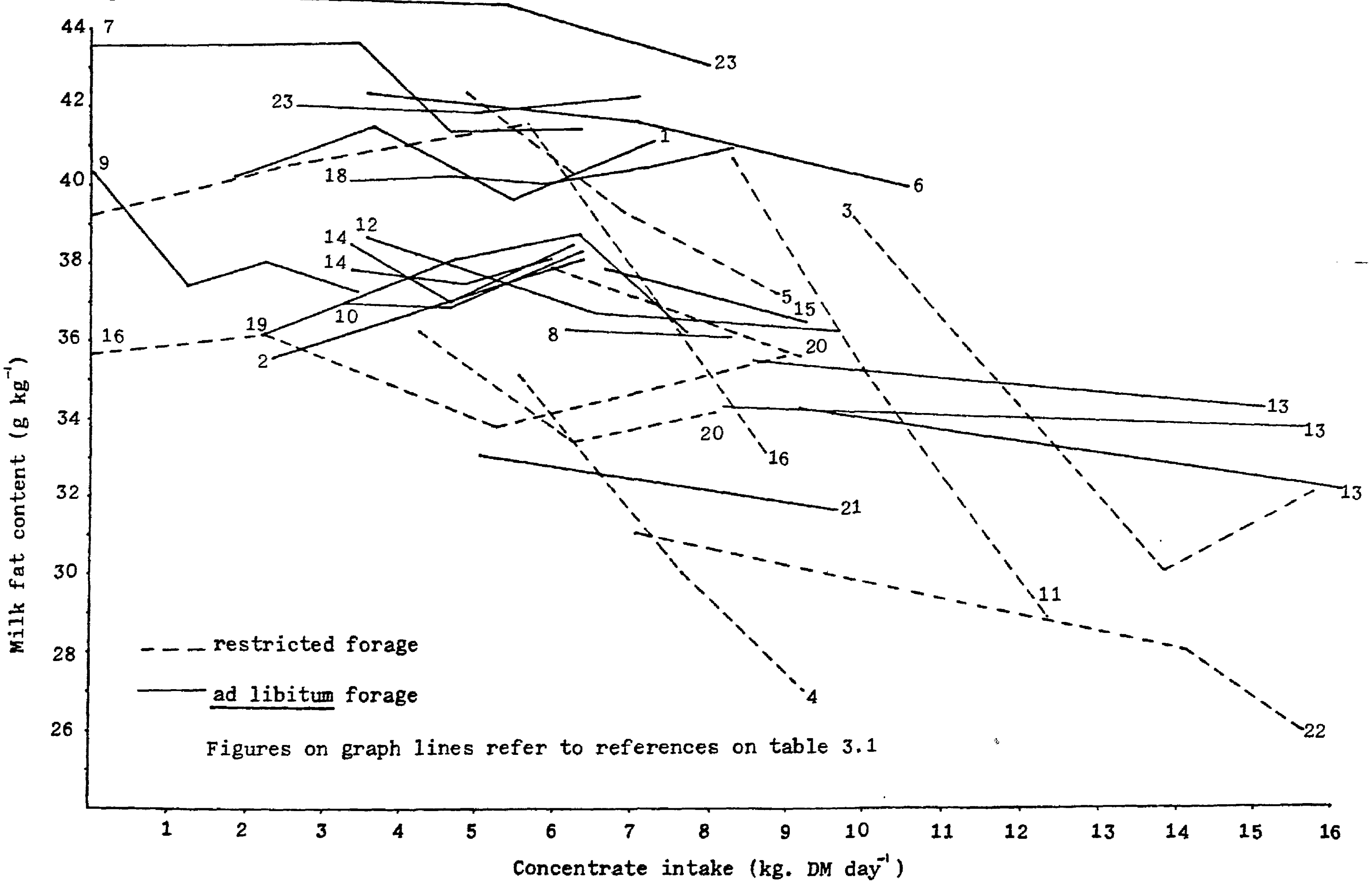
Continued over..

Table 3.1 continued

Concentrate forage ratio at highest level	Forage type A. ad libitum R. restricted		Type of concentrate	Average change in fat content (g kg^{-1}) and significance	Average change in fat yield (g) and significance	Reference
69 : 31	hay	A.	holstein friesian	-0.30	-3.70	Oldenbroek, 1979 (13)
68 : 32			dutch red & white	-0.07	+6.90	
70 : 30			dutch friesian	-0.18	+1.50	
40 : 60	silage	A.	high /low treat	+0.04	+18.5	Steen and Gordon, 1980a (14)
42 : 58			uniform treat	+0.13	+46.2	
52 : 48	mean of all silages	A.	52% barley 21% maize	-0.53	+8.4	Steen and Gordon, 1980b (15)
45 : 55	hay late cut	R.	30% barley	-0.08	+31.1	Vinet *et al.*,1980 (16)
45 : 55	hay early "	R.	30% barley	-0.62	+7.40	
49 : 51	silage	A.	NA	-0.30*	+23.3	Blair *et al.*, 1981 (17)
47 : 53	silage	A.	NA	+0.15	+32.0	Gordon, 1981 (18)
52 : 48	silage	A.	50% barley	+0.10	+28.0	Laird *et al.*,1981 (19)
63 : 37	hay	R.	58% barley 20% maize cows	-0.83*	+24.7	Strickland and Broster,1981 (20)
			heifers	-0.58*	+15.0	
57 : 43	silage	A.	NA	-0.31*	+24.2	Blair *et al.*,1982a (21)
76 : 24	hay	R.	53% barley	-0.53*	-4.60	Kincaid and Cronrath, 1982 (22)
39 : 61	hay	A.	80% grain	-0.32	+8.80	Bertilsson, 1983 (23)
35 : 65	silage	A.	80% grain	+0.04	+18.4	
			Mean..	-0.41	+14.2	
			Mean A.	-0.10	+22.1	
			Mean R.	-1.14	-3.30	

Fig. 3.1

The effect of concentrate dry matter intake on milk fat content



An explanation for the inconsistent patterns in milk fat content change in response to additional concentrates was given by Sutton (1980). He concluded that depressions in milk fat content are relatively small until the proportion of forage in the diet is reduced to about 40%. Only 9 out of the 23 experiments in Table 3.1 had forage contents, at the highest level of concentrates, less than 40%.

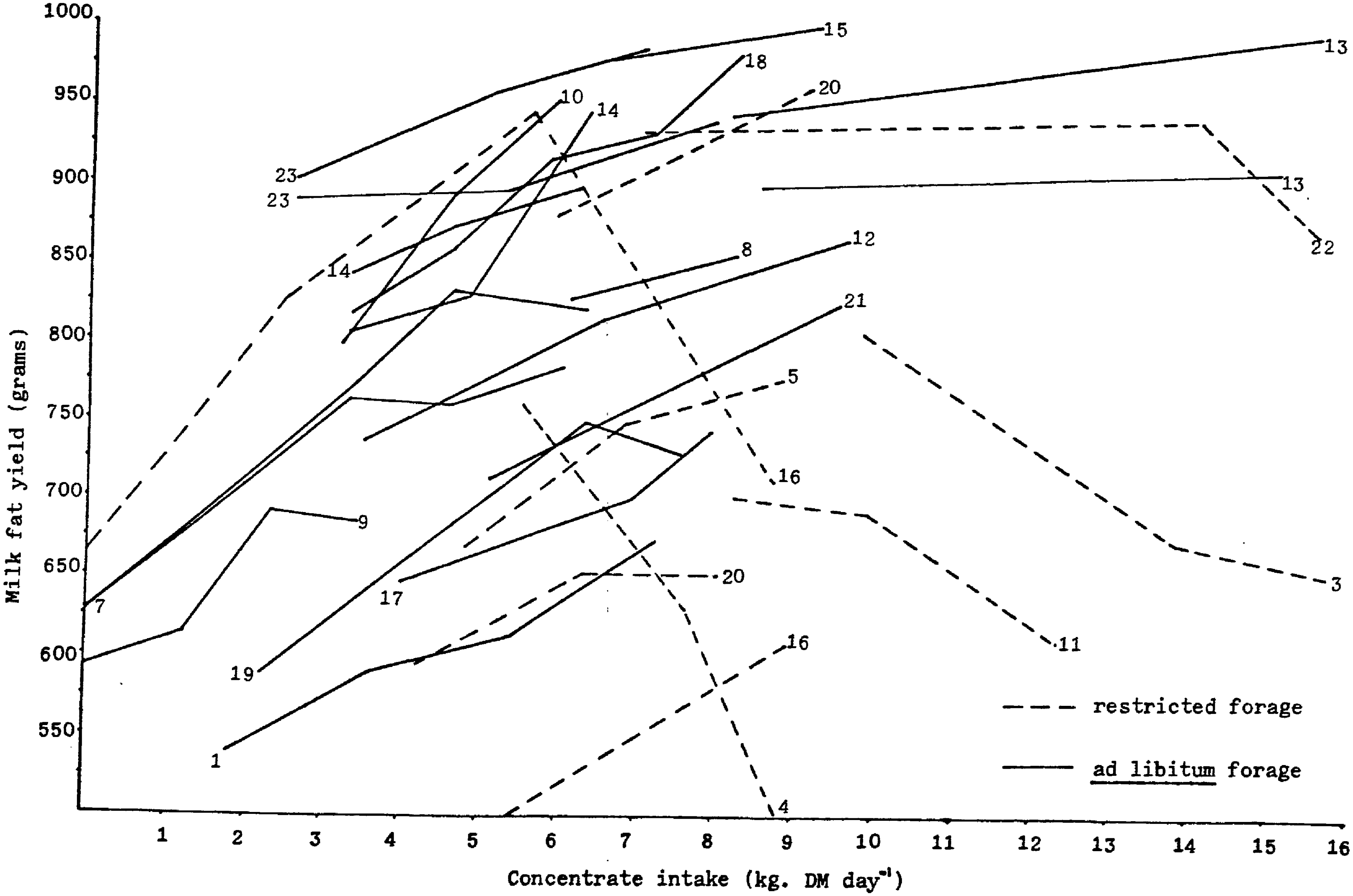
The decrease in milk fat content with additional concentrate feeding is mainly due to the change in concentrate:forage ratio and can occur without an increase in energy intake (Thomas, 1980a).

Milk fat content is related positively to the molar proportions of acetic and butyric acids and negatively to the proportion of propionic acid (Sutton, 1980, 1981). Results indicate that reasonable milk fat contents have only been maintained when the acetic:propionic acid ratio is greater than 3:1 and the acetic + butyric:propionic acid ratio is greater than 4:1 (Flatt *et al*, 1969; Storry and Sutton, 1969; Sutton *et al*, 1979).

Relationships between VFA and milk fat content based on hay diets create uncertainties about extrapolation to silage based diets, as patterns of rumen fermentation found by adding concentrates to hay based diets are different from those of silage diets (Rohr *et al*, 1974; Chalmers *et al*, 1978; Thomas and Castle, 1978).

From the study of 23 experiments (Table 3.1 and Figure 3.2) the general trend was an increase in milk fat yield (g) as concentrate dry matter intake increased. The mean increase in milk fat yield from Table 3.1 was +14.2 g per kg increase in concentrate dry matter intake.

Fig. 3.2 The effect of concentrate dry matter intake on milk fat yield



When the experiments were separated into restricted and *ad libitum* forage, the restricted forage experiments had a mean decrease in milk fat yield of -3.3 g per kg increase in concentrate dry matter whereas the *ad libitum* experiments had a mean increase in milk fat yield of +22.1 g per kg increase in concentrate dry matter.

Oldham and Sutton (1979) reported that total milk fat yield was only reduced with increased concentrates at a 90% concentrate diet and concluded that, providing the concentrate:forage ratio was not greater than 60:40 additional concentrates would increase milk fat yield, as the depression in milk fat content is not severe enough to outweigh the increase in milk yield associated with the increased energy intake. The data presented in Table 3.1 suggest that at a concentrate:forage ratio of 60:40 and with restricted forage, milk fat content is depressed sufficiently to reduce milk fat yield.

The type of concentrate can also affect milk fat content. The extent to which cereals cause a depression in milk fat content is closely related to the rate at which they are fermented in the rumen (Sutton, 1981; Oldham and Sutton, 1979). Maize and sorghum are fermented more slowly when raw than when heated and more slowly than barley or wheat. In consequence they tend to support higher ratios of acetic propionic acid and hence milk fat contents (Sutton *et al*, 1979).

There is an increasing tendency for commercial concentrates to consist of a wide range of by-products and cereals may constitute only a small proportion of the total (Table 3.2, Wilson *et al*, 1981) and it seems probable that these complex concentrates are fermented more slowly than traditional concentrates with high cereal inclusions and in consequence their effects on milk fat content may be less severe (Sutton, 1981).

Table 3.2 Percentage composition of Cattle Compounds 1979-1982

Standard dairy ration	1979 July-Dec. (%)	1982 Jan.-June (%)
Total cereals	40	15
Cereal by-products	29	41
Animal/vegetable proteins	16	19
Other	15	25

(Feed compounder, January 1983)

3.2 Protein content and yield

There is little benefit to be achieved in milk protein content through over-generous feeding, whilst energy deficiencies will reduce milk protein content (Kirchgessner *et al*, 1967; Oldham and Sutton, 1979). There are reports, however, that increases in energy intake *per se* in mid-lactation are generally, although not invariably associated with an increase in milk protein content (Kaufman, 1980; Thomas, 1980a). The effects may depend partly on energy intake and partly on an increase in dietary concentrate:forage ratio. With iso-energetic diets, Chalmers *et al* (1978) reported that milk protein content was consistently increased with the proportion of concentrate in the diet but these effects were small and non-significant.

Protein supplements have been shown to have less of an effect on milk protein content relative to energy supplementation and responses to protein supplements are mainly evident with diets providing 80% or less of the protein requirements (Kaufman, 1980). Figure 3.3 shows the relative effects of protein and energy supply on milk protein content.

Table 3.3 <u>Change in protein content and yield per kg. increase in concentrate dry matter</u>

Concentrate forage ratio at highest level	Forage type A. ad libitum R. restricted	Type of concentrate	Average change in protein content ($g\ kg^{-1}$) & sig.	Average change in protein yield (g) and significance	Reference
45 : 55	hay and silage A.	43% barley 32% beet pulp 10% flaked maize	+0.44**	24.2	Holmes *et al.*, 1960 (1) exp.1
80 : 20	alfalfa hay R.	75% maize 23% soya	+0.02	-17.3	Flatt *et al.*, 1969 (2)
61 : 39	hay and beet pulp R.	40% barley 40% oats	-1.28*	+26.8	Wiktorsson, 1971 (3)
43 : 57 40 : 60	silage A.	barley dried grass	+0.32 +0.37	+18.2 +35.0	Castle and Watson, 1975 (4)
NA	silage A.	36% barley 36% maize	+0.86***	+32.9	Gordon, 1976 (5)
23 : 77	silage A.	groundnut only	+0.17*	+36.8	Castle *et al.*, 1977 (6)
40 : 60	silage A.	35% barley 35% maize	+0.19	+39.9	Gordon, 1977 (7)
53 : 47	mean of all silages A.	35% barley 35% oil cake	+0.05	+24.9	Kristensen *et al.*, 1979 (8)
69 : 31 68 : 32 70 : 30	hay A.	holstein friesian dutch red & white dutch friesian	+0.19 +0.17 +0.12	+10.7 +12.8 +8.30	Oldenbroek, 1979 (9)
40 : 60 42 : 58	silage A.	30% barley high/low uniform	+0.12 +0.37	+16.5 +42.7	Steen and Gordon, 1980a (10)

Continued over..

Table 3.3 continued

Concentrate forage ratio at highest level	Forage type A. ad libitum R. restricted	Type of concentrate	Average change in protein content ($g\ kg^{-1}$) & sig.	Average change in protein yield (g) and significance	Reference
52 : 48	mean of all silages A.	52% barley 21% maize	+0.04	+20.4	Steen and Gordon,1980b (11)
45 : 55 45 : 55	hay late cut hay early cut R.	30% barley	+0.29* +0.36*	+33.9 +24.3	Vinet *et al.*, 1980 (12)
49 : 51	silage A.	NA	+0.47*	+34.0	Blair *et al.*, 1981 (13)
47 : 53	silage A.	NA	+0.37***	+35.3	Gordon, 1981 (14)
52 : 48	silage A.	50% barley	+0.71***	+34.8***	Laird *et al.*, 1981 (15)
57 : 43	silage A.	NA	+0.29**	+35.3	Blair *et al.*, 1982a (16)
76 : 24	hay R.	53% barley	+0.12	+17.4	Kincaid and Cronrath, 1982(17)
39 : 61 35 : 65	hay silage A.	80% grain	+0.25* +0.40**	+17.5 +23.1	Bertilsson, 1983 (18)
		Mean..	+0.28	Mean.. +25.3	
		Restricted	+0.18	+20.6	
		Ad libitum	+0.31	+26.5	

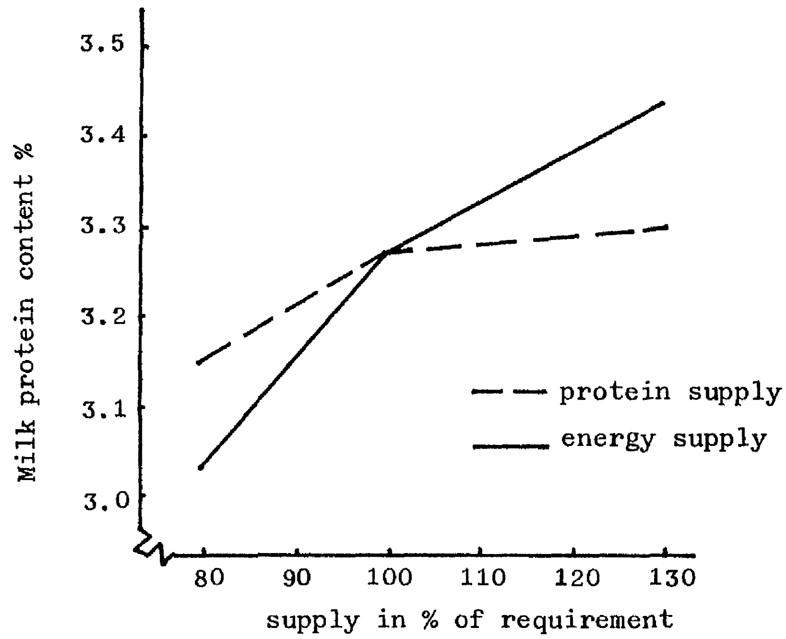


Fig.3.3 Influence of the supply of energy and protein on the milk protein content

(Kaufman, 1980)

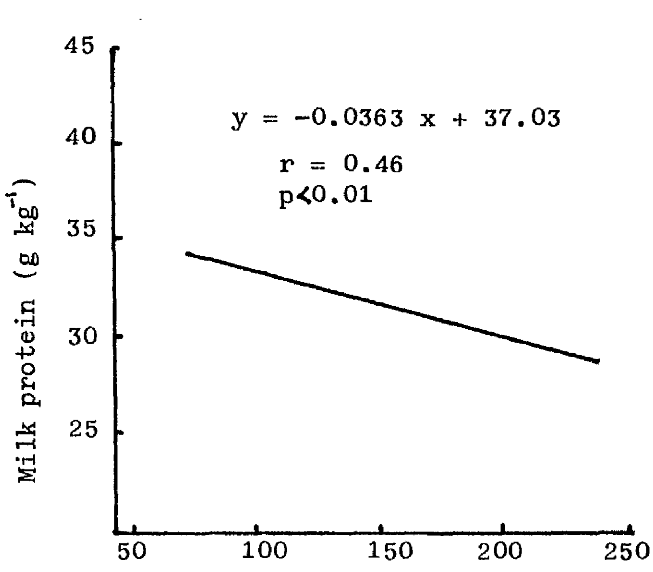
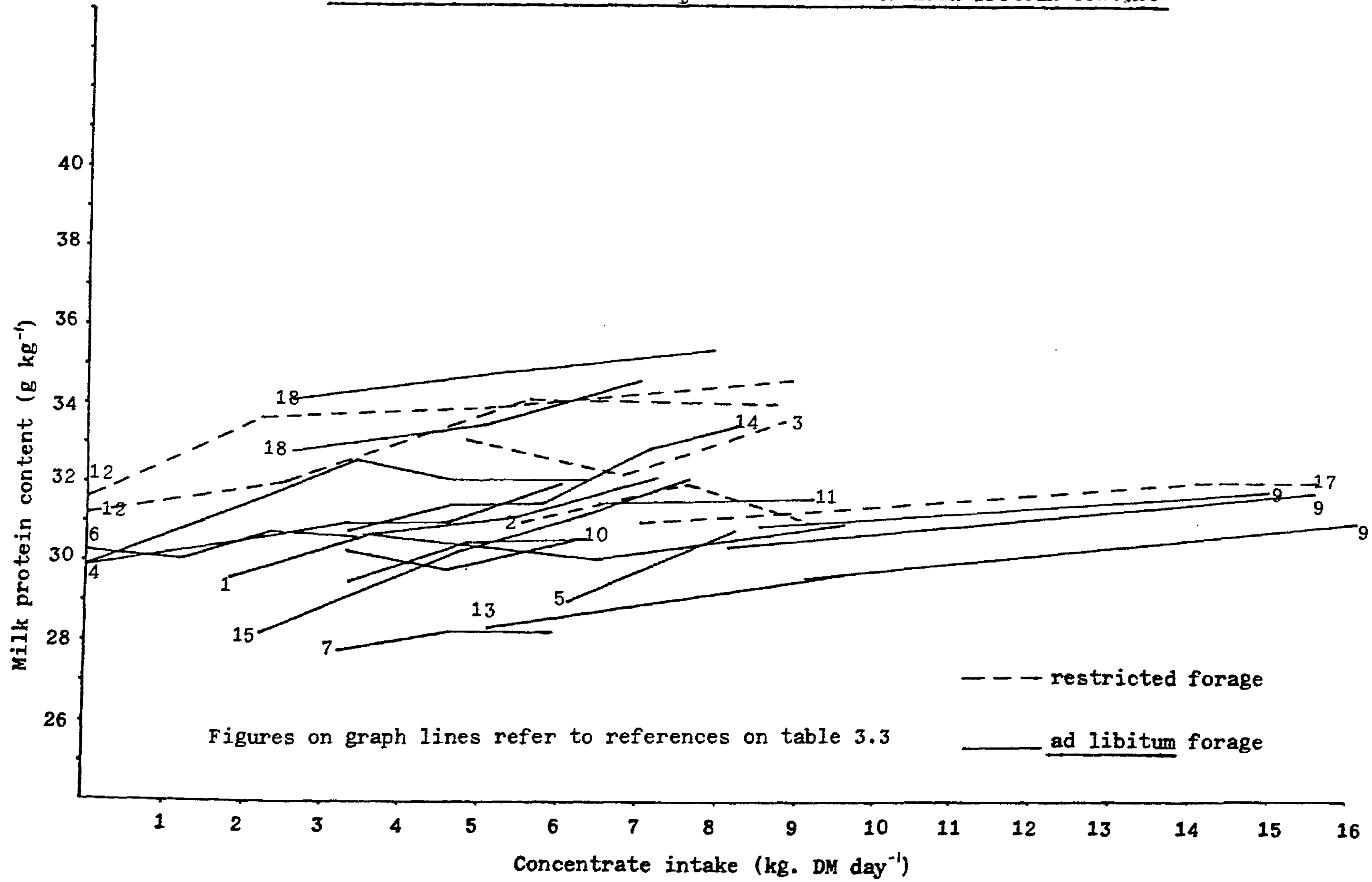


Fig.3.4 The relationship between milk yield (kg/wk) and milk protein content (g kg^{-1}) at 15 weeks after calving.

(Oldham and Sutton, 1979)

Fig. 3.5 The effect of concentrate dry matter intake on milk protein content



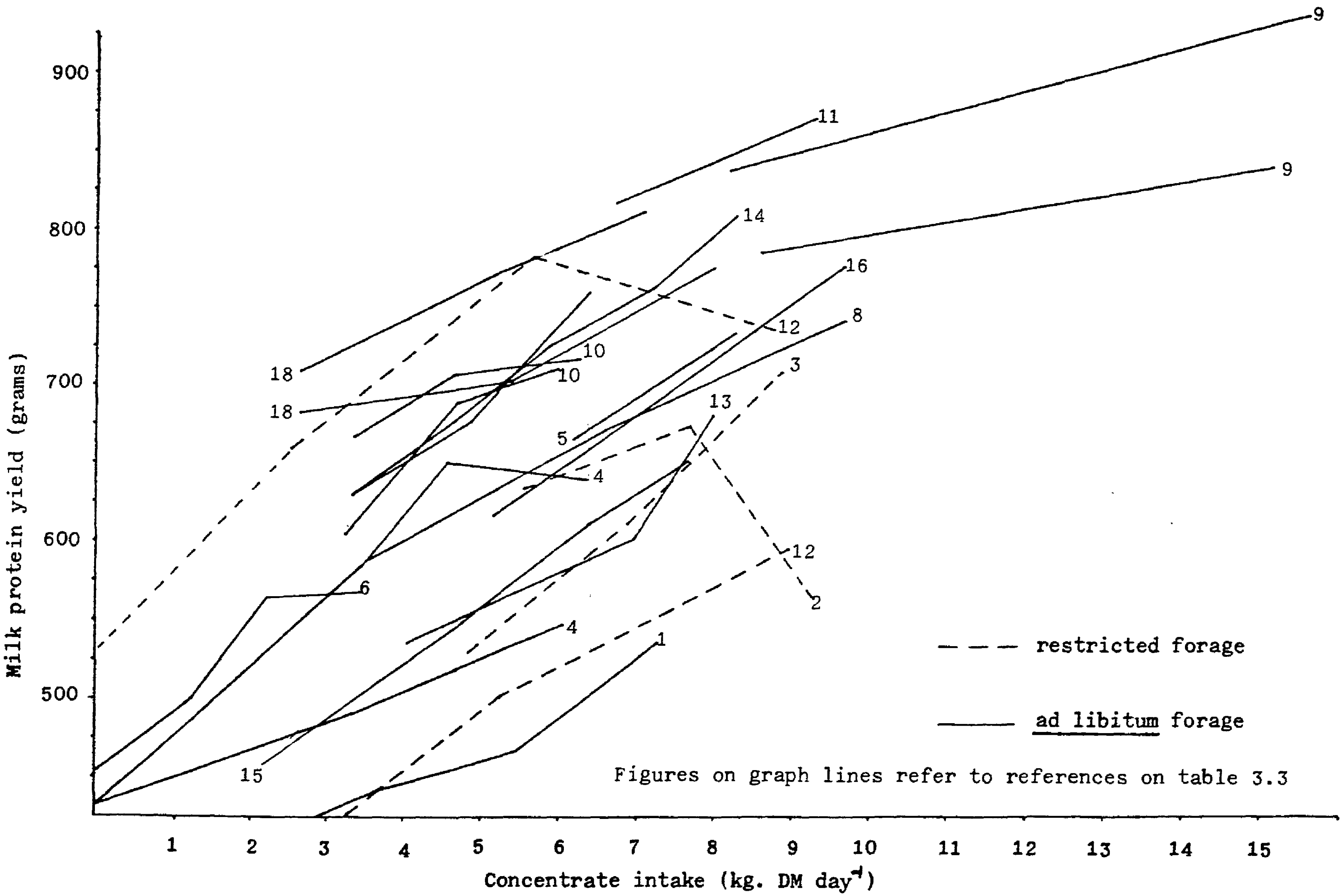
In the 19 experiments listed in Table 3.3 and illustrated in Figure 3.5 the average responses are the combined effects of an increase in protein and energy intake and a change in forage:concentrate ratio. The mean response from Table 3.3 was 0.28 g kg^{-1} per kg concentrate dry matter intake. Cows fed restricted forage had a mean response of 0.18 g kg^{-1} per kg increase in concentrate dry matter whilst cows on *ad libitum* forage had an average response of 0.31 g kg^{-1} per kg increase in concentrate dry matter intake. Half of the experiments in Table 3.3 reported a significant increase in milk protein content and none found a negative response by feeding additional concentrates.

There is a negative correlation between milk yield and protein content, reflecting a greater energy deficit for the higher yielding cow at a given level of energy intake (Oldham and Sutton, 1979; Kaufman, 1980; Figure 3.4).

It has been possible to increase milk protein content with intraruminal infusions of propionic acid with hay based diets (Rook and Balch, 1961). With silage diets, Chalmers *et al* (1980) were unable to significantly increase milk protein content by infusing propionic acid into the rumen and it was reported that silage itself exerts a dominant influence in the rumen even when present in small amounts (Rohr *et al*, 1974; Chalmers *et al*, 1978). The type of cereal concentrate used has been shown to have little effect on milk protein content (Chalmers *et al*, 1978).

The mean response in milk protein yield per kg increase in concentrate dry matter is illustrated in Figure 3.6 and was found to be 25.3 g day^{-1} from Table 3.3. The response for *ad libitum* forage and

Fig.3.6 The effect of concentrate dry matter intake on milk protein yield



Figures on graph lines refer to references on table 3.3

restricted forage experiments was 26.5 g day^{-1} and 20.6 g day^{-1} respectively per kg increase in concentrate dry matter. The experiments based on restricted forages (all hay) in Table 3.3 had a greater mean concentrate:forage ratio at the highest level of concentrate supplementation, 61:39, compared with the *ad libitum* forage experiments (82% silage diets) of 48:52.

In practice a move to higher concentrate levels may increase propionate production, but the main effects will be in milk yield and the main milk protein benefits will be seen in milk protein yields and not milk protein content (Oldham and Sutton, 1979). This is clearly illustrated in Figures 3.5 and 3.6 in that additional concentrates result in a greater response in milk protein yield than in milk protein content.

CHAPTER 4 - THE EFFECT OF CONCENTRATES ON ENERGY PARTITION

At a given stage of lactation, as the level of concentrate/energy intake is raised above the maintenance requirement, the incremental response in terms of milk yield becomes progressively smaller and that proportion of energy partitioned toward body reserves gets larger (Broster and Alderman, 1977; Owen, 1981; Bines and Hart, 1982, see Figure 4.1 and 4.2).

The complex mechanisms controlling this partition have been discussed (Thomas, 1980a; Bines and Hart, 1982). They suggest that the primary regulatory mechanism is endocrinological involving the blood concentrations of key hormones regulating metabolism, e.g. insulin, prolactin and growth hormone and the effects of nutrition on energy partition are suggested as being secondary operating in part through the influence of nutrition on hormonal secretions.

Energy partition is affected by a number of factors including: level of feeding, ration composition, stage of lactation, stage of maturity, genetic potential and frequency of milking (Broster, 1972; Thomas, 1980a; Swan, 1981).

Increased levels of feeding up to four times maintenance requirements are associated with some reduction in organic matter digestibility this being greater for diets containing a greater proportion of concentrates (Ekern, 1972b Trimberger *et al*, 1972; Thomas and Rook, 1981).

For diets with high concentrate:forage ratios, a greater proportion of their energy is partitioned toward body reserves than to milk

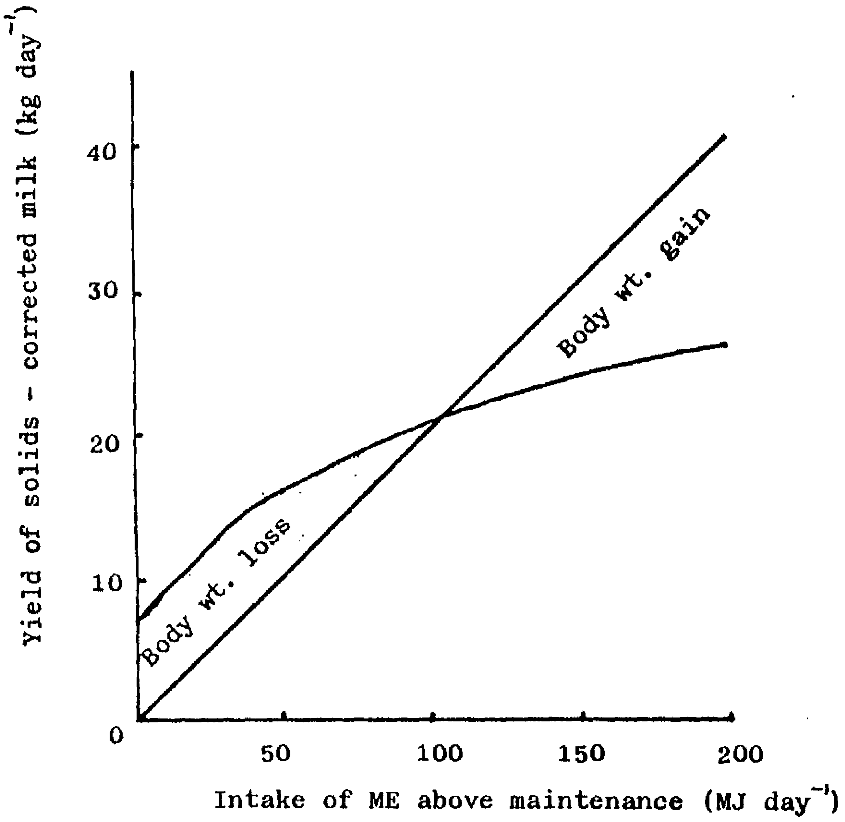


Fig. 4.1 The effect of intake of metabolizable energy (ME) on milk output and body weight change.

(Broster and Thomas, 1981)

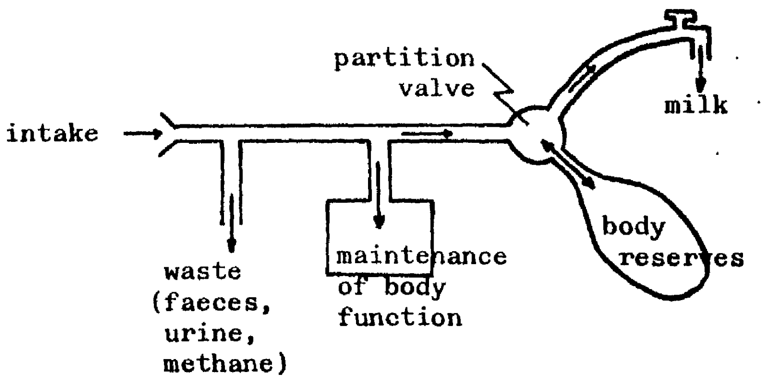


Fig. 4.2 Model cow

(Owen, 1981)

production (Ronning and Laben, 1966; Broster *et al*, 1977; Sutton *et al*, 1977).

Calorimetric evidence and studies on VFA changes associated with high concentrate:forage ratios show that the factors associated with a depression in milk fat content may be linked to the increased partition of energy toward body reserves (Broster *et al*, 1978; Broster and Thomas, 1981).

A lower pH, a higher ratio of propionic acid to acetic acid within the rumen, a reduction in the numbers of cellulolytic and fibre digesting bacteria and an increase in lactic acid and propionic acid-producing bacteria are all characteristic of diets containing very high proportions of concentrates (Flatt *et al*, 1969; Broster *et al*, 1977; Thomas and Rook, 1981). These changes are associated with increased blood insulin levels which switches fat synthesis from mammary to adipose tissue (Hart *et al*, 1979; Bines and Hart, 1982).

The crude protein content of the concentrate and total diet can affect the partition of energy. Diets of higher crude protein content cause a greater proportion of energy to be partitioned toward milk production than toward body tissue gain (Gordon and Forbes, 1970; Oldham, 1980; Broster and Oldham, 1981). However, Oldham (1980) suggests that these relationships are by no means conclusive and should be the target for future research.

The higher yielding cow partitions a greater proportion of ME intake towards milk production than to body reserves, the converse occurring with the low yielding cow providing both are given equal feed intakes (Broster *et al*, 1975 a, 1975 b; Wiktorsson, 1979; Broster and

Thomas, 1981). Broster *et al* (1975) reported a significant negative relationship between milk yield and liveweight change with cows fed the same quantity of feed.

When forage is offered *ad libitum* the higher yielder, on a given concentrate intake, has a higher intake of forage than the lower yielder (see Figure 2.3). The high yielder's ME intake above maintenance, when additional concentrates are given, is greater than the low yielder's and it is therefore reasonable to suggest that they both partition a similar amount of energy toward body reserves with a given increase in concentrate input (Broster and Thomas, 1981).

There are phases of mobilisation and deposition of body fat and protein throughout a lactation as well as growth to a mature weight at the fourth lactation (Broster, 1972; Bines, 1976; Østergaard and Thysen, 1982 and see Figures 4.3 and 4.4). Such factors should be considered when quantifying responses to concentrates. Additional concentrates in early lactation reduce liveweight loss, whereas in mid and late lactation they increase liveweight gain.

A study of 15 experiments (Table 4.1, Figure 4.5) where a range of concentrate levels had been compared, shows that for every kg increase in concentrate dry matter intake the average liveweight change was +0.08 kg day^{-1}. Figure 4.5 indicates that at very low levels of concentrate feeding net losses in liveweight occur which is in agreement with Blair *et al* (1981) and Castle (1982).

In early lactation when voluntary feed intake cannot meet energy requirements the cows' body reserves are mobilised to make good the deficit, whereas in mid and late lactation when voluntary feed intake

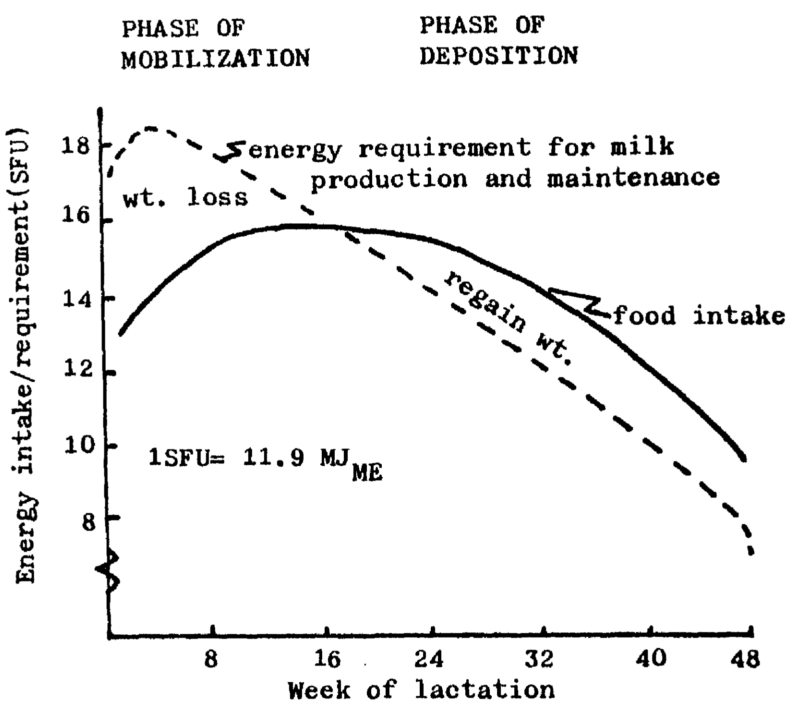


Fig. 4.3 Voluntary foodintake and food requirement through lactation for a high yielding cow

(Østergaard and Thysen, 1982)

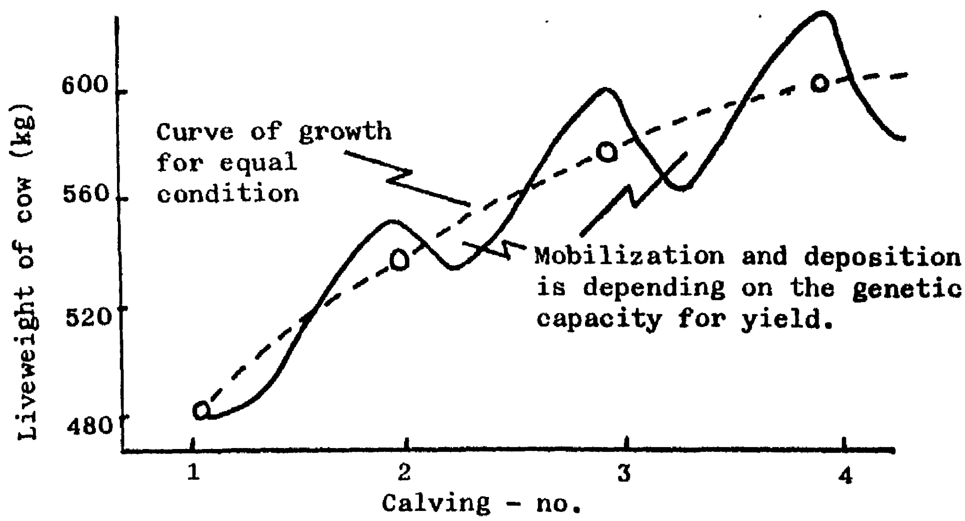


Fig. 4.4 Weight and growth of the dairy cow from 1st to 4th calving.

(Østergaard and Thysen, 1982)

Table 4.1 Change in liveweight per kg. increase in concentrate dry matter

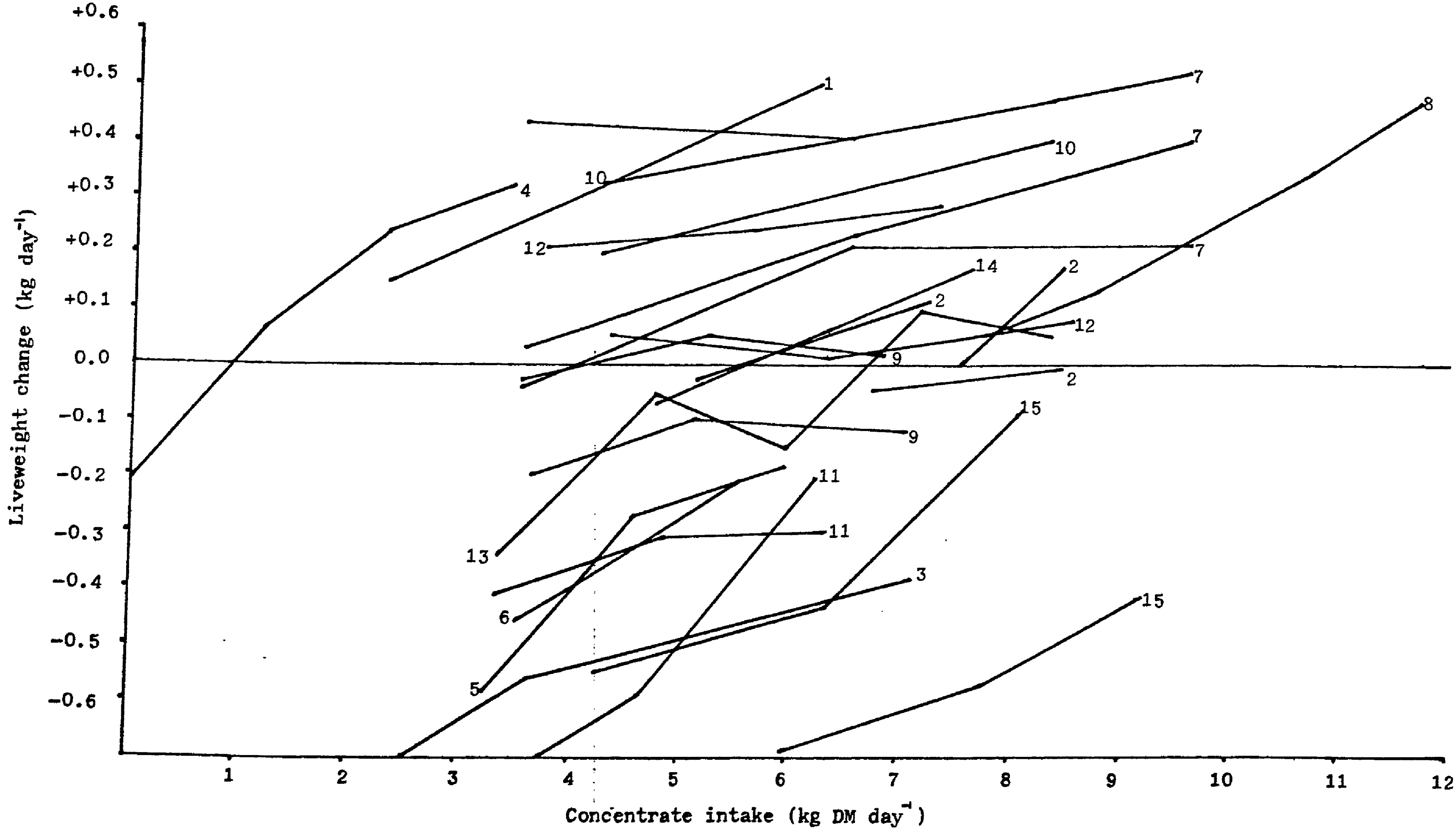
Concentrate forage ratio at highest level	Forage type A. *ad libitum* R. restricted	Stage of lactation	Type of concentrate	Average change in liveweight (kg day^{-1}) and significance	Reference
44 : 56	silage and hay A.	8 - 20 wks.	NA	+0.09	Foot and Line, 1966 (1)
45 : 55 54 : 46 56 : 44	silage A.	3 - 22 wks.	NA exp 0 exp 1 exp 2	+0.07* +0.02 +0.19	Ekern, 1972a (2)
52 : 48	silage A.	1st 8 wks.	NA	+0.07	Gleeson, 1972 (3)
23 : 77	silage A.	7 - 23 wks	groundnut only	+0.16*	Castle *et al.*, 1977 (4)
40 : 60	silage A.	1st 85 days	35% barley 35% maize	+0.15*	Gordon, 1977 (5)
NA	hay R.	1st 20 wks	NA	+0.13*	Johnson, 1977 (6)
53 : 47	silage high D med D A. low D	14 - 23 wks	35% barley 35% oil cakes	+0.01 +0.06 +0.04	Kristensen *et al.*, 1979 (7)
65 : 35	silage A.	1 - 24 wks	35% barley 35% oil cakes	+0.10	Østergaard, 1979 (8)

Continued over...

Table 4.1 continued

Concentrate forage ratio at highest level	Forage type A. *ad libitum* R. restricted	Stage of lactation	Type of concentrate	Average change in liveweight (kg day^{-1}) and significance	Reference
43 : 57 45 : 55	silage high D / low D A.	7 - 23 wks	41% maize	+0.02 +0.02	Castle *et al.*, 1980 (9)
49 : 51 50 : 50	silage high D / low D A.	6 - 12 wks	NA	+0.04* +0.05*	Moisey and Leaver, 1980 (10)
40 : 60 42 : 58	silage A. high/low uniform	1st 100 days	36% barley 36% maize	+0.20*** +0.04***	Steen and Gordon, 1980a (11)
49 : 51	silage A. cows heifers	2 - 25 wks	NA	+0.01 +0.02	Blair *et al.*, 1981 (12)
47 : 53	silage A.	1st 170 days	NA	+0.08*	Gordon, 1981 (13)
52 : 48	silage A.	1st 21 wks	50% barley	+0.08**	Laird et al., 1981 (14)
63 : 37	hay R.	wks 3 - 10	58% barley cows 20% maize heifers	+0.08* +0.12*	Strickland and Broster, 1981 (15)
			Mean..	+0.08	

Fig. 4.5 The effect of concentrate dry matter intake on liveweight change (kg day^{-1})



can meet energy requirements, energy is stored as body reserves (Flatt *et al*, 1969; Broster, 1975; Broster and Alderman, 1977). The amount of fat and other body reserves mobilised in early lactation varies according to the amount of reserves, genetic potential, and the magnitude of the energy deficit (Bines and Hart, 1982; Johnson, 1982).

Liveweight change *per se* can be misleading as an accurate measure of body tissue anabolism or catabolism, due to variations in gut fill and body tissue hydration (Ronning and Laben, 1966; Moe *et al*, 1971; Johnson, 1983).

The cow has a potential to lose 30-50 kg of empty body fat and 0-10 kg of empty body protein (Moe *et al*, 1971; Bines and Hart, 1982). Estimates of the energy value of weight changes have been made (Moe *et al*, 1971; MAFF, 1975; ARC, 1980; Alderman *et al*, 1982). ARC (1980) reviewed all previous data and made no firm conclusions, but suggested the previous recommendation of 28 MJ of ME per kg liveweight loss (MAEF, 1975) should be increased to 34 MJ of ME per kg liveweight loss.

It is possible to estimate body tissue loss by visual observation (Moe *et al*, 1971; Frood and Croxton, 1978). Condition scoring on a scale of 0 - thin to 5 - fat was devised by Mulvany (1977) to estimate the relative changes in external body fat reserves.

The efficiency with which metabolisable energy (ME) is used for milk production and body tissue deposition in the lactating animal is similar at approximately 60% (Van Es, 1976) and althouth the efficiency with which tissue energy is converted to milk energy is high at around 80%, the overall efficiency (80 x 60 = 48%) is lower than the direct conversion of food ME to milk at 60% (Van Es and Van Honing, 1979).

These important relationships must be considered when developing suitable feeding strategies for dairy cows (Bines, 1976).

CHAPTER 5 - PATTERN OF CONCENTRATE ALLOCATION

'Pattern of concentrate allocation' refers to the method by which a given gross quantity of concentrates is distributed between individual cows and between different stages of lactation. It is essential that any planned comparisons of different patterns of allocation between groups of cows does not confound pattern with level of concentrate *per se*. Various patterns of concentrate allocation to achieve a total intake of 1·2 tonnes over 20 weeks is shown in Figure 5.1 (Broster and Thomas, 1981).

Feeding broadly commensurate with milk yield is probably the most common method of allocating concentrates. This system is based on previous studies using maintenance diets of hay, and concentrates for production (Woodman, 1957; Blaxter, 1956; Burt, 1957). Under such a regime proportionately more concentrates are fed in early lactation and proportionately more to higher yielding animals. This approach has recently been questioned in view of increasing experimental evidence that such complex systems of allocation are unnecessary (Johnson, 1979; Østergaard, 1979; Steen and Gordon, 1980 a; Moisey and Leaver, 1982).

These studies have questioned:

1. whether a greater proportion of the concentrates fed during the lactation should be fed in early lactation, and/or

2. whether a greater proportion of concentrates fed to the herd should be allocated to cows of higher milk yield potential.

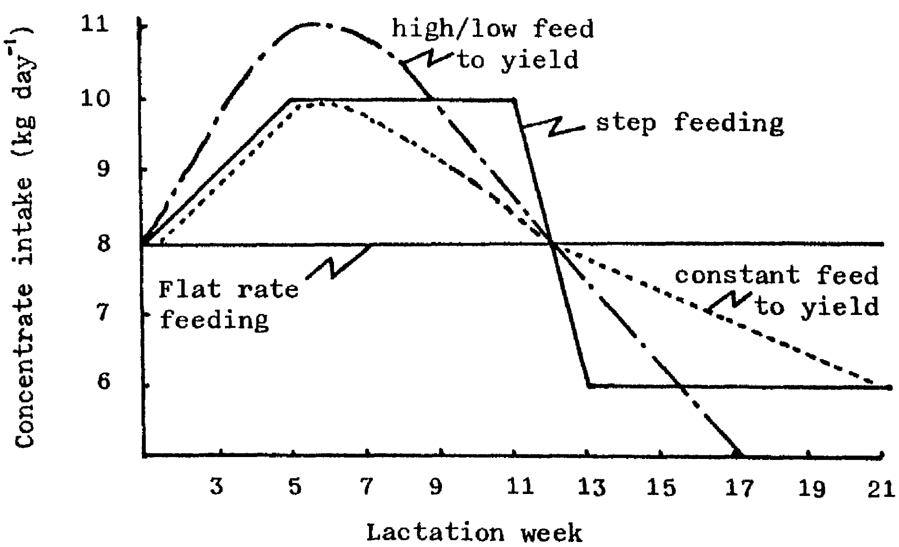


Fig. 5.1 Four different patterns of concentrate allocation all using 1.2 tonnes of concentrate over the 1st 20 wks of lactation

(Broster and Thomas, 1981)

5.1 Stage of lactation

Stage of lactation has been used as a criterion for allocating concentrates (Broster, 1970, Broster *et al*, 1969, 1975). Arguments in favour of allocating more concentrates in early lactation are based on the events characteristic of the lactation cycle after calving, i.e. the slow increase in voluntary food intake causing a delay between peak milk yield and maximum voluntary food intake, and the factors responsible for controlling feed intake and partition of nutrients (Broster, 1975; Bines, 1976; Forbes, 1977).

The factors controlling energy partition have been discussed in Chapter 4 and indicate that in early lactation body tissues are mobilised to meet the energy requirements of peak lactation, whereas in mid and late lactation energy is stored as body reserves (Flatt *et al*, 1969).

Studies on voluntary feed intake indicate that intake is controlled by a combination of physical and metabolic factors (Balch and Campling, 1962; Baumgardt, 1970; Campling, 1980). The extent to which physical and metabolic control influences intake during different stages of the lactation has important implications on the most appropriate pattern of concentrate allocation.

With diets based mainly on forage, physical factors are likely to control forage intake (Campling, 1969; Jarrige *et al*, 1974; Campling, 1980, Chapter 1). However, forage is rarely the sole diet for lactating cows and most forages are supplemented with varying amounts of concentrates (see Chapter 1).

With hay/concentrate diets of less than about 70% digestibility (DMD), voluntary feed intake is limited by physical factors such as:

rumen capacity, rumen distension, and the rate of passage of forage through the digestive tract (Osbourn, 1967; Jarrige *et al*, 1974, Campling, 1980). Factors controlling silage intake are much more complex and poorly understood, being also influenced by factors other than rumen fill (Wilkins *et al*, 1971, Demarquilly, 1973; Jarrige *et al*, 1974; Hermansen, 1980).

As the proportion of concentrates in the diet increases resulting in diet digestibilities of over 70% (DMD), intake begins to be limited by factors other than rumen fill and rate of passage and these are referred to as metabolic (Baumgardt, 1970; Bull *et al*, 1976; Baille and Della Fera, 1981). Metabolic control is characterised by the animal maintaining a constant energy intake irrespective of further increases in dietary digestibility, achieved by the animal reducing total dry matter intake (Conrad *et al*, 1964, Baumgardt, 1970; Ellis, 1978).

Where physical control of intake is limiting in early lactation it would be reasonable to argue that feeding a diet of higher nutrient density may improve total dry matter intake and performance. If metabolic factors were controlling intake any attempt to increase nutrient density would be unlikely to improve ME intake or performance.

There is little conclusive evidence that intake in early and mid lactation, at dietary dry matter digestibilities exceeding 70%, is totally controlled by metabolic factors. Physical restrictions limit maximum energy intake even with diets up to 80% dry matter digestibility in the first few weeks of lactation (Forbes, 1977) and observations that high concentrate:forage ratios reduce the interval between peak yield and peak intake (Bines, 1976, Broster *et al*, 1977) is further evidence to confirm this. When energy balance is achieved there is little critical evidence to show that the animal maintains a constant energy intake, moreover it would seem that its energy intake continues to rise only to partition this increase in energy intake toward body reserves and become fatter, (Ronning and Laben, 1966; Broster *et al*, 1977; Forbes, 1977). Fatness and/or metabolic upsets reduce intake only at extreme concentrate:forage ratios and low levels of fibre intake (Broster *et al*, 1981).

The direct conversion of food energy to milk is biologically the most efficient (Van Es, 1976), and therefore it is beneficial, if possible, to meet the energy demands of early lactation directly from feed intake (Bines, 1976). Challenge feeding or *ad libitum* feeding of concentrates in early lactation has been studied as a means of maximising energy intake in early lactation (Ekern, 1972; Trimberger *et al*, 1972; Kincaid and Cronrath, 1982). Most studies on *ad libitum* concentrate feeding report increased total feed intakes, no significant increases in milk production, and liveweight loss reduced. This implies that too high a level of concentrates may only result in energy being partitioned toward body reserves (Chapter 4) not increasing milk yield (Chapter 2) and depressing milk fat content (Chapter 3). (Kesler and Spahr, 1964; Ronning and Laben, 1966; Sutton *et al*, 1977).

Complete diets of constant nutrient density throughout early and mid lactation have been compared with complete diets of relatively higher nutrient density in early lactation and relatively lower nutrient density in mid lactation (Akinyele and Spahr, 1975; Everson *et al*, 1976; Wray, 1981). They all reported little benefit, in any aspect of performance, by feeding a diet of relatively higher nutrient density in early lactation. Moseley *et al* (1976) also reported detrimental fluctuations in energy intake and milk production to abrupt changes in con-

Table. 5.1 A comparison of milk production from different patterns of concentrate allocation

Forage type A. ad libitum R. restricted	High/low pattern	Period of measurement	Uniform or *low/high pattern	High/low minus uniform and significance	Reference
hay R.	17.95	experimental (kg day^{-1})	17.18	+0.77 NS	Broster et al., 1969* (heifers)
	5069	305 days (kg)	4606	+463 NS	
complete diet A.	6394	total lactation (kg)	6572	-178 NS	Everson et al., 1976 (cows)
silage A.	20.2	weeks 1-36 (kg day^{-1}) all high/ low vs all uniform	20.3	-0.10 NS	Østergaard, 1979 (cows & heifers)
silage A.	1682	indoor period (kg)	1681	+1.0 NS	Steen and Gordon, 1980a (cows)
	4893	total lactation (kg)	5021	-128 NS	
hay R.	2244	weeks 3-18 cows	2159	+85 NS	Strickland and Broster, 1981
	1765	total (kg) heifers	1757	+8 NS	
silage A.	3257	indoor period (kg)	3311	-54 NS	Gordon, 1982 (heifers)
	4739	305 days (kg)	4800	-61 NS	
complete diet A.	3241	experimental (kg)	3398	-157 NS	Wray, 1982 (heifers)
	4954	305 days (kg)	5148	-194 NS	
hay R.	4127	experimental (kg)	4222	-95 NS	Johnson, 1983 (cows)
	6908	total lactation (kg)	7078	-170 NS	
			Mean +/- =	-30	

centrate:forage ratio of complete diets.

Where forage is offered with concentrates fed separately in controlled amounts, high/low patterns of concentrate feeding have also been compared with uniform patterns (Table 5.1: Østergaard, 1979; Steen and Gordon, 1980 a; Gordon, 1982). When milk output has been corrected for total solids content or for energy content, Johnson (1983) and Thomas (1983) report no differences between patterns of concentrate allocation at any point during the experiments. There was a tendency for the uncorrected milk yields on the high/low patterns to have a greater peak milk yield and thereafter a much poorer persistency compared to the uniform patterns (Steen and Gordon, 1980 a; Johnson, 1983) which produced more milk during the latter part of the experiments.

This superior persistency of the uniform patterns of concentrate allocation compensating totally for the higher peak milk yields on the high/low patterns contradicts previous reports (Broster, 1972, 1976, Broster *et al*, 1975). They reported that variations in peak milk yield accounted for 83% of the variation in total lactation yield, whereas variation in persistency accounted for only 21% of the variation in total lactation yield and that total lactation yield was likely to be increased by 200-220 kg per kg increase in peak milk yield.

Broster *et al* (1969, 1975) also argued that by feeding proportionately more concentrates in early lactation the residual effects in later lactation were approximately four times that of the immediate effects (see Table 2.2). These contradictions have partly been explained by Broster and Thomas (1981) taking into account forage qualities and whether forage was offered *ad libitum* or restricted. Broster and Thomas (1980) report that milk yield responses to concentrates are greater with fixed basal diets (see Chapter 2.1) through the lack of any substitution effects. Also Broster *et al* (1969, 1975) and Gleeson (1970) did not compare a high/low with a uniform treatment. A more extreme comparison (Broster *et al*, 1969; Gleeson, 1970) between a high/low and a low/high treatment was studied, with heifers only, which in conjunction with restricted forage meant a much more severe restriction in early lactation than a uniform treatment would have given.

Broster and Thomas (1981) claim that residual effects are only observed when low and medium planes of nutrition are offered in early lactation whereas with *ad libitum* high quality forage diets residual effects are unlikely to occur (see Chapter 2.7).

5.2 Yield potential

Milk yield has been shown to have a significant relationship with forage dry matter intake and total intake (Bines, 1976, 1979, 1980; Leaver, 1980; Greenhalgh and Reid, 1982). The response in terms of total dry matter intake to a kg increase in milk yield is 0.1-0.36 kg day. Wood *et al* (1980) found a significant positive correlation between milk yield and total liveweight. Liveweight or size of cow is the animal factor having the greatest impact on intake (Bines, 1979, 1980; ARC, 1980). High yielding cows in early-mid and late lactation have an increased appetite compared with lower yielders, ranging from 0.1-0.4 kg day^{-1} depending on the composition of their diet (Monteiro, 1972; Journet and Remond, 1976; Broster and Alderman, 1977).

Where animals are treated as individuals an attempt is made to maximise the energy intake of the high yielding cow up to a point of optimal M/D in the diet (Broster, 1980; Leaver, 1980). The optimum M/D could be defined as the point at which metabolic control takes over from physical control and maximum ME intake is achieved with the lowest proportion of concentrates.

At a given level of concentrate feeding the higher yielding cow will consume more forage and therefore have a diet with a lower proportion of concentrates. There is therefore an argument for feeding proportionately more concentrates to the higher yielder to optimise its M/D (Leaver, 1980). This optimum M/D may vary according to stage of lactation as a given energy intake can be achieved at lower M/D in late lactation when appetite or rumen fill is not limiting.

The milk yield responses to additional concentrates have been discussed for fixed versus *ad libitum* forage feeding, lactation effects and cow potential effects in Chapter 2. The conclusions indicated that with fixed feeding the milk yield response to extra concentrates was directly proportional to current yield and this relationship applied equally to cows of different potential and to an individual cow between different stages of lactation (Broster and Thomas, 1981). With *ad libitum* feeding, the response to concentrate dry matter is the same amongst cows of different current milk yields. Thomas (1980) however, found that if input was expressed as intake of ME there was a trend for high yielders to show a greater milk yield response. It has also been shown that the effects of cow potential can only be fully exploited at high levels of concentrates (Strickland and Lessells, 1971; Johnson, 1979; Altman, 1980).

Careful attention to experimental design is essential to avoid problems in interpreting results of experiments concerned with whether the performance of a group of cows is significantly improved by feeding proportionately more to the higher yielding animals (Broster, 1970, 1972; Altman, 1980). If concentrates are offered at a constant amount per kg of milk produced, any benefits in performance will be a combination of feeding more in early lactation when the yields of all animals are high and feeding proportionately more to the higher yielders (Broster, 1970, 1972). Consequently, experiments need to be designed with pre-determined rates of feeding to cows of different yield potential (Johnson, 1979; Moisey and Leaver, 1982).

A further complication is defining milk yield potential (Altman, 1980). Previous lactation yield was found to be of little benefit since correlation between lactations is only 0.6 (Broster and Thomas, 1981). Milk production during a standard feeding period of 14 days post-calving is one suitable measure of future milk yield potential (Strickland and Lessells, 1971; Johnson, 1977; Altman, 1980).

Where cows of pre-determined yield potential have been differently fed varying levels of concentrate over a major part of lactation, no significant improvements in total performance have been reported compared with a simple uniform allowance to all animals irrespective of milk yield potential (Johnson, 1979; Moisey and Leaver, 1982).

Even when allocating concentrates at a constant rate per kg, or feeding at a greater rate per kg milk produced in early lactation and a lower rate in later lactation, little or no benefit compared with a uniform pattern of a similar total quantity of concentrates has been observed (Wiktorsson, 1971; Johnson, 1977, Østergaard, 1979). The most striking feature of these experiments was the much greater post peak milk yield decline for the "feeding to yield" treatments (Østergaard and Thysen, 1982).

A simple alternative to feeding individuals differential amounts of concentrates is to have cows grouped according to milk yield. In these circumstances changing cows from one group to another has detrimental effects of feed intake and milk yield as a result of the abrupt change in concentrate:forage ratio and social environment (Moseley *et al*, 1976; Coppock, 1977; Bryant, 1980; Coppock *et al*, 1981).

The range of yield potential that can be accomodated by one single group ration has been suggested as 5 to 7.5 kg milk yield about the mean yield of the group (Broster and Thomas, 1981). Such claims have not been critically examined and must remain tentative since the range of yield potential that can be accomodated depends on forage quality and the buffering capacity of the cow.

The uniform pattern of concentrate distribution relies on the higher yielding cow consuming large amounts of forage to adjust for a relatively lower intake of concentrates in early lactation. Previous experiments have used high D value silages (Østergaard, 1979; Steen and Gordon, 1980 a; Moisey and Leaver, 1982). No information is available for poorer quality forages where differential feeding may result in improved average performance.

EXPERIMENTAL

CHAPTER 6

EXPERIMENT 1 A COMPARISON OF THREE PATTERNS OF CONCENTRATE ALLOCATION FOR AUTUMN - CALVING COWS AND HEIFERS OFFERED SILAGE *AD LIBITUM*

Introduction

Previous studies with restricted forage feeding have suggested that peak milk yield is the key to total lactation performance and that output of milk during the lactation is likely to change by 150 to 200 kg per kg change in milk yield at this time (Blaxter, 1950; Broster and Strickland, 1977; Broster, 1975). These studies also report that total lactation response to early lactation feeding increases with yield potential.

Recent experimental evidence appears to conflict with the idea of feeding to yield and suggests that a uniform pattern of concentrate allocation will produce similar average levels of performance (Johnson, 1977, 1979, 1983; Østergaard, 1979; Steen and Gordon, 1980a). This apparent conflict may partly be explained by differences in forage quality in the different trials and also because much of the earlier work, e.g. Broster *et al* (1969, 1975) was with restricted forage whilst recent experiments have been with *ad libitum* high quality forage.

Further clarification is needed to indicate whether it is necessary to feed cows proportionately more concentrates in early lactation and/or feed proportionately more to higher yielding cows. The simple alternative is to have a uniform pattern of concentrate allocation for all cows.

This experiment had the objective of examining three approaches to concentrate allocation for cows and heifers offered good quality silage *ad libitum*.

MATERIALS AND METHODS

Livestock and management

Forty-eight British Friesian animals were used, including 24 cows and 24 heifers. Their calving dates ranged from 27 August to 18 September 1980 (cows) and 27 August to 22 October (heifers). The experiment ran from September 1980 to March 1981.

All the cows calved at grass, and six heifers which had not calved by the end of September were calved indoors in calving boxes. After calving, cows and heifers were grouped separately in a cubicle building, milked twice daily at 05.15 h and 15.30 h and offered silage *ad libitum* once daily from a forage box in a feed passage.

The animals began their experimental period on average 14 days after calving (range 10-17 days). During this 14 day period both cows and heifers were fed 6 kg day^{-1} of the concentrate shown in Table 6.10 for the first week and 8 kg day^{-1} for the second week. All animals received 1 kg of concentrates in the parlour at each milking with the remainder fed through programmed out-of-parlour feeders sited in the housing area. (Both in and out-of-parlour feeders were calibrated at weekly intervals). The initial 14 day values for milk yield, live-weight, condition scores and parity can be seen in Appendix 1.

Table 6.10 Chemical Composition of Feeds (g kg^{-1} DM)

	Silage		Concentrate
	1st cut	2nd cut	
Oven dry matter	229	217	859
Crude protein	169	179	191
Organic matter	888	878	894
DOMD (*in vitro*)	655	653	748
Ammonia N as % of total N	11.8	8.9	-
Predicted ME (MJ kg^{-1})	10.5	10.5	13.1*
DCP	113	123	162
Calcium	5.9	7.0	11.4
Phosphorus	4.1	4.2	6.2
Magnesium	2.2	2.6	8.5

* Corrected ME assuming oil content of 50 g kg^{-1}.

Table 6.11 Physical Ingredients of Concentrate (kg 1000 kg^{-1})

Barley	145
Maize	320
Wheat feed	95
Maize gluten	100
Maize germ	25
Maize grains	45
Soya	150
Fish meal	25
Fat supplement	12.5
Molasses	50
Limestone	6
Dicalcium phosphate	9
Salt	8
Vitamin supplement	5
Calcined magnesite	4.5
	1000 kg

Diets

Two cuts of a perennial ryegrass sward were harvested on 27 May and 10 July 1980. 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 Ltd., 850 g formic acid l^{-1}) at 2.2 litres tonne^{-1}. The silage was ensiled in two unroofed silage bunkers and sheeted with black polythene. All animals were offered these silages during their 20 weeks on experiment. The primary growth was used during weeks 1 to 12 of the experiment and the regrowth between weeks 13 and 25. The concentrate supplement was in the form of a 9 mm pellet. The chemical composition of the silages and the concentrate and the physical ingredients of the concentrate are given in Tables 6.10 and 6.11 respectively.

Treatments

The animals were allocated to the three treatments as they reached 14 days post-calving. The treatment groups of 8 cows and 8 heifers were balanced according to the milk yields, liveweights and condition scores during this initial period. Mean treatment group allocations of concentrate over the 20 week period were 1260 kg fresh weight per head.

The three treatments were: concentrates fed flat rate (F), at a decreasing rate (D) or to yield (Y).

Treatment F: 9 kg concentrates fresh weight day^{-1} to all 16 animals for the whole 20 weeks of the experiment.

Treatment D: 11, 10, 9, 8 and 7 kg day^{-1} fresh weight of concentrates for weeks 1 to 4, 5 to 8, 9 to 12, 13 to 16 and 17 to 20 respectively.

9 kg/d.

Treatment Y: A flat rate of concentrates based on each individual animal's milk yield at 14 days post-calving. Each cow was offered 0.5 kg concentrates kg^{-1} milk based on her milk yield at 14 days minus 8.5 kg, e.g. a cow yielding 20.5 kg day^{-1} at 14 days was offered (20.5 - 8.5) x 0.5 = 6 kg day^{-1} of concentrates fresh weight. This amount (to the nearest kg) was that animal's ration for the entire 20 weeks. In the case of heifers each animal was fed 0.5 kg concentrates kg^{-1} milk based on their milk yield at 14 days plus 1.5 kg, e.g. a heifer yielding 20.5 kg day^{-1} was offered (20.5 + 1.5) x 0.5 = 11 kg day^{-1} fresh weight. The average concentrate consumption day^{-1} for the group of 16 was 9 kg with a range from 7 to 12 kg for individuals within the group.

Records and analytical methods

Silage was weighed separately for groups of cows and heifers daily. The quantity offered was approximately 10% in excess of their daily requirement. Silage refusals were weighed twice weekly on Monday and Thursday and silage dry matters were carried out daily. Group silage intakes were thus determined weekly. The method used to calculate individual silage intakes from weekly group silage intakes is described in Appendix 3. Concentrate refusals from the programmed out-of-parlour feeders, were recorded daily for each individual animal.

Weekly samples of silage and concentrate were taken for chemical analysis. The techniques and equations used for the chemical analysis of the feed-stuffs were those practised by Alexander and McGowan (1966, 1969) at the West of Scotland Agricultural College (Appendix 2).

Milk yields of individual animals were recorded weekly and a sample taken for the analysis of fat, protein and lactose content from which solids-not-fat and total solids content were determined. The machine used to determine the milk compositions was a 1st Electric Milkoscan 203 (Biggs, 1979).

Liveweights were measured weekly after the p.m. milking and condition scoring was carried out fortnightly using the tail head system devised by Mulvany (1977).

During the pre-experimental and experimental periods records were maintained of fertility, mastitis occurrences and all other aspects of health.

During the residual period from week 21 to 43 all the animals were treated as one group. The initial part of the residual period was indoors, this length of time for individuals depending on the time at which they finished 20 weeks on experiment relative to going out to grass on 14 April 1981, and the rest of the residual period was on set stocked grass pasture.

For the first 6 weeks all animals were offered 6 kg day^{-1} concentrates fresh weight of a high magnesium concentrate cube and thereafter all were offered 1 kg day^{-1} of a summer concentrate cube (130 g kg^{-1} crude protein content).

Statistical analysis

The results were statistically analysed using a 3 x 2 factorial design (3 treatments and 2 parities) (Steel and Torrie, 1960). Data for cows and heifers were analysed in successive four week periods and for the whole trial.

Missing plots were calculated using equation 6.10 of Steel and Torrie (1960).

$$X = \frac{rB + tT - G}{(r - 1)(t - 1)} \quad \text{.......................... Equation 6.10}$$

where r and t are the numbers of blocks and treatments.

B and T are the totals of the observed observations in the block and treatment containing the missing plot unit.

G is the grand total.

RESULTS

Feed intake

The results of the 20 week experiment were divided into 5 successive 4 week periods. The intakes of concentrate and silage and the calculated intakes of ME, RDP and UDP are presented in Table 6.12.

In period 1 the silage intake was significantly depressed ($p < 0.001$) in treatment D for both cows and heifers compared with treatments F and Y. There were no significant differences in total dry matter intake or metabolisable energy (ME) intake between the three treatments due to the high substitution rate of concentrates for silage (1.18 and 0.78 kg reduction in silage DM intake per kg increase in concentrate DM intake for heifers and cows respectively).

A similar trend was apparent in period 2 where treatment D in both cows and heifers received on average 1 kg additional concentrate dry matter to treatments F or Y. Total dry matter intakes and ME intakes were not significantly different between the three treatments. In period 4 and 5 both cows and heifers on treatment D received less con-

Table 6.12 Mean Daily Intakes of Dry Matter and the Calculated Metabolisable Energy, RDP and UDP Intake

	Treatments						SED		
	Flat		Decreasing		To yield				
	Cows	Heifers	Cows	Heifers	Cows	Heifers	Treatment	Parity	T x P
Period 1									
Silage DM intake (kg day^{-1})	10.4	7.9	9.3	4.7	10.6	6.9	0.48 ***	0.39 ***	0.67 NS
Concentrate DM intake (kg day^{-1})	7.7	7.5	9.3	9.0	8.0	6.8	-	-	-
Total DM intake (kg day^{-1})	18.1	15.4	18.6	13.7	18.6	13.7	0.48 NS	0.39 ***	0.68 NS
Total ME intake (MJ day^{-1})	210	181	220	167	216	164	5.2 NS	4.3 ***	7.4 NS
RDP intake (g day^{-1})	2436 (1638)	2071 (1412)	2501 (1716)	1839 (1306)	2503 (1685)	1842 (1280)	-	-	-
UDP intake (g day^{-1})	793 (455)	697 (256)	847 (673)	675 (383)	817 (640)	623 (224)	-	-	-

Figures in brackets ( ) are the estimated protein requirements from ARC (1980).

Table 6.12 (continued) Mean Daily Intakes of Dry Matter and the Calculated Metabolisable Energy, RDP and UDP Intake

	Treatments						SED		
	Flat		Decreasing		To yield				
	Cows	Heifers	Cows	Heifers	Cows	Heifers	Treatment	Parity	T x P
Period 2									
Silage DM intake (kg day^{-1})	11.5	8.1	10.7	7.7	11.4	9.0	0.55 NS	0.45 ***	0.78 NS
Concentrate DM intake (kg day^{-1})	7.7	7.6	8.6	8.5	7.7	7.5	-	-	-
Total DM intake (kg day^{-1})	19.2	15.7	19.3	16.2	19.1	16.5	0.65 NS	0.53 ***	0.92 NS
Total ME intake (MJ day^{-1})	222	185	225	192	221	193	7.2 NS	5.9 ***	10.2 NS
RDP intake (g day^{-1})	2584 (1732)	2111 (1443)	2596 (1755)	2178 (1498)	2571 (1724)	2220 (1505)	-	-	-
UDP intake (g day^{-1})	830 (833)	709 (307)	855 (899)	747 (500)	827 (996)	734 (396)	-	-	-

Figures in brackets ( ) are the estimated protein requirements from ARC (1980).

Table 6.12 (continued) Mean Daily Intakes of Dry Matter and the Calculated Metabolisable Energy, RDP and UDP Intakes

	Treatments						SED		
	Flat		Decreasing		To yield				
	Cows	Heifers	Cows	Heifers	Cows	Heifers	Treatment	Parity	T x P
Period 3									
Silage DM intake (kg day^{-1})	9.8	8.2	10.3	8.6	10.7	7.5	0.69 NS	0.57 ***	0.98 NS
Concentrate DM intake (kg day^{-1})	7.7	7.7	7.7	7.7	7.6	7.8	-	-	-
Total DM intake (kg day^{-1})	17.5	15.9	18.0	16.3	18.3	15.3	0.72 NS	0.59 ***	1.02 NS
Total ME intake (MJ day^{-1})	204	18 7	209	191	212	181	7.8 NS	6.4 **	11.0 NS
RDP intake (g day^{-1})	2355 (1591)	2138 (1459)	2422 (1630)	2192 (1490)	2463 (1654)	2057 (1412)	-	-	-
UDP intake (g day^{-1})	772 (643)	718 (735)	789 (620)	732 (517)	797 (605)	700 (485)	-	-	-

Figures in brackets ( ) are the estimated protein requirements from ARC (1980).

Table 6.12 (continued) Mean Daily Intakes of Dry Matter and the Calculated Metabolisable Energy, RDP and UDP Intakes

	Treatments								
	Flat		Decreasing		To yield		SED		
	Cows	Heifers	Cows	Heifers	Cows	Heifers	Treatment	Parity	T x P
Period 4									
Silage DM intake (kg day^{-1})	9.5	7.7	11.1	8.8	10.8	5.9	0.58 *	0.47 ***	0.82 *
Concentrate DM intake (kg day^{-1})	7.7	7.7	6.9	7.2	7.6	8.1	-	-	-
Total DM intake (MJ day^{-1})	17.2	15.4	18.0	16.0	18.4	14.0	0.62 NS	0.51 ***	0.88 NS
Total ME intake (MJ day^{-1})	201	182	207	187	213	168	6.8 NS	5.6 **	9.6 NS
RDP intake (g day^{-1})	2314 (1568)	2071 (1420)	2423 (1615)	2152 (1459)	2476 (1661)	1881 (1310)	-	-	-
UDP intake (g day^{-1})	762 (513)	702 (547)	771 (691)	710 (502)	801 (682)	664 (436)	-	-	-

Figures in brackets ( ) are the estimated protein requirements from ARC (1980).

Table 6.12 (continued) Mean Daily Intakes of Dry Matter and the Calculated Metabolisable Energy, RDP and UDP Intake

	Treatments						SED		
	Flat		Decreasing		To yield				
	Cows	Heifers	Cows	Heifers	Cows	Heifers	Treatment	Parity	T x P
Period 5									
Silage DM intake (kg day^{-1})	9.4	7.3	11.4	8.6	10.2	7.3	0.64 *	0.52 ***	0.91 NS
Concentrate DM intake (kg day^{-1})	7.7	7.8	6.0	6.3	7.6	8.2	-	-	-
Total DM intake (MJ day^{-1})	17.1	15.1	17.4	14.9	17.8	15.5	0.62 NS	0.51 ***	0.88 NS
Total ME intake (MJ day^{-1})	193	174	190	167	200	179	6.3 NS	5.2 ***	9.0 NS
RDP intake (g day^{-1})	2376 (1505)	2088 (1357)	2435 (1482)	2074 (1303)	2477 (1560)	2142 (1396)	-	-	-
UDP intake (g day^{-1})	778 (448)	708 (258)	752 (544)	669 (332)	801 (523)	731 (402)	-	-	-

Figures in brackets ( ) are the estimated protein requirements from ARC (1980).

Table 6.12 (continued) Mean Daily Intakes of Dry Matter and the Calculated Metabolisable Energy, RDP and UDP Intake

	Treatments						SED		
	Flat		Decreasing		To yield				
	Cows	Heifers	Cows	Heifers	Cows	Heifers	Treatment	Parity	T x P
Mean of 1 to 5									
Silage DM intake (kg day^{-1})	10.1	7.8	10.6	7.7	10.7	7.3	0.43 NS	0.35 ***	0.61 NS
Concentrate DM intake (kg day^{-1})	7.7	7.6	7.7	7.7	7.7	7.7	-	-	-
Total DM intake (kg day^{-1})	17.8	15.4	18.3	15.4	18.4	15.0	0.48 NS	0.39 ***	0.68 NS
Total ME intake (MJ day^{-1})	206	181	210	180	212	177	5.3 NS	4.3 ***	7.5 NS
RDP intake (g day^{-1})	2411 (1607)	2083 (1412)	2480 (1638)	2083 (1404)	2493 (1654)	2028 (1379)	-	-	-
UDP intake (g day^{-1})	787 (578)	702 (421)	804 (685)	705 (447)	807 (689)	691 (387)	-	-	-

Figures in brackets ( ) are the estimated protein requirements from ARC (1980).

centrates on average than treatments F and Y, and ate significantly ($p < 0.05$) more silage dry matter.

Over the whole experiment there were no significant differences in silage intake, total dry matter intake or ME intake between the three treatments. Cows ate significantly more silage ($p < 0.001$) and had significantly greater total dry matter intakes ($p < 0.001$) and ME intakes ($p < 0.001$) than heifers.

The relative intakes of protein (g day^{-1} of rumen degradable (RDP) and undegradable (UDP) protein) were derived from the group intakes of silage and concentrate using degradability values of 0.8 for silage and 0.7 for concentrate (ARC, 1980). In all periods and within treatments the intakes of protein, both for RDP and UDP, satisfied the requirements laid down by ARC (1980).

Milk production

The mean daily milk yields for each period and for the complete trial are presented in Table 6.13 and the lactation curves are shown in Figure 6.10. Peak milk yields, the time to reach peak milk yield and the rate of decline per week as a % of peak yield are presented in Table 6.14.

There were no significant differences in milk yield between the three treatments in any period but there was a consistent difference between the milk yield of cows and heifers ($p < 0.001$). For cows there was a lower coefficient of variation in treatment F in each period, but this was not evident for heifers. Cows had significantly ($p < 0.001$) greater peak yields, significantly shorter intervals to peak milk yield

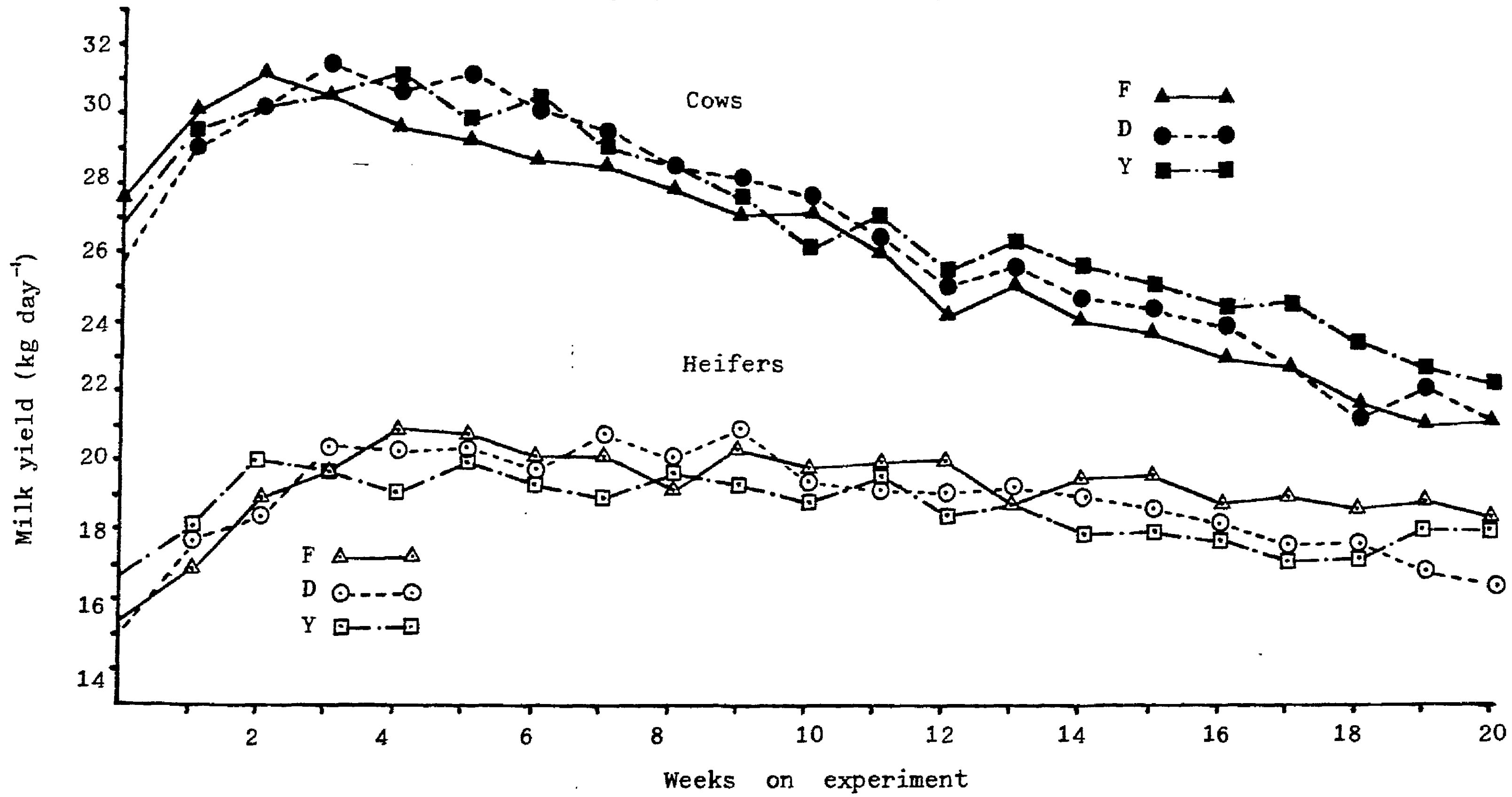
Table 6.13 Milk Yields

	Treatments						SED		
	Flat		Decreasing		To yield				
	Cows	Heifers	Cows	Heifers	Cows	Heifers	Treatment	Parity	T x P
Period 1									
Milk yield (kg day^{-1})	30.4	19.2	30.3	19.2	30.2	19.3	1.30 NS	1.10 ***	1.84 NS
Period 2									
Milk yield (kg day^{-1})	28.6	20.2	29.8	20.3	29.4	19.7	1.33 NS	1.09 ***	1.89 NS
Period 3									
Milk yield (kg day^{-1})	26.0	20.1	26.7	19.7	26.3	19.2	1.17 NS	0.95 ***	1.65 NS
Period 4									
Milk yield (kg day^{-1})	23.8	19.2	24.6	18.8	25.3	18.2	1.10 NS	0.90 ***	1.56 NS
Period 5									
Milk yield (kg day^{-1})	22.0	18.8	22.2	17.4	23.4	17.9	1.00 NS	0.82 ***	1.42 NS
Mean of 1 to 5									
Milk yield (kg day^{-1})	26.2	19.5	26.7	19.1	26.9	18.8	1.12 NS	0.92 ***	1.59 NS
(Coefficient of variation)	9.4	16.8	13.4	11.5	12.3	15.6			

Table 6.14 Peak Milk Yield, Weeks to Peak Yield from Calving and Rate of Decline as a % of Peak Yield

	Treatments						SED		
	Flat		Decreasing		To yield				
	Cows	Heifers	Cows	Heifers	Cows	Heifers	Treatment	Parity	T x P
Peak milk yield (kg day^{-1})	32.3	22.1	32.5	22.3	32.0	21.2	1.37 NS	1.12 ***	1.94 NS
Weeks to reach peak milk yield from calving	4.3	8.4	5.6	8.6	5.8	7.6	0.85 NS	0.90 ***	1.20 NS
Rate of decline per week as % of peak milk yield	1.7	0.8	1.9	1.4	1.6	0.8	0.15 **	0.12 ***	0.21 NS
Peak milk yield adjusted for 14 day milk yields	26.9		28.2		26.2		0.93 NS		

Fig. 6.10 Mean daily milk yields for the six treatment groups over the 20 week experimental period



($p < 0.001$) from calving and significantly greater rates of decline from peak milk yield than the heifers ($p < 0.001$). The adjusted peak milk yields were higher for treatment D although the differences were not sig.

For cows and heifers combined there was a significantly greater rate of decline from peak milk yield in treatment D ($p < 0.01$) compared with F and Y. A slightly greater interval to reach peak milk yield and a slightly greater peak milk yield in treatment D compared with F and Y contributed to this difference.

Milk composition

There were no significant effects of pattern of concentrate allocation on milk composition during the whole experiment (Table 6.15). Therefore weekly mean values for each of the three treatments were combined for cows and heifers in Figure 6.11 to show the lactational trends for milk fat content and milk protein content.

Heifers had significantly ($p < 0.01$) lower milk fat contents during period 1 but overall there was no significant difference between cows and heifers in milk fat content. There was a consistent trend for heifers to produce milk with greater protein content (Figure 6.11). As a result the overall mean milk protein content was significantly greater ($p < 0.05$) for the heifers. Heifers also produced milk with significantly greater milk lactose ($p < 0.01$) and solids-not-fat content ($p < 0.01$) than cows but there were no differences between cows and heifers in milk total solids content over the whole experiment.

Liveweight and condition score

Figure 6.12 shows the weekly lactational effects on liveweight for cows and heifers. Table 6.16 lists mean liveweights during each of the

Fig. 6.11 Milk fat and protein content for cows and heifers over the 20 week experimental period

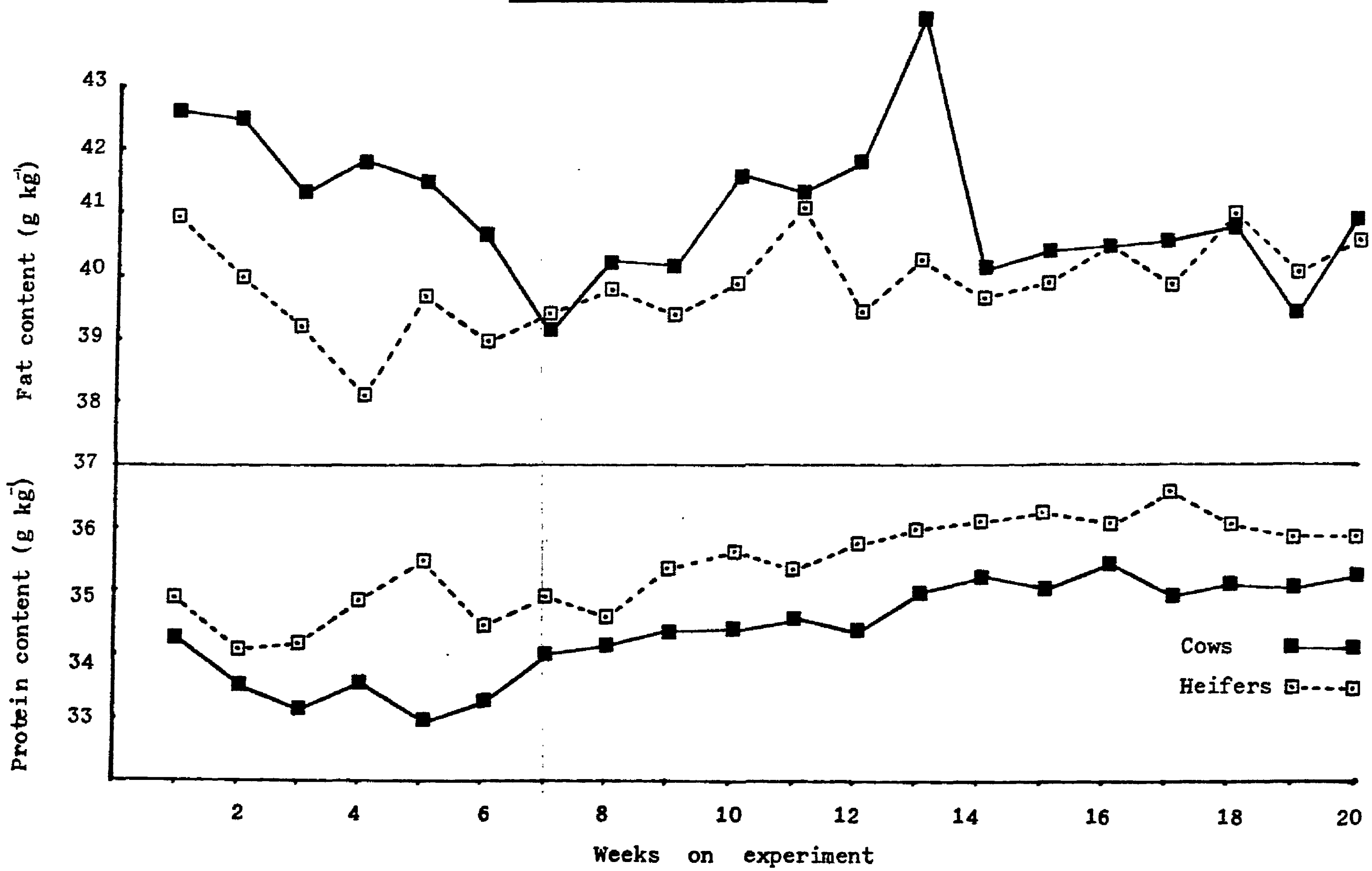


Table 6.15 Milk Composition for Each Period and Mean for Whole 20 Weeks (g kg^{-1})

	Treatments						SED		
	Flat		Decreasing		To yield				
	Cows	Heifers	Cows	Heifers	Cows	Heifers	Treatment	Parity	T x P
Period 1									
Milk fat content	41.9	38.9	41.7	39.6	42.4	39.8	1.09 NS	0.89 **	1.54 NS
Milk protein content	32.4	34.8	33.3	35.3	35.0	33.2	0.67 NS	0.55 NS	0.95 **
Milk lactose content	49.4	50.5	50.1	50.3	49.5	50.5	0.33 NS	0.27 *	0.47 NS
Period 2									
Milk fat content	39.5	40.2	39.1	38.9	42.1	39.1	1.20 NS	0.98 NS	1.70 NS
Milk protein content	32.8	34.5	33.0	35.5	34.8	34.3	0.63 NS	0.51 *	0.89 NS
Milk lactose content	49.3	50.2	50.1	50.1	49.7	50.3	0.36 NS	0.30 NS	0.51 NS

Table 6.15 (continued) Milk Composition for Each Period and Mean for Whole 20 Weeks (g kg^{-1})

	Treatments						SED		
	Flat		Decreasing		To yield				
	Cows	Heifers	Cows	Heifers	Cows	Heifers	Treatment	Parity	T x P
Period 3									
Milk fat content	40.4	39.2	40.1	39.4	42.9	40.9	1.24 NS	1.01 NS	1.75 NS
Milk protein content	33.8	35.4	33.7	36.0	35.6	34.9	0.63 NS	0.52 *	0.89 NS
Milk lactose content	48.5	49.9	49.0	49.8	48.7	49.6	0.35 NS	0.28 ***	0.49 NS
Period 4									
Milk fat content	39.9	40.6	40.3	38.6	43.4	40.8	1.42 NS	1.16 NS	2.01 NS
Milk protein content	35.1	35.9	33.9	36.4	36.3	35.7	0.63 NS	0.51 *	0.89 NS
Milk lactose content	48.0	49.9	48.6	49.1	48.3	49.0	0.35 NS	0.29 **	0.50 NS

Table 6.15 (continued) Milk Composition for Each Period and Mean for Whole 20 Weeks (g kg^{-1})

	Treatments						SED		
	Flat		Decreasing		To yield				
	Cows	Heifers	Cows	Heifers	Cows	Heifers	Treatment	Parity	T x P
Period 5									
Milk fat content	39.9	40.7	38.5	39.3	42.6	40.8	1.35 NS	1.10 NS	1.91 NS
Milk protein content	35.1	36.0	34.3	36.1	35.6	35.9	0.76 NS	0.62 NS	1.07 NS
Milk lactose content	48.5	49.8	48.5	49.1	48.7	49.5	0.41 NS	0.34 *	0.58 NS
Mean of Whole Trial									
Milk fat content	40.3	39.9	39.9	39.2	42.7	40.3	1.09 NS	0.89 NS	1.54 NS
Milk protein content	33.8	35.3	33.7	35.9	35.5	34.8	0.59 NS	0.48 *	0.83 NS
Milk lactose content	48.7	50.0	49.3	49.7	49.0	49.8	0.32 NS	0.26 **	0.45 NS
Milk s-n-f content	90.1	92.8	90.4	93.0	91.9	92.1	0.66 NS	0.54 **	0.93 NS
Milk T.S. content	130.4	132.7	130.3	132.2	134.6	132.3	1.42 NS	1.16 NS	2.01 NS

Fig. 6.12 Liveweight for cows and heifers over the 20 week experimental period

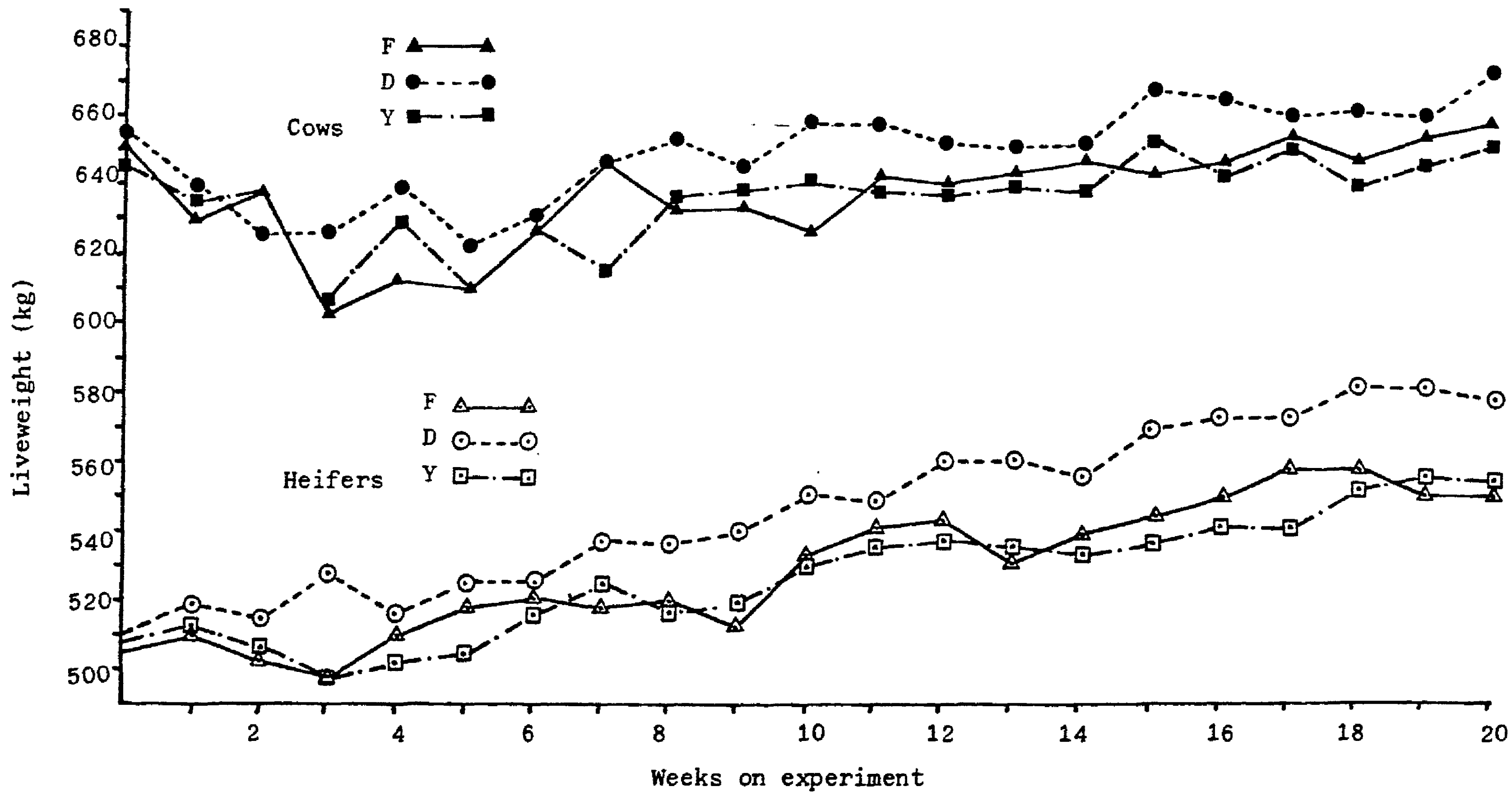


Table 6.16 Liveweights and Liveweight Changes for Each Period and for the Whole Experiment

	Treatments								
	Flat		Decreasing		To yield		SED		
	Cows	Heifers	Cows	Heifers	Cows	Heifers	Treatment	Parity	T x P
Period 1									
Mean liveweight (kg)	620	506	632	511	626	505	15.08 NS	12.31 ***	21.32 NS
Liveweight change (kg day^{-1})	-1.22	-0.06	-0.05	-0.03	-0.84	-0.47	0.36 NS	0.29 NS	0.51 NS
Period 2									
Mean liveweight (kg)	628	518	636	531	620	515	14.42 NS	11.77 ***	20.39 NS
Liveweight change (kg day^{-1})	+1.35	+0.02	+1.69	+0.67	+0.98	+0.59	0.38 NS	0.31 **	0.54 NS
Period 3									
Mean liveweight (kg)	633	532	652	549	637	530	14.61 NS	11.93 ***	20.66 NS
Liveweight change (kg day^{-1})	+0.34	+1.44	+0.23	+0.78	+0.05	+0.71	0.28 NS	0.23 **	0.40 NS

Table 6.16 (continued) Liveweights and Liveweight Changes for Each Period and for the Whole Experiment

	Treatments						SED		
	Flat		Decreasing		To yield				
	Cows	Heifers	Cows	Heifers	Cows	Heifers	Treatment	Parity	T x P
Period 4									
Mean liveweight (kg)	644	540	657	564	643	535	16.55 NS	13.51 ***	23.40 NS
Liveweight change (kg day^{-1})	+0.11	+0.82	+0.87	+0.81	+0.41	+0.38	0.30 NS	0.24 NS	0.42 NS
Period 5									
Mean liveweight (kg)	652	553	662	578	646	548	17.38 NS	14.19 ***	24.58 NS
Liveweight change (kg day^{-1})	+0.13	-0.37	+0.47	+0.15	+0.14	+0.56	0.28 NS	0.23 NS	0.39 NS
Mean of 1 to 5									
Liveweight (kg)	635.2	529.8	647.7	548.2	634.3	526.5	15.11 NS	12.34 ***	21.36 NS
Liveweight change (kg day^{-1})	+0.14	+0.37	+0.64	+0.48	+0.15	+0.36	0.12 *	0.1 NS	0.17 NS

Table 6.17 Condition Scores and Condition Score Changes

	Treatments						SED		
	Flat		Decreasing		To yield				
	Cows	Heifers	Cows	Heifers	Cows	Heifers	Treatment	Parity	T x P
Mean initial condition score	2.50	2.47	2.56	2.70	2.69	2.41	-	-	-
Mean condition score at 20 weeks	2.4	2.8	2.6	2.9	2.7	2.6	0.17 NS	0.14 NS	0.24 NS
Condition score change	-0.1	+0.3	0.0	+0.2	0.0	+0.2	0.17 NS	0.14 *	0.24 NS

5 periods and the changes in liveweight during each period, calculated by regression analysis over the 4 weekly weighings.

There were no significant treatment effects during any of the 5 periods although there was a trend for both cows and heifers on treatment D to have a lower liveweight loss in period 1 and thereafter a greater liveweight gain. Over the whole experiment there was a significantly greater ($p < 0.05$) average liveweight gain on treatment D in both cows and heifers compared with F and Y.

There were no significant treatment differences in condition score or condition score change over the experiment. Table 6.17 shows that cows lost condition during the experiment whilst heifers gained in condition ($p < 0.01$) over the experiment.

Health

General health during the experimental period was good and no animals' data were withdrawn from the statistical analysis. Three of the cows in treatment F were not served due to udder shape and lameness. Cases of mastitis that were treated with antibiotics were equally distributed through all treatments and there were no reported cases of coliform mastitis. Cases of mastitis had no significant effects on the overall results. In cases where mastitis infections occurred on the day of milk recording and sampling these values were ignored and a mean value of the previous and subsequent week's data were used.

The calving intervals for the 3 treatments and between the cows and heifers were not significantly different and averaged 384, 385 and 387 for treatments F, D and Y respectively.

Residual period

Milk production during the residual period, when all animals were treated as one group, was not significantly different between parity or treatments. 305 day milk yields were significantly ($p < 0.001$) greater for the cows compared with the heifers (Table 6.18). There were no significant residual effects in any other parameter between the 3 treatment groups.

Missing plots were used for two of the heifers during the residual period as one died and another was culled for infertility. Two of the cows were dried off prematurely, one due to summer mastitis and another due to severe lameness and missing plots were used for 3 animals.

Table 6.18 305-day Milk Yield and Milk Production during Residual Period

	Treatments						SED		
	Flat		Decreasing		To yield				
	Cows	Heifers	Cows	Heifers	Cows	Heifers	Treatment	Parity	T x P
Milk production during residual period (kg)	2265	2128	2471	2272	2670	2151	179.7 NS	146.7 NS	254 NS
305 day milk yield (kg)	6425	5099	6530	5247	6828	5033	296.7 NS	242.2 ***	419.6 NS

DISCUSSION

In the present experiment the pattern of concentrate allocation had no significant effect on milk yield during the experimental or residual period. This agrees with previous studies (Johnson, 1977; Østergaard, 1979; Steen and Gordon, 1980 a; Gordon, 1982) which applied to autumn and spring calving cows, and to cows and heifers.

The results of this experiment show that animals on treatment D had a significantly ($p < 0.01$) greater decline from peak milk yield compared with treatments F and Y. Østergaard (1979) also reported that a uniform pattern of concentrate allocation gave a greater persistency than a decreasing pattern of concentrate allocation. Steen and Gordon (1980 a) observed that although the mean peak yield of animals on a high/low pattern of concentrate allocation treatment was higher than that of the animals on a uniform pattern of concentrate allocation (27.2 vs 24.7 kg day^{-1}) the total milk output during the indoor period was similar on the two treatments.

Pattern of milk production over the lactation for each of the three treatments in the present study and in those of Østergaard (1979), Steen and Gordon (1980 a) and Gordon (1982) was a reflection of the way the total quantity of concentrates was distributed over a given period, i.e. uniform patterns of allocation feed proportionately less concentrates in early lactation compared with stepped patterns and as a result milk production in early lactation is less than with stepped, whereas in later lactation the reverse occurs. Contrary to Broster *et al* 1975 and Broster (1975) the differences between treatments in milk yield decline from peak milk yield compensated totally for differences in peak milk yield. This may be a reflection of the high quality

Table 6.19 Relationship between 14 day Yields and Peak Yields and 305 day Yields and Peak Yields

	Treatment							
	F		D		Y		SED	
	Cows	Heifers	Cows	Heifers	Cows	Heifers	Parity	Treatment
305 day milk yield (kg) ÷ Peak milk yield (kg day^{-1})	201	231	201	237	214	240	6.3 ***	7.7 NS
Peak milk yield (kg day^{-1}) ÷ 14 day milk yield (kg day^{-1})	1.18	1.44	1.28	1.54	1.21	1.26	0.05 ***	0.06 *

silage offered *ad libitum* used in this and the previous experiments (Østergaard, 1979, Steen and Gordon, 1980 a, Gordon, 1982), whereas Broster *et al* (1975) used poorer quality restricted hay as a basal diet. This is further supported by reports from Broster *et al* (1982), using *ad libitum* silage, who found no differences in milk production when comparing a uniform and a stepped pattern of concentrate allocation.

Broster *et al* (1969) and Gleeson (1970) reported that a high/low pattern of concentrate allocation gave a better overall performance than a low/high and it seems likely that a low level of feeding in early lactation followed by a high level will not perform as well as a uniform pattern which was not compared in these studies.

Table 6.19 indicates that peak milk yield multiplied by a factor of 205 was the average relationship obtained for cows which did not differ between the different patterns of concentrate allocation. MAFF (1975) recommend 200 as a figure for predicting 305 day yields from yield at peak. This relationship was significantly higher ($p < 0.001$) for heifers at 236. Regression analysis of the data indicates a less precise relationship between peak yield and 305 day yield for cows compared with heifers. Equations 6.11 and 6.12 indicate that for every kg change in peak milk yield total 305 day yield increased on average by 131 and 183 kg for cows and heifers respectively.

Cows: $y = 2353 + 131x$ .... Equation 6.11

where y = 305 day yield (kg) x = peak yield (kg day^{-1})

Correlation coefficient (r) = 0.63

Standard error of slope (b) = 34.7

Residual standard deviation = 628

Significance ($p < 0.01$) = **

Heifers: $y = 1136 + 183x$ .... Equation 6.12

Correlation coefficient (r) = 0.85

Standard error of slope (b) = 24.5

Residual standard deviation = 386

Significance ($p < 0.001$) = ***

The relationship between 14 day milk yield and peak milk yield was significantly different for cows and heifers (see Table 6.19). The average relationship of 1.22 for cows was similar to a value of 1.3 recommended by Johnson (1977, 1983). The value recommended by MAFF (1975) of 1.1 would have underestimated peak yield in the present experiment. Pattern of concentrate allocation significantly ($p < 0.05$) affected the relationship between 14 day yield and peak. Cows and heifers on treatment D had an average figure of 1.44 compared with the average for F and Y treatments of 1.31 and 1.23 respectively. This may be explained by the higher group levels of concentrates for the D treatments during the first period of the experiment which resulted in a non-significant increase in peak milk yields for the D treatments. Level of nutrition between 14 days and peak milk yield can therefore influence the relationship between the two.

During the experimental period milk fat and protein contents were at an acceptable level and did not show the extreme lactational changes that have been observed in other studies (Johnson, 1977). They are, however, similar to previous work at Crichton Royal Farm by Laird *et al* (1981). Results from this study did not support the results of Gordon (1982) where a uniform system of concentrate allocation resulted in a significant increase in the milk fat content produced during the treatment period for heifers. The present results agree with Johnson (1977), Østergaard (1979) and Steen and Gordon (1980 a) who reported no effect

Table 6.20 Concentrates as a Proportion of the Total Dry Matter Intake (%)

	Treatments							
	F		D		Y			
	Cows	Heifers	Cows	Heifers	Cows	(range)	Heifers	(range)
Period 1	43	48	50	66	43	(49-38)	50	(65-36)
Period 2	40	48	45	53	40	(45-31)	46	(50-40)
Period 3	44	48	43	47	42	(51-33)	51	(60-41)
Period 4	45	50	38	45	41	(49-32)	58	(68-48)
Period 5	45	52	35	42	43	(54-34)	53	(69-41)
Average	43	49	42	51	42		52	

of pattern of concentrate allocation on milk fat content. This experiment confirms observations from previous studies that different patterns of allocating the same total amount of concentrates over a period result in similar intakes of silage over that period when the silage is offered *ad libitum*.

Table 6.20 shows concentrate as a percentage of the total dry matter intake for the treatment groups. During all periods and in all treatments, heifers had greater concentrate/forage ratios than cows. This was probably responsible for their significantly lower milk fat contents in period 1 ($p < 0.01$) and higher overall milk protein contents ($p < 0.05$) compared with cows (see Figure 6.11). Chalmers *et al* (1978) also concluded that higher concentrate/forage ratios consistently increased milk protein content but this was small and non-significant. In treatment F the silage intakes resulted in a fairly constant concentrate/forage ratio during the experiment. In period 1 cows and heifers in treatment D had the highest concentrate/forage ratio relative to treatments F and Y and this gradually decreased until period 5 when cows and heifers in treatment D had the lowest concentrate/forage ratio relative to F and Y. The greater extremes in concentrate/forage ratios for heifers in treatments D between different stages of lactation and in Y between different individuals may be responsible for heifers on treatment F having a slightly better overall performance, as it has been reported that abrupt changes in concentrate/forage ratio can have a detrimental effect on performance (Mosley *et al*, 1976) and can lead to lameness problems in heifers fed too high a concentrate/forage ratio (Wray, 1981).

There is a fear that a uniform pattern of concentrate allocation will result in lower yielding cows exceeding their 'energy requirements' in later lactation (Greenhalgh and Reid, 1980). The evidence from Chalmers *et al* (1982) and Steen and Gordon (1980 a) suggests on the contrary that high levels of concentrate feeding in early lactation cause a greater partition of energy toward body reserves or reduction in weight loss which may continue subsequently when concentrates are reduced later in lactation. It was evident in this experiment that animals on treatment D partitioned more toward body reserves in early lactation or lost less condition and subsequently gained proportionately more weight in later lactation compared with treatments F and Y.

Milk production at pasture was similar for all three treatments and for cows and heifers. Steen and Gordon (1980 a) and Gordon (1982) reported similar observations and differences in total lactation yield were only apparent between cows and heifers.

Gordon (1982) posed the question of whether a uniform pattern of concentrate allocation with heifers would be equally applicable to cows of high production potential. It would seem from these results and those of Moisey and Leaver (1982) and Johnson (1983) that a uniform pattern of concentrate allocation can also be applied to high yielding cows without detriment to average milk yields.

SUMMARY

In a 20-week experiment commencing at week 3 *post-partum* high quality (660 g digestible organic matter per kg dry matter) silage was offered *ad libitum* to 3 treatment groups of autumn-calving British Friesian dairy cows each containing 8 cows and 8 heifers. Each treatment group received, on average, 1260 kg cow^{-1} fresh weight of a 180 g kg^{-1} crude protein concentrate. The 3 treatments compared: a flat-rate, a stepped and a to yield pattern of concentrate allocation. The results indicated that with *ad libitum* high quality silage, pattern of concentrate allocation had no significant effects on any aspects of performance, all 3 treatments having similar average levels of performance during the 20-week experiment and during the residual period up to 305 days post-calving.

CHAPTER 7

EXPERIMENT 2 - A COMPARISON OF TWO PATTERNS OF CONCENTRATE ALLOCATION FOR AUTUMN CALVING COWS OFFERED TWO QUALITIES OF SILAGE *AD LIBITUM*

Introduction

In the previous experiment, Chapter 6, a comparison was made of three patterns of concentrate allocation: a flat rate, a decreasing rate, and a feeding to yield treatment, together with *ad libitum* silage of 66 DOMD. The results confirmed previous observations (Østergaard, 1979; Steen and Gordon, 1980 a; Gordon, 1982) that when high quality silage (≥ 65 DOMD) is available *ad libitum* the pattern of concentrate allocation is not critical.

It has been suggested (Taylor, 1979; Broster, 1980; MAFF, 1981) that the provision of *ad libitum* high quality forage is fundamental to the success of flat rate feeding. In circumstances where forage is poor in quality then allocation of concentrates according to yield and giving emphasis to early lactation feeding may result in improved average performance.

Information is therefore required on whether the pattern of concentrate allocation is of importance when a low D-value silage is offered *ad libitum*.

This experiment examined two patterns of concentrate allocation with two silage qualities offered *ad libitum*.

MATERIALS AND METHODS

Livestock and management

Forty-eight British Friesian cows were used. Their calving dates ranged from 29 August to 25 October 1981 with a mean calving date of 25 September. The experiment ran from September 1981 to April 1982.

All the cows calved at grass and were brought inside after 24 hours. During the first 14 days after calving (pre-experimental) cows were housed in a self-feed shed and offered 63 D-value silage *ad libitum* and 8 kg day^{-1} fresh weight of concentrate (Table 7.1) fed in the parlour.

The cows were allocated to the four treatments as they reached 14 days post-calving (range 10-17 days) and were transferred from a self-feed silage shed to a cubicle building and offered silage once daily from a forage box during the experimental period.

During the experimental period the cows were milked at 0515 hours and 1530 hours and received 1 kg of concentrate fresh weight in the parlour at each milking with the remainder fed through two programmed out-of-parlour feeders sited in the housing area.

The initial 14 day values for milk yield, liveweight, condition scores and parity can be seen in Appendix 4.

Diets

The high D-value (H) and the low D-value (L) silages were first cut material from the same parennial ryegrass sward (both had the same fertiliser levels, 150 kg N ha^{-1} in March) with the area divided in a

60:40 ratio and cut at two different dates: 25 May (H) and 17 June (L). The 60% portion of the field was cut on 25 May and yielded 4.7 tonnes grass DM ha^{-1}, whilst the 40% portion of the field was cut on 17 June and yielded 7.5 tonnes grass DM ha^{-1}.

Both silages were low in dry matter due to poor weather conditions at ensiling and both had formic acid (Add-F, BP Nutrition International Ltd., 850 g formic acid l^{-1}) applied at the rate of 3 litres $tonne^{-1}$. Both silages were cut with a drum mower and harvested with a precision-chop forage harvester.

The early cut grass was left in the field for 24 hours and during that time 9.5 mm rainfall fell on it. To achieve the required D-value it was therefore harvested immediately having to accept a low dry matter content. The later cut grass, to achieve a similar dry matter content to the early cut grass, was direct cut with a drum mower and picked up within 2 hours.

Table 7.10 indicates that both silages had similar dry matters and fermentation patterns, the major difference being 6.3 units of D-value and 57 g kg^{-1} crude protein content. Both silages had similar NH_4N % total N but these were higher than the recommended level of under 10%. The silages were ensiled in two separate unroofed silage bunkers and sheeted with black polythene.

The concentrate supplement was in the form of a fat coated 6 mm pellet, the chemical composition and physical ingredients of which can be seen in Table 7.10 and 7.11 respectively.

Table 7.10 Chemical Composition of Feeds (g kg^{-1} DM)

	Silage		Concentrate
	High D-value	Low D-value	
Oven dry matter (g kg^{-1})	171	163	865
Crude protein	171	114	193
Organic matter	889	903	908
DOMD (*in vitro*)	648	585	755
Ammonia N as % of total N	15.4	12.3	-
Predicted ME (MJ kg^{-1})	10.5	8.9	13.2*
DCP	115.3	68.2	160
Calcium (g kg^{-1})	5.3	4.4	11.2
Phosphorus (g kg^{-1})	4.0	3.3	6.7
Magnesium (g kg^{-1})	2.2	1.9	5.3
pH	4.3	4.2	-

* corrected ME assuming oil content of 45 g kg^{-1}.

Table 7.11 Physical Ingredients of Concentrate (kg 1,000 kg^{-1})

Soya	145
Wheat	290
Barley	140
Maize gluten	100
Dark grains	45
Wheat feed	95
Kelloggs	25
Molasses	50
Fish meal	25
Fat 50%	30
Mineral/vitamin	25
Binder	25
Calcium/magnesium	45
	1,000 kg

Treatments

In a 25 week experiment commencing at week 3 *post partum* the H and L silages were offered *ad libitum* to two groups of 24 autumn calving dairy cows.

Within each silage quality group two groups of 12 animals were used to compare two patterns of concentrate allocation: a flat rate (F) and a variable rate (V). All four treatment groups HF, HV, LF and LV received on average 1,575 kg cow^{-1} fresh weight of concentrate over the 25 weeks.

Treatment F cows were all individually fed a flat rate of 9 kg day^{-1} fresh weight of concentrate throughout. Treatment V cows received different stepped patterns of concentrate allocation which were initially based on their 14 day milk yields, and then their daily amounts were reduced by 1 kg at 10, 15 and 20 weeks.

The patterns of concentrate allocation to individuals according to their 14 day milk yields are shown in Table 7.12. Adjustments were made to ensure that all treatment group averages over 25 weeks would be exactly 1,575 kg cow^{-1}. The average concentrate consumption day^{-1} for the groups of 12 animals HV, LV over the whole 25 weeks was 9 kg day^{-1} with a range from 13.8 to 5.8 kg day^{-1} fresh weight for individuals within the group.

Records and analytical methods

Silage was weighed separately for each silage quality group of 24 cows. The quantity offered to each group was approximately 10% in excess of their daily requirement. Silage refusals were weighed twice

Table 7.12 Pattern of Concentrate Allocation (kg day^{-1} fresh weight) over the 25 weeks for different 14 day milk yields

	14 day milk yields (kg day^{-1})							
	17.7-19.6	19.7-21.6	21.7-23.6	23.7-25.6	25.7-27.6	27.7-29.6	29.7-31.6	31.7-33.6
Experimental week								
1-10	7	8	9	10	11	12	13	14
11-15	6	7	8	9	10	11	12	13
16-20	5	6	7	8	9	10	11	12
21-25	4	5	6	7	8	9	10	11
Mean level over 25 weeks	5.8	6.8	7.8	8.8	9.8	10.8	11.8	12.8

equivalent to: (14 day milk yield - 7.0 kg) x 0.5 = Mean level for 25 weeks to nearest kg.

weekly on Monday and Thursday and silage dry matters were taken daily. Group silage intakes were thus determined weekly and the method used to calculate individual silage intakes from weekly group silage intakes is described in Appendix 3. Concentrate refusals from the programmed out-of-parlour feeders were recorded daily for each individual animal and both in and out-of-parlour feeders were calibrated weekly. The recording of milk yields and composition, liveweight and condition scoring and the techniques and equations used for the chemical analysis of the feedstuffs were outlined in Chapter 6.

During the residual period from week 26-41 all the animals were treated as one group on set-stocked pasture. The initial part of the residual period was indoors this period being shorter than experiment 1 due to the different length of experiments. Cows were turned out to grass on 21 April 1982. During the first 2 weeks of the grazing period cows were offered 2 kg day^{-1} fresh weight of the same concentrate used in the experiment and thereafter 1 kg day^{-1} of the same concentrate until being dried off at 43 weeks post-calving.

Statistical analysis

The results were statistically analysed using a 2 x 2 factorial design (2 silage qualities x 2 concentrate treatments) (Steel and Torrie, 1960). The data were analysed in 5 5-week periods and then for the whole trial. The method described in Chapter 6, experiment 1 was used to calculate missing plot values. Where possible co-variance analysis was performed on data using values obtained during the standard feeding period from calving to 14 days after calving as the co-variate. The standard errors for adjusted data were calculated using the Steel and Torrie (1960) equation 15.9, page 316.

RESULTS

Feed intake

The intake of concentrates, silage and the calculated intakes of ME, RDP and UDP are presented in Table 7.13. In each period the H silage resulted in a significantly higher silage dry matter intake which resulted in significantly greater total dry matter intakes and total ME intakes compared with the L silage.

The total difference in mean daily energy intake between the H and L silages of 26.5 MJ ME can be explained by the energy densities of the total ration for each silage which averaged 11.8 and 11.0 MJ kg^{-1} DM for the H and L silages respectively. On average the 6.3 units difference in D-value between the H and L silages resulted in a daily increase of 4.2 MJ ME, 0.22 kg silage DM intake and 0.21 kg total DM intake per unit increase in D-value.

The pattern of concentrate allocation did not significantly affect daily silage dry matter intake, total dry matter intake or ME intake when averaged over the whole experiment. The small substitution effects in period 1 of 0.0 and 0.22 on the L and H silages respectively, combined with the higher group concentrate intakes on the HV and LV treatments, resulted in significantly ($p < 0.05$) higher total dry matter and ME intakes for the HV and LV treatments compared with treatments HF and LF. There was no observed concentrate pattern x silage quality interaction in period 1. In period 2 silage DM intake on treatments HF and LF were significantly ($p < 0.05$) greater than treatments HV and LV respectively due to the substitution of concentrates for silage on the V treatments (average substitution rate 1.0). Consequently there were no observed differences in total DM intake or energy

Table 7.13 Mean Daily Intakes of Dry Matter and the Calculated Metabolisable Energy, RDP and UDP Intakes

		Treatments				SED		
		HF	HV	LF	LV	Pattern	Quality	P x Q
Period 1								
Silage DM	(kg)	8.6	8.4	7.5	7.5	0.33 NS	0.33 **	0.47 NS
Concentrate DM	(kg)	7.7	8.6	7.4	8.4	-	-	-
Total DM	(kg)	16.3	17.0	14.9	15.9	0.39 *	0.39 **	0.54 NS
Total ME	(MJ)	192	200	164	176	4.7 *	4.7 ***	6.6 NS
RDP	(g)	2217 (1498) ‡	2311 (1560)	1684 (1279)	1819 (1373)	-	-	-
UDP	(g)	740 (602)	785 (672)	600 (377)	657 (475)	-	-	-
Period 2								
Silage DM	(kg)	9.6	8.4	7.6	6.8	0.50 *	0.50 **	0.71 NS
Concentrate DM	(kg)	7.8	8.7	7.6	8.7	-	-	-
Total DM	(kg)	17.3	17.1	15.2	15.5	0.51 NS	0.51 ***	0.72 NS
Total ME	(MJ)	202	203	169	175	5.7 NS	5.7 ***	8.0 NS
RDP	(g)	2367 (1576)	2324 (1583)	1720 (1318)	1795 (1365)	-	-	-
UDP	(g)	780 (480)	791 (560)	613 (469)	659 (551)	-	-	-

‡ Figures in brackets are estimated protein requirements from ARC (1980.

Table 7.13 (continued) Mean Daily Intakes of Dry Matter and the Calculated Metabolisable Energy, RDP and UDP Intakes

		Treatments				SED		
		HF	HV	LF	LV	Pattern	Quality	P x Q
Period 3								
Silage DM	(kg)	9.8	9.4	7.6	7.8	0.36 NS	0.36 ***	0.52 NS
Concentrate DM	(kg)	7.8	8.1	8.1	8.0	-	-	-
Total DM	(kg)	17.6	17.5	15.6	15.8	0.39 NS	0.39 ***	0.55 NS
Total ME	(MJ)	205	205	174	175	4.5 NS	4.5 ***	6.4 NS
RDP	(g)	2395 (1599)[ǂ]	2380 (1599)	1787 (1357)	1792 (1365)	-	-	-
UDP	(g)	787 (545)	791 (634)	642 (539)	641 (570)	-	-	-
Period 4								
Silage DM	(kg)	9.1	8.8	7.8	7.5	0.41 NS	0.41 **	0.58 NS
Concentrate DM	(kg)	7.8	7.1	7.9	7.7	-	-	-
Total DM	(kg)	16.9	15.9	15.7	15.2	0.42 NS	0.42 *	0.60 NS
Total ME	(MJ)	200	192	173	168	6.1 NS	6.1 ***	8.6 NS
RDP	(g)	2299 (1560)	2163 (1498)	1779 (1373)	1724 (1310)	-	-	-
UDP	(g)	762 (502)	712 (476)	635 (600)	617 (550)	-	-	-

ǂ Figures in brackets are estimated protein requirements from ARC (1980).

Table 7.13 (continued) Mean Daily Intakes of Dry Matter and the Calculated Metabolisable Energy, RDP and UDP Intakes

		Treatments				SED		
		HF	HV	LF	LV	Pattern	Quality	P x Q
Period 5								
Silage DM	(kg)	8.6	8.8	7.2	8.6	0.46 NS	0.46 NS	0.65 NS
Concentrate DM	(kg)	7.8	6.4	7.8	6.2	-	-	-
Total DM	(kg)	16.4	15.1	14.9	14.8	0.49 NS	0.49 NS	0.69 NS
Total ME	(MJ)	192	175	166	159	5.5 *	5.5 ***	7.8 NS
RDP	(g)	2231 (1498)	2069 (1365)	1711 (1295)	1622 (1240)	-	-	-
UDP	(g)	746 (479)[‡]	671 (462)	615 (483)	555 (477)	-	-	-
Mean of whole trial								
Silage DM	(kg)	9.2	8.7	7.5	7.6	0.32 NS	0.32 ***	0.45 NS
Concentrate DM	(kg)	7.8	7.8	7.7	7.8	-	-	-
Total DM	(kg)	16.9	16.5	15.3	15.4	0.36 NS	0.36 **	0.51 NS
Total ME	(MJ)	198	195	169	171	4.4 NS	4.4 ***	6.3 NS
RDP	(g)	2313 (1544)	2244 (1521)	1724 (1318)	1747 (1334)	-	-	-
UDP	(g)	765 (543)	749 (562)	617 (483)	624 (510)	-	-	-

‡ Figures in brackets are estimated protein requirements from ARC (1980).

intake between the different patterns of concentrate allocation in period 2. In periods 3 and 4 pattern of concentrate allocation had no significant effects on daily silage, total dry matter or ME intakes. During period 5 treatments HV and LV were offered 1.5 kg day^{-1} less concentrates on average to the group than treatments HF and LF which resulted in a significant ($p < 0.05$) increase in energy intake for treatments HF and LF (substitution rate = 0.53).

The intakes of protein RDP and UDP were derived from the group intakes of silage and concentrates using degradability values of 0.8 for silage and 0.7 for concentrate (ARC, 1980). In all periods and within all treatments the intakes of protein, for both RDP and UDP satisfied the requirements laid out by ARC (1980). The major influence on the protein intakes was that of silage quality. The L silage had a very low protein content which was reflected in the intakes of protein in treatments LF and LV compared with treatments HF and HV.

Milk production

The mean daily milk yields for each period and for the complete trial are presented in Table 7.14 and the lactation curves are illustrated in Figure 7.10. Peak milk yields, the time to reach peak milk yield, the rate of decline per week as a % of peak yield, and the mean coefficient of variation for milk yield for each treatment for the whole trial are presented in Table 7.15.

Pattern of concentrate allocation did not significantly affect peak milk yield, the number of weeks from calving to peak milk yield, or the mean daily milk yields in any of the 5 periods. There was, however, a tendency for peak milk yields to be greater on the V treatments

Fig 7.10 Mean daily milk yields (kg day^{-1}) of the four treatment groups over the 25 week experimental period

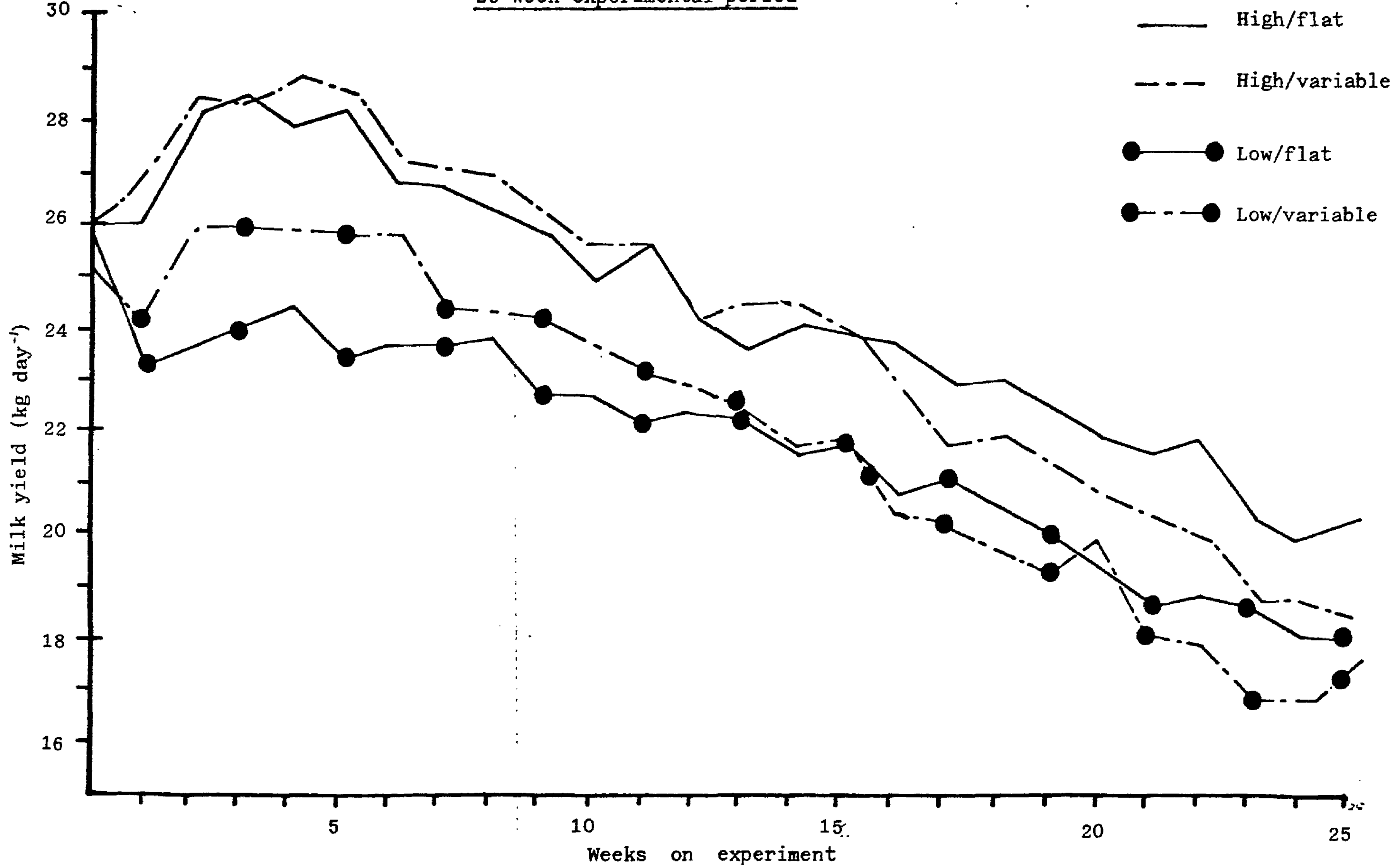


Table 7.14 Mean Daily Milk Yields for Each Period and for the Whole Trial (kg)

	Treatments				SED		
	HF	HV	LF	LV	Pattern	Quality	P x Q
Period 1							
Milk yield (kg unadjusted)	27.8	28.2	23.8	25.6	1.07 NS	1.07 **	1.52 NS
(adjusted)	(27.8)	(28.2)	(23.8)	(25.7)	0.77 NS	0.77 ***	1.08 NS
Period 2							
Milk yield (kg unadjusted)	26.1	26.6	23.3	24.6	1.13 NS	1.13 *	1.60 NS
(adjusted)	(26.1)	(26.6)	(23.3)	(24.7)	0.81 NS	0.81 **	1.15 NS
Period 3							
Milk yield (kg unadjusted)	24.3	24.6	22.0	22.5	1.01 NS	1.01 *	1.43 NS
(adjusted)	(24.3)	(24.6)	(22.0)	(22.6)	0.77 NS	0.77 *	1.10 NS
Period 4							
Milk yield (kg unadjusted)	22.8	21.8	20.5	20.0	0.88 NS	0.88 *	1.25 NS
(adjusted)	(22.8)	(21.7)	(20.4)	(20.1)	0.66 NS	0.66 **	0.94 NS

Table 7.14 (continued) Mean Daily Milk Yields for Each Period and for the Whole Trial (kg)

	Treatments				SED		
	HF	HV	LF	LV	Pattern	Quality	P x Q
Period 5							
Milk yield (kg unadjusted)	20.9	19.4	18.5	17.5	1.00 NS	1.00 *	1.41 NS
(adjusted)	(20.9)	(19.3)	(18.5)	(17.6)	0.81 NS	0.81 *	1.14 NS
Mean of whole trial							
Milk yield (kg unadjusted)	24.4	24.1	21.6	22.0	0.94 NS	0.94 *	1.33 NS
(adjusted)	(24.4)	(24.1)	(21.6)	(22.1)	0.66 NS	0.66 **	0.94 NS

Table 7.15 Peak Milk Yield, Weeks to reach Peak Milk Yield from Calving and Rate of Decline per Week as % of Peak Milk Yield

	Treatments				SED		
	HF	HV	LF	LV	Pattern	Quality	P x Q
Peak milk yield (kg day^{-1})	29.9	30.6	26.0	27.8	1.26 NS	1.26 *	1.78 NS
Weeks to reach peak milk yield from calving	6.0	6.1	7.3	6.4	0.60 NS	0.60 NS	0.84 NS
Rate of decline per week as % of peak milk yield	1.2	1.6	1.3	1.7	0.15 **	0.15 NS	0.21 NS
Coefficient of variation (%) for milk yield over whole 25 weeks	10.8	18.5	14.2	19.3	-	-	-

(see Figure 7.10). The average milk yield response to the additional 1 kg of concentrate dry matter offered to both the V treatments in periods 1 and 2 was 0.50 and 1.60 kg milk per kg concentrate dry matter for treatments HV and LV respectively. This greater response on the low quality silage is clearly illustrated in Figure 7.10.

The significantly greater ($p < 0.01$) rate of decline in milk yield per week as a percentage of peak milk yield on treatments HV and LV meant that the pattern of concentrate allocation over the 25 weeks did not significantly affect the average daily milk yields. The coefficient of variation for milk yield within each treatment group was greater for the V treatment compared with the F treatment in both qualities of silage.

The H silage resulted in a significantly ($p < 0.05$) greater peak milk yield and a significantly greater mean daily milk yield in each period and overall compared with the L silage. The mean milk yield response over 25 weeks was +0.37 kg day^{-1} milk per unit increase in D-value.

Silage quality did not significantly affect the time to reach peak milk yield which was on average 6.5 weeks for all four treatments or the rate of decline in milk yield per week as a % of peak milk yield which averaged 1.4% and 1.5% for the H and L silages respectively.

Milk composition

Pattern of concentrate allocation significantly ($p < 0.01$) increased milk protein content during period 2 on the variable rate treatments LV and HV. This was the only observed effect which the

Fig. 7.11 The effect of silage quality on milk fat and protein content over 25 weeks

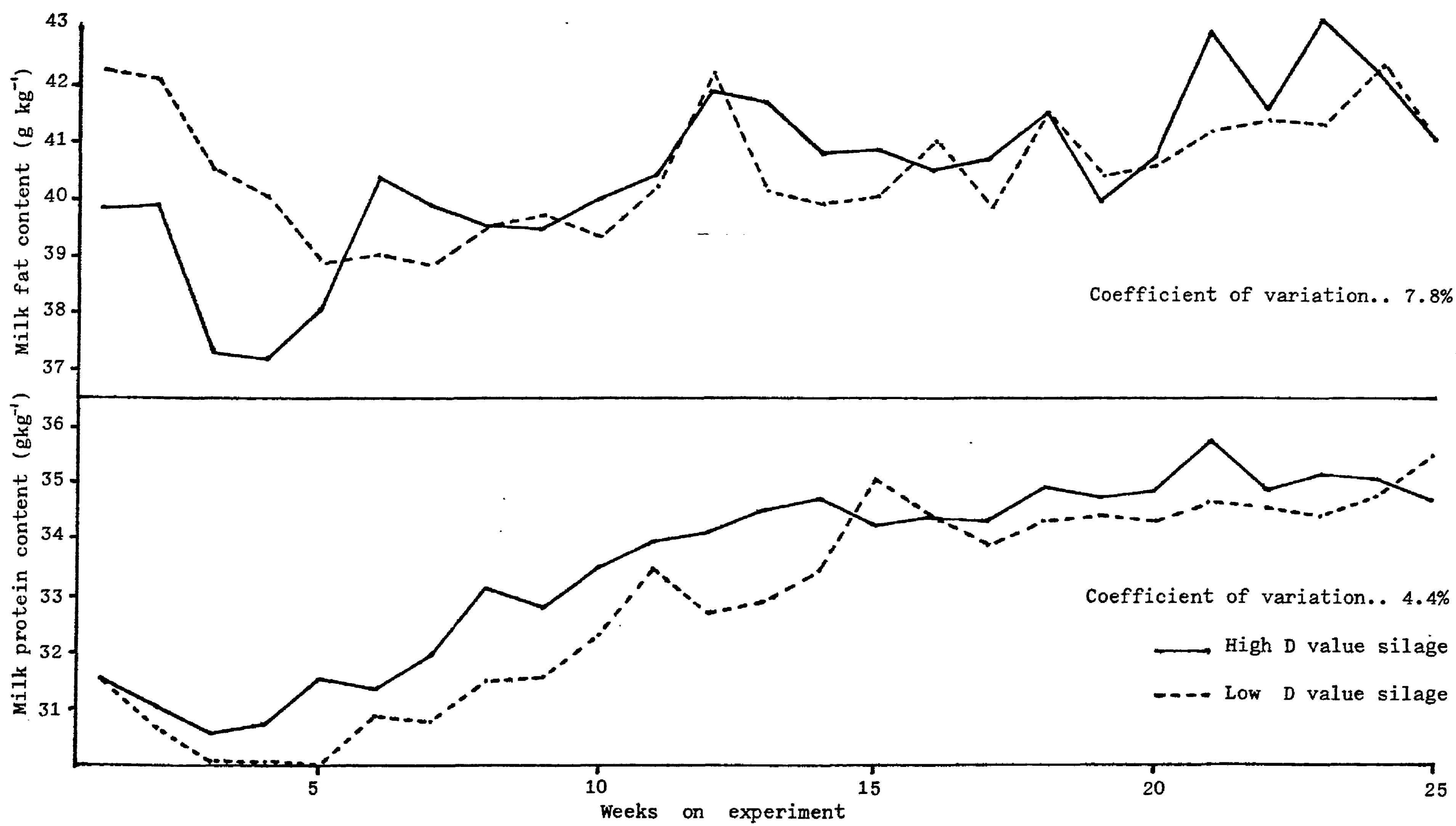


Table 7.16 Milk Composition for Each Period and the Mean for the Whole 25 Weeks (g kg^{-1})

	Treatments				SED		
	HF	HV	LF	LV	Pattern	Quality	P x Q
Period 1							
Milk fat content	38.4	38.8	40.4	41.1	1.15 NS	1.15 NS	1.63 NS
Milk protein content	30.7	31.8	30.1	30.8	0.47 NS	0.47 NS	0.67 NS
Milk lactose content	50.2	49.7	48.8	48.8	0.39 NS	0.39 **	0.55 NS
Period 2							
Milk fat content	40.1	40.0	39.5	39.4	0.97 NS	0.97 NS	1.37 NS
Milk protein content	32.1	33.2	31.1	32.0	0.43 *	0.43 *	0.61 NS
Milk lactose content	49.6	49.4	48.6	48.6	0.38 NS	0.38 *	0.54 NS
Period 3							
Milk fat content	40.7	41.9	40.4	40.9	1.08 NS	1.08 NS	1.53 NS
Milk protein content	34.2	34.7	33.0	34.2	0.53 NS	0.53 NS	0.76 NS
Milk lactose content	49.1	48.5	48.2	48.1	0.34 NS	0.34 NS	0.47 NS

Table 7.16 (continued) Milk Composition for Each Period and the Mean for the Whole 25 Weeks (g kg^{-1})

	Treatments				SED		
	HF	HV	LF	LV	Pattern	Quality	P x Q
Period 4							
Milk fat content	40.8	40.7	40.4	41.5	1.09 NS	1.09 NS	1.54 NS
Milk protein content	34.7	34.8	33.8	34.8	0.56 NS	0.56 NS	0.79 NS
Milk lactose content	48.4	47.8	47.4	47.5	0.42 NS	0.42 NS	0.59 NS
Period 5							
Milk fat content	42.0	42.4	40.9	42.4	0.94 NS	0.94 NS	1.33 NS
Milk protein content	35.0	35.3	34.8	34.8	0.53 NS	0.53 NS	0.75 NS
Milk lactose content	48.0	47.2	47.2	47.2	0.38 NS	0.38 NS	0.54 NS
Mean of whole trial							
Milk fat content	40.3	40.6	40.4	41.0	0.91 NS	0.91 NS	1.29 NS
Milk protein content	33.2	33.8	32.4	33.1	0.42 NS	0.42 NS	0.59 NS
Milk lactose content	49.2	48.7	48.1	48.1	0.33 NS	0.33 *	0.47 NS
Milk s-n-f content	89.8	90.0	88.0	88.7	0.58 NS	0.58 *	0.83 NS
Milk total solids con.	130.1	130.5	128.4	129.6	1.29 NS	1.29 NS	1.82 NS

pattern of concentrate allocation had on milk composition during the whole 25 week experimental period (see Table 7.16). Over the whole trial, pattern of concentrate allocation did not significantly affect milk composition. The weekly mean values for the H and the L silages are illustrated in Figure 7.11 for milk fat and protein content to show the general lactational trends.

Cows on the H silage during periods 1 and 2 and overall produced milk with a significantly ($p < 0.05$) greater milk lactose and solids-not-fat content than the cows on the L silage. No significant effects of silage quality were observed for milk fat content or milk protein content although there was a consistent trend for milk protein content to be greater for the H silage (Figure 7.11).

The significant, although small effects, on milk lactose and solids-not-fat content of silage quality were primarily due to the low coefficients of variation observed for these two parameters of 2.4% and 2.3% for milk lactose and solids-not-fat content respectively, compared with the values of 7.8% and 4.4% obtained for milk fat and protein content respectively.

Liveweight and liveweight change

Pattern of concentrate allocation had no significant effect on total liveweight or liveweight change over the 25 week experiment (Table 7.17). During period 4, however, treatments HF and LF had a significantly ($p < 0.05$) greater liveweight gain compared with treatments HV and LV. This effect was similar for both silage qualities. At the end of the 25 weeks treatment F cows were on average 10 kg heavier than treatment V cows but this difference was not significant.

Fig. 7.12 Liveweight over 25 weeks for the four treatment groups

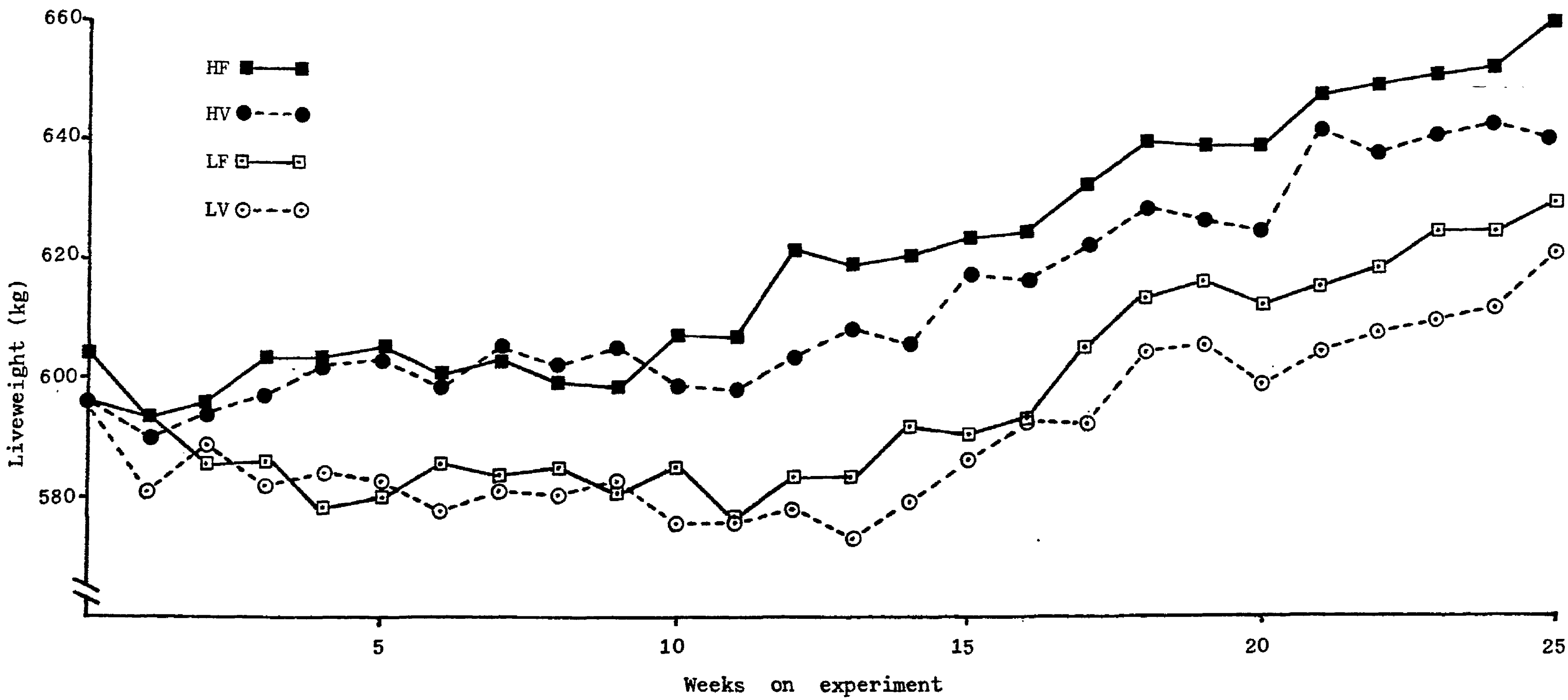


Table 7.17 Liveweight[‡] and Liveweight Change for Each Period and the Mean for the Whole 25 Weeks

	Treatments				SED		
	HF	HV	LF	LV	Pattern	Quality	P x Q
Period 1							
Liveweight (kg)	595	598	586	595	6.1 NS	6.1 NS	8.7 NS
Liveweight change (kg day^{-1})	0.16	0.29	-0.48	-0.34	0.20 NS	0.20 **	0.28 NS
Period 2							
Liveweight (kg)	596	603	584	581	7.2 NS	7.2 *	10.2 NS
Liveweight change (kg day^{-1})	0.09	0.00	-0.05	-0.06	0.17 NS	0.17 NS	0.24 NS
Period 3							
Liveweight (kg)	613	608	586	579	7.6 NS	7.6 ***	10.8 NS
Liveweight change (kg day^{-1})	0.34	0.53	0.34	0.18	0.16 NS	0.16 NS	0.22 NS
Period 4							
Liveweight (kg)	629	625	609	601	8.7 NS	8.7 *	12.4 NS
Liveweight change (kg day^{-1})	0.53	0.29	0.75	0.45	0.12 *	0.12 NS	0.16 NS

‡ Liveweights adjusted using 14 day weights as covariate.

Table 7.17 (continued) Liveweight[‡] and Liveweight Change for Each Period and the Mean for the Whole 25 Weeks

	Treatments				SED		
	HF	HV	LF	LV	Pattern	Quality	P x Q
Period 5							
Liveweight (kg)	646	642	624	613	9.4 NS	9.4 *	13.4 NS
Liveweight change (kg day^{-1})	0.47	0.35	− 0.49	0.56	0.12 NS	0.12 NS	0.17 NS
Mean of whole trial							
Liveweight (kg)	616	615	598	592	7.3 NS	7.3 **	10.4 NS
Liveweight change (kg day^{-1})	0.32	0.29	0.21	0.16	0.06 NS	0.06 *	0.08 NS

‡ Liveweights adjusted using 14 day weights as covariate.

Figure 7.12 illustrates the lactational trends in cow liveweights the major effect coming from silage quality. The main effect of silage quality was obtained during period 1; treatments HF and HV had small liveweight gains whereas treatments LF and LV had significant ($p < 0.01$) liveweight losses. After period 1 cows on the H silage were consistently on average 20 kg heavier than cows on the L silage and at the end of the experiment cows on the H silage were on average significantly ($p < 0.05$) heavier (24 kg) than the cows on the L silage.

Body condition score

Pattern of concentrate allocation had no significant effects on body condition score as seen in Table 7.18. Figure 7.13 illustrates that there was a tendency for treatment LF to have the lowest overall body condition score during periods 2, 3, 4 and 5 compared with treatment LV. The reverse happened in the high quality silage in that treatment HF had the highest overall body condition score compared with treatment HV.

Silage quality had marked effects on body condition score. On average treatments HF and HV had significantly ($p < 0.05$) greater body condition scores than treatments LF and LV and at the end of the experimental period cows on the H silage were on average significantly ($p < 0.05$) higher in body condition averaging 2.65 compared to the cows on the L silage with a body condition score of 2.25.

Fertility and health

Table 7.20 illustrates the treatment effects on various aspects of fertility. The number of days to first service was similar for all four treatment groups. The conception rate fo first service was lower

Fig. 7.13 Body condition score over 25 weeks for the four treatment groups

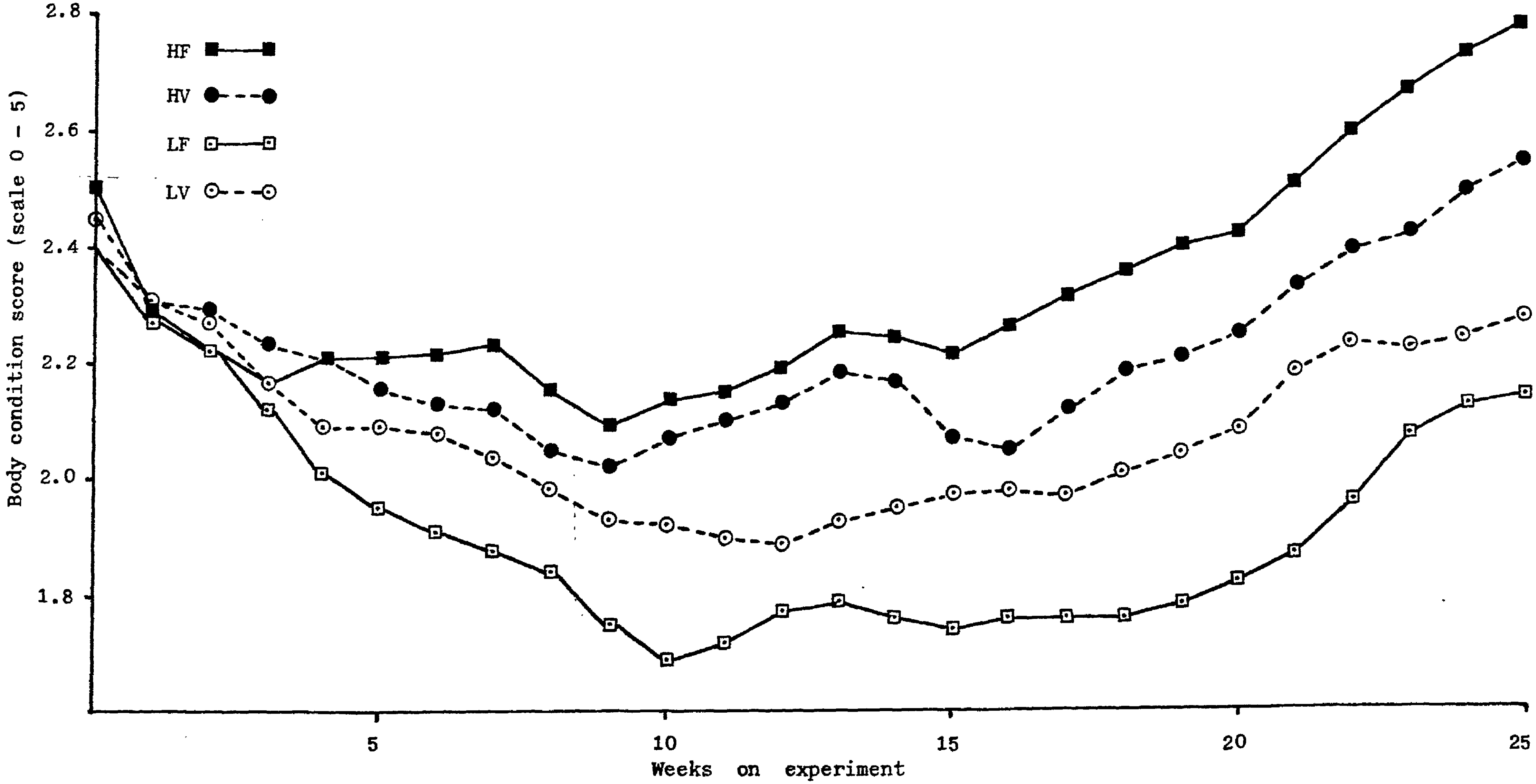


Table 7.18 Body Condition Score

	Treatments				SED		
	HF	HV	LF	LV	Pattern	Quality	P x Q
Initial condition score	2.5	2.5	2.4	2.4	-	-	-
Final condition score at 25 weeks	2.8	2.5	2.2	2.3	0.17 NS	0.17 *	0.24 NS
Total change over 25 weeks	+0.3	+0.1	-0.3	-0.1	0.17 NS	0.17 **	0.24 NS
Average condition score over whole trial	2.3	2.2	1.9	2.1	0.10 NS	0.10 *	0.14 NS

Table 7.20 Fertility Information for the Four Treatment Groups

	HF	HV	LF	LV
Days to 1st service	70	73	74	75
Calving to successful service	85	82	120	99
Conception to 1st service	6/12 (50%)	7/11 (64%)	4/10 (40%)	6/12 (50%)
Calving interval	367	364	404	381
(number of animals)	(11)	(10)	(10)	(10)
Number barren	1	1	0	2
Number not served*	0	1	2	0

* Animals not served were selected for culling due to low milk production and previous persistent cases of mastitis.

on average for the L silage although the small numbers of animals make specific conclusions impossible. There was a general trend for the calving intervals to be shorter for the H silage treatments compared with the L silage treatments.

During the experimental period one animal on treatment LV was replaced, due to extreme lameness, by an identical animal which was similar in liveweight and milk production at the time of replacement and at 14 days post-calving. The data for the replacement animal were included in the final analysis.

There were no cases of coliform mastitis recorded during the experimental period and other less severe cases of mastitis were evenly distributed over the four-treatment groups.

Residual period

The residual period consisted of 2 weeks indoors on 7 kg concentrates and silage *ad libitum*, a week of grazing during the day and silage at night with 5 kg day^{-1} concentrate followed by 13 weeks at set-stocked grazing with 1 kg day^{-1} of concentrate. The concentrate used was the same as that used during the experimental period.

Table 7.19 shows the milk production during the residual period and the total 305 day milk production. There were no significant effects of silage quality or pattern of concentrate allocation on the milk produced during the residual period which averaged 1,595 kg for all four treatment groups.

The 305 day milk yield was 301 kg greater on average for the H silage compared with the L silage which amounted to 48 kg extra milk

Table 7.19 Milk Production during the Residual Period and 305 day Yields for the Four Treatment Groups

	Treatments				SED	
	HF	HV	LF	LV	Pattern	Quality
Milk production during residual period (kg)	1623	1527	1654	1577	131 NS	131 NS
305 day milk yield (kg)	6215	6096	5786	5924	213 NS	213 NS

at 305 days per unit increase in silage D-value fed during the experimental period. This difference, however, was not significant.

Pattern of concentrate allocation did not significantly affect 305 day milk yields which averaged 6,001 kg for treatments HF and LF and 6,010 kg for treatments HV and LV.

Milk compositions during the residual period were similar for the four treatment groups and although the cow body weights and body condition scores for treatments HF and HV were on average significantly ($p < 0.05$) greater than treatments LV and LV at the end of the experimental period, by 43 weeks post-calving there were no observed differences between the four treatment groups for either body weight or body condition score.

DISCUSSION

In line with the previous experiment and others (Østergaard, 1979; Steen and Gordon, 1980 a; Gordon, 1982) there was a tendency for the V treatments to have a larger peak milk yield and thereafter a greater post peak decline in milk yield compared with the uniform pattern of concentrate allocation. The milk yield response during period 1 and 2 to the additional concentrates offered to treatment LV compared with treatment LF was larger at 1.6 kg milk per kg concentrate dry matter compared to a milk yield response between treatments HV and HF of 0.5 kg milk per kg concentrate dry matter. These observed differences were not significantly different. Other studies have reported greater milk yield responses to additional supplementation for low compared with high D-value silages (Kristensen *et al*, 1979; Moisey and Leaver, 1980; Gordon, 1981a). Few studies have compared such a large difference in silage D-value as in the present study and as a result none have reported such a large difference in milk yield response to a similar increase in concentrate supplement.

During periods 4 and 5 the milk yields for treatments LV and HV were less than treatments LF and HF respectively. Overall, therefore, the results from this experiment suggest that even with a more moderate quality silage offered *ad libitum* pattern of concentrate allocation has no significant effect on average daily milk yield.

There were no significant differences in the time to reach peak milk yield between the four treatments which averaged 6.5 weeks. These figures are similar to those of the previous experiment which used slightly older cows and compare well with other studies (Johnson, 1977, 1983).

The coefficient of variation for milk yield over the 25 weeks was lower for the F treatments 13% compared to the V treatments 18.9%. These figures suggest that the F treatments have a similar mean daily milk yield but a much smaller range in individual animal's milk yields around the mean for the group compared with the V treatments (Table 7.21). Equations 7.10, 7.11, 7.12 and 7.13 indicate that the correlation between 14 day milk yield and the mean daily milk yield over 25 weeks is consistently higher for the V treatments.

HV $\quad y = 5.51 + 0.72\,x$ 7.10

$r = 0.82 \quad b = 0.16 \quad RSD = 2.71 \quad (p < 0.01)$

LV $\quad y = 4.12 + 0.70\,x$ 7.11

$r = 0.92 \quad b = 0.09 \quad RSD = 1.72 \quad (p < 0.001)$

HF $\quad y = 14.87 + 0.37\,x$ 7.12

$r = 0.65 \quad b = 0.14 \quad RSD = 2.09 \quad (p < 0.05)$

LF $\quad y = 8.21 + 0.52\,x$ 7.13

$r = 0.69 \quad b = 0.18 \quad RSD = 2.35 \quad (p < 0.05)$

r = correlation coefficient, b = standard error of slope, RSD = residual standard deviation, y = mean daily milk yield over 25 weeks, x = 14 day milk yield.

Silage quality had by far the most significant effect on the mean daily milk production over the 25 weeks and the average milk yield response was 0.37 kg day^{-1} per unit increase in D-value. This response is similar to Thomas *et al* (1981) who reported a mean response of 0.3 kg milk day^{-1} per unit increase in silage D-value but large compared with other studies (Thomas, 1980; Gordon, 1980; Castle, 1982). Thomas (1980) found an average response of 0.29 kg milk per ΔD and reported a wide

Table 7.21 Average Milk Yields for the Six Highest and Six Lowest Yielders

	Treatments			
	HF	HV	LF	LV
Mean yield of the 6 highest yielders	26.5	27.7	24.1	25.1
Mean yield of the 6 lowest yielders	22.4	20.6	19.2	19.0
Overall mean	24.5	24.2	21.7	22.1

variation in this response. Castle (1982) from a study of 18 silages from the Hannah Research Institute found a mean response of 0.24 kg milk per ΔD.

Pattern of concentrate allocation had no overall significant effect on any aspect of milk composition which agrees with the previous experiment and others (Johnson, 1977; Steen and Gordon, 1980 a; Moisey and Leaver, 1982).

Silage quality had significant overall effects on milk lactose content and solids-not-fat content but did not significantly affect milk fat and protein content. Thomas *et al* (1981) reported that high D-value silage produced milk with a significantly lower milk fat content and higher milk protein content than lower quality silage. In this experiment milk protein content was consistently higher for the H silage but the difference was not significant. Thomas *et al* (1981) used 74 DOMD silage with a low cellulose content which may have contributed to the lower milk fat content through a reduction in the fibre content in the ration. The present experiment's H silage DOMD was 65 and this would be expected to provide sufficient fibre to maintain milk fat contents at a reasonable level.

Other studies in line with the present experiment (Kristensen *et al*, 1979; Castle *et al*, 1980; Steen and Gordon, 1980b) have reported no significant effects of silage quality on milk fat or protein contents. The significantly higher milk lactose content for the high quality silage in this experiment does not agree with any previous studies where different silage qualities have been compared. Other experiments at Crichton Royal Farm (Laird *et al*, 1981; Moisey and Leaver, 1982) have consistently found significant effects of different levels of nutrition on milk lactose content.

The coefficient of variation for the milk fat and protein contents were 7.8% and 4.4% respectively. These were considerably greater than those observed for milk lactose and solids not fat content which were 2.4 and 2.3% respectively. This may partly explain the significant differences observed for milk lactose and solids-not-fat contents. Other studies (Clapperton *et al*, 1978; Malestein *et al*, 1981) have reported that observed differences in milk composition, especially milk fat content, have not been statistically significant as a result of large day to day and animal variations.

The F treatments in period 1, had on average a significantly ($p < 0.05$) lower total ME intake compared with the average for the V treatments. However, these effects were compensated for by the F treatments having a significantly ($p > 0.05$) greater ME intake than the V treatments in period 5. Therefore the overall energy intakes were a reflection of the distribution of concentrates being proportionately less in early lactation in the F treatments but proportionately more in mid-lactation compared to the V treatments. These observations are similar to other studies (Østergaard, 1979; Steen and Gordon, 1980 a; Gordon, 1982). However, these other studies have not described the patterns of energy intake during the experimental period.

Silage quality had significant effects on silage and total ME intake. The average response in silage dry matter intake to a unit increase in D-value was +0.22 kg day^{-1}. This response is large compared with other reports of Thomas (1980) (0.15 kg DM per unit change in D-value) and Thomas *et al* (1981) (0.04 kg DM per unit change in D-value). An explanation for the large response obtained in this experiment may be the fact that the difference in DOMD between two silages was large at 6.3 units and also the low quality silage was low compared to other studies and one may expect the largest responses to increasing silage D-value at lower silage D-values.

The crude protein contents of the two silages differed and illustrated the large depression in crude protein content by delayed first cut. These observations are similar to others (Castle *et al*, 1980; Steen and Gordon, 1980 b) who also observed large depressions in silage crude protein content of late cut material.

During the residual period the milk yields were similar for all four treatments and the overall 305 day differences in milk yield were similar to those obtained during the indoor feeding period. Despite the 3.4 kg difference in peak milk yields between the two qualities of silage there were no observed residual effects at pasture which supports the observations of Steen and Gordon (1980 a) and Thomas *et al* (1981).

At the end of lactation there were no differences in any other aspects of performance and animals that had significantly lower weights at turnout on the L silage were able to compensate for this during the residual period.

The calving intervals for cows on the L silage were on average 27 days longer than those on the H silage, this may have been as a result of the significantly greater liveweight losses and condition scores during the service period which corresponded to periods 2 and 3 of the experiment.

The theoretical effect of date of first cut and/or frequency of cutting on the cow feeding days and milk output per ha has previously been discussed in detail (Castle *et al*, 1980, Thomas *et al*, 1981; Corrall *et al*, 1982). The present results also provide further evidence to illustrate the differences in grass yield and the increase in cow feeding days by delaying first cut. The theoretical cow feeding days and milk outputs per ha from the present experiment are detailed in Table 7.22 and show the larger theoretical milk output ha^{-1} for the later cut silage. These results are in line with Castle *et al* (1980). It also must be stressed that the present and Castle *et al* (1980) figures are based on first cut silages only and consideration must also be given to the rest of the growing season to provide a total and more meaningful analysis (Corrall *et al*, 1982).

Table 7.22 The Theoretical Production from the Two Silages made from First Harvest Material only and Similar Levels of Concentrates

	High D	Low D
Cow days per ha	445	844
Milk output per ha (kg)	10,838	18,399

SUMMARY

In a 25-week experiment commencing at week 3 *post-partum*, silages of 650 g and 590 g digestible organic matter per kg dry matter were offered *ad libitum* to 2 groups of 24 autumn-calving British Friesian dairy cows. Within each silage quality group two patterns of concentrate allocation were compared: a flat-rate and a variable rate. All 4 treatment groups received, on average, 1575 kg fresh weight per cow of a 170 g kg^{-1} crude protein concentrate over the 25 weeks. Average levels of performance were not significantly affected by pattern of concentrate allocation within both the high and low quality silages during the 25-week experimental period or the residual period up to 305 days post-calving. The effects of silage quality were significant during the 25-week experiment but did not significantly affect performance during the residual period. It is concluded that uniform patterns of concentrate allocation can be adopted with both high and low D-value silages, offered *ad libitum*, without any adverse effects on cow performance.

CHAPTER 8

EXPERIMENT 3 A COMPARISON OF TWO LEVELS AND TWO PATTERNS OF CONCENTRATE ALLOCATION FOR AUTUMN CALVING DAIRY COWS OFFERED SILAGE *AD LIBITUM*

Introduction

In experiment 2, Chapter 7, the pattern of concentrate allocation had no significant effect on performance with high or low quality silage at similar levels of concentrate intake. Experiment 1 fed the same daily quantity of concentrate and confirmed previous experimental results (Østergaard, 1979; Steen and Gordon, 1980 a; Gordon, 1982).

The total quantity of concentrates fed over a given period has a much more significant effect on animal performance than the pattern of allocation with high D-value silage (Steen and Gordon, 1980 a; Moisey and Leaver, 1982). The optimum level of concentrate to feed is frequently assessed by the financial response in milk yield to an additional kg of concentrate compared with the cost of the additional kg of concentrate (Gordon, 1981 a). The total amount of concentrate fed to a herd affects the quantity of silage eaten/required (Chapter 1). It is therefore argued that the optimum level of concentrate fed must be judged in relation to the annual stocking rate, the substitution of concentrates for forage and the utilisation of the grazing and conservation area (Leaver, 1983; Doyle, 1983).

The effect of pattern of concentrate allocation may be different at different total levels of concentrate. The objective of this experiment was to clarify whether pattern of concentrate allocation is more critical at low or high levels of concentrate feeding.

MATERIALS AND METHODS

Livestock and management

Forty-eight British Friesian cows were used. Their calving dates ranged from 26 August to 21 October with a mean calving date of 21 September. The experiment ran from September 1982 to April 1983.

All cows calved at grass and were brought inside after 24 hours. During the first 14 days after calving (pre-experimental) cows were housed in an easy feed cubicle building with a central feed passage and were offered the experimental silage *ad libitum* and 8 kg day^{-1} fresh weight of concentrate (Table 8.10), all fed in the parlour.

The cows were allocated to the four treatment groups as they reached 14 days post-calving (range 10-17 days) and were then transferred to another cubicle building with a central feed passage and were offered silage once daily from a forage box during the experimental period.

The cows were milked at 0515 h and 1630 h and received 1 kg of the experimental concentrate in the parlour at each milking with the remainder of the experimental ration fed through two programmed out-of-parlour feeders sited in the housing area.

The initial 14 day values for milk yield, liveweight, condition scores and parity can be seen in Appendix 5.

Diets

The silage used was from the primary growth of a perennial ryegrass sward which had 150 kg N ha^{-1} applied in March. The silage was

Table 8.10 Chemical Composition of Feeds (g kg^{-1} DM)

	Silage	Concentrate
Oven dry matter (g kg^{-1})	231	864
Crude protein	133	196
Organic matter	906	906
DOMD (*in vitro*)	662	752
Predicted ME (MJ kg^{-1})	10.6	13.0*
DCP	80.3	171.0
Ammonia N as % of total N	9.9	-
pH	4.0	-
Calcium	5.4	11.4
Phosphorus	3.2	7.7
Magnesium	2.1	4.7

* Corrected ME assuming oil content of 45 g kg^{-1}.

Table 8.11 Physical Ingredients of Concentrate (kg 1000 kg^{-1})

Barley	243.0
Maize gluten	202.5
Wheat	200.0
Soya	150.0
Wheat feed	80.0
Molasses	50.0
Fish meal	25.0
Spray fat	20.0
Minerals/vitamins	20.0
Dicalcium phosphate	5.0
Calcium/magnesium	4.5
	1000 kg

cut with a drum mower and wilted for 24 hours before being harvested on 30, 31 May and 1 June with a precision chop forage harvester applying formic acid (Add-F, BP Nutrition International Ltd., 850 g formic acid l^{-1}) at 2.2 litres $tonne^{-1}$. Weather during this period was ideal and no rain fell on the silage. The silage was ensiled in two unroofed silage bunkers and sheeted with black polythene. All animals were offered this silage during their 2 week pre-experimental and 25 week experimental period. Table 8.10 indicates that the silage was well preserved with an acceptable pH of 4.0 and Ammonia N as a % of total N of less than 10%.

The concentrate supplement was in the form of a fat coated 6 mm pellet, the chemical composition and physical ingredients of which can be seen in Table 8.10 and 8.11 respectively.

Treatments

In a 25 week experiment commencing at week 3 *post-partum* two mean levels of concentrate were fed: 1925 kg cow^{-1} (H) and 1225 kg cow^{-1} (L) each with 24 cows. Within each of these two concentrate levels two groups of 12 animals were used to compare two patterns of concentrate allocation; a flat rate (F) and a variable rate (V). All cows on treatments HF and LF were offered 11 and 7 kg day^{-1} fresh weight respectively of concentrate throughout. Individual cows on treatments LV and HV received different stepped patterns of concentrate allocation which were initially based on their 14 day milk yields and then their daily amounts were reduced by 1 kg at 5 weeks and 2 kg at 10, 15 and 20 weeks. The factors used to calculate individual concentrate levels from 14 day milk yields differed for the two levels of concentrate HV and LV. Table 8.12 illustrates the methods used to calculate individual cow concentrate levels from 14 day milk yields for treatments HV

Table 8.12 Pattern of Concentrate Allocation (kg day^{-1} fresh weight) over the 25 weeks for different 14-day Milk Yields on the High and Low Concentrate Levels

	14-day milk yields for the high and low concentrate levels (kg day^{-1})										
HIGH	$\geq$27.6	27.5 to 26.0	25.9 to 24.5	24.4 to 23.0	22.9 to 21.4	21.3 to 19.9	19.8 to 18.3	18.2 to 16.8			
LOW					$\geq$32.3	32.2 to 29.6	29.5 to 26.9	26.8 to 24.2	24.1 to 21.5	21.4 to 19.3	$\leq$19.2
Experimental Week											
1-5	16	16	15	14	13	12	11	10	9	8	7
6-10	16	15	14	13	12	11	10	9	8	7	6
11-15	14	13	12	11	10	9	8	7	6	5	4
16-20	12	11	10	9	8	7	6	5	4	3	2
21-25	10	9	8	7	6	5	4	3	2	2	2
Mean over 25 weeks	13.6	12.8	11.8	10.8	9.8	8.8	7.8	6.8	5.8	5.0	4.2

High level $\equiv$ (14-day yield - 7.0) x 0.65 = Mean level for 25 weeks to nearest kg.

Low level $\equiv$ (14-day yield - 7.0) x 0.37 = Mean level for 25 weeks to nearest kg.

and LV. Group concentrate levels were planned to average those given in Table 8.13.

Table 8.13 Planned Group Concentrate Levels kg hd^{-1} d^{-1} Freshweight

Experimental Week	Treatments			
	LF	LV	HF	HV
1-5	7	10.25	11	14.25
6-10	7	9.25	11	13.25
11-15	7	7.25	11	11.25
16-20	7	5.25	11	9.25
21-25	7	3.25	11	7.25
Mean over 25 weeks	7	7.05	11	11.05

Records and analytical methods

Silage was weighed separately for each concentrate level group of 24 cows. The quantity offered to each of the two groups was approximately 10% in excess of their daily requirement. Silage refusals were weighed twice weekly on Monday and Thursday and silage dry matters were taken daily. Group silage intakes were thus determined weekly, and the method used to calculate individual silage intakes from weekly group silage intakes is described in Appendix 3. Concentrate refusals from the programmed out-of-parlour feeders were recorded daily for each individual animal and both in and out-of-parlour feeders were calibrated weekly. The recording of milk yields and composition, liveweight and condition scoring were similar to those outlined in Chapter 6. The techniques and equations used for the chemical analysis of the feedstuffs were modified in July 1982 and differed from those used in experiment 1 and 2. The modified equations can be seen in Appendix 2 together with the previous equations.

During the residual period from week 27-43 of lactation, all the animals were treated as one group. The initial part of the residual period was indoors, this length of time being similar to that in experiment 2 but varying for individual animals depending on their calving dates. During the indoor residual period which averaged 3 weeks, all cows were fed 6 kg day^{-1} of concentrates.

Cows were turned out to grass on 20 April 1983. During the first 3 weeks at grass cows were in at night, as a result of heavy rainfall, and were all fed 5 kg of concentrates for the first, 4 kg for the second and 3 kg day^{-1} for the third week. After the third week at grass cows were turned out all day and fed 2 kg day^{-1} of concentrate thereafter until being dried off at 43 weeks post-calving.

Statistical analysis

This is identical to that described in Chapter 7 apart from the 2 x 2 factorial being (2 levels of concentrate x 2 patterns of allocation).

RESULTS

Feed intake

As a result of concentrate refusals in period 1 in treatments HV and LV, mainly HV, the planned group concentrate intakes had to be adjusted in period 3 to ensure that the total intakes of concentrate over 25 weeks were similar to treatments HF and LF respectively (see Figure 8.10).

The intake of concentrates, silage and the calculated intakes of ME, RDP and UDP are presented in Table 8.14. The average affect of

Fig. 8.10 Actual average daily concentrate intake (kg fresh wt.) for each week of the experiment.

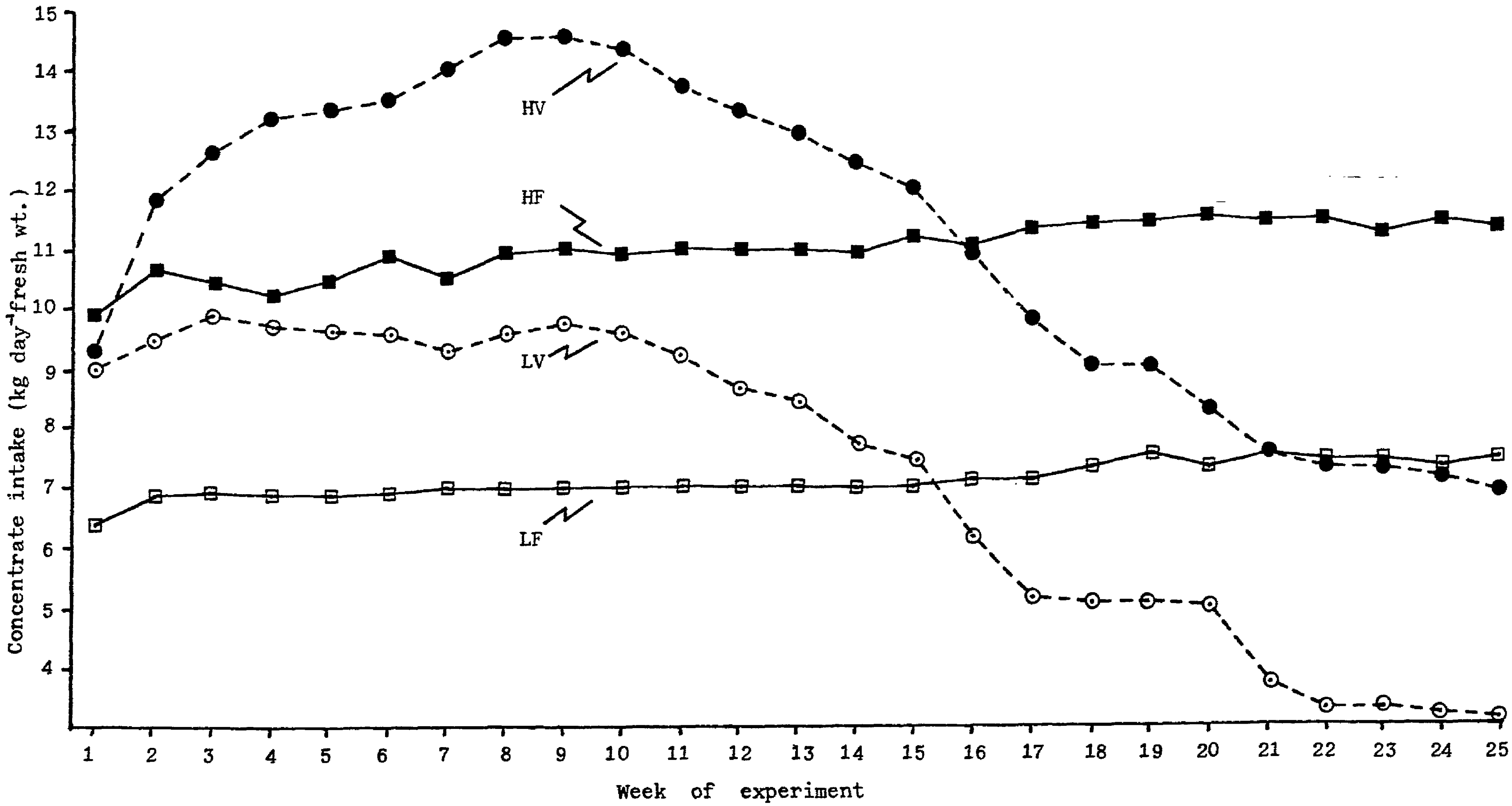


Table 8.14 Mean Daily Intakes of Dry Matter and the Calculated Metabolisable Energy, RDP and UDP Intakes

	Treatments				SED		
	HF	HV	LF	LV	Pattern	Level	P x L
Period 1							
Silage DM (kg)	9.5[a][ǂ]	6.3[c]	9.8[a]	8.4[b]	0.38 ***	0.38 **	0.54 *
Concentrate DM (kg)	8.9	10.4	5.8	8.2	-	-	-
Total DM (kg)	18.4	16.6	15.7	16.6	0.51 NS	0.51 *	0.72 *
Total ME (MJ)	219	203	183	198	6.0 NS	6.0 **	8.5 *
RDP (g)	2232(1708)[ǂǂ]	2097(1583)	1839(1427)	2019(1544)	-	-	-
UDP (g)	777 (442)	780 (591)	602 (296)	705 (449)	-	-	-
Period 2							
Silage DM (kg)	10.0[a]	5.5[b]	9.8[a]	8.1[a]	0.66 ***	0.66 NS	0.94 *
Concentrate DM (kg)	9.3	12.2	6.0	8.2	-	-	-
Total DM (kg)	19.3	17.7	15.8	16.3	0.63 NS	0.63 ***	0.89 NS
Total ME (MJ)	230	219	185	195	7.0 NS	7.0 ***	9.9 NS
RDP (g)	2340(1794)	2259(1708)	1866(1443)	1987(1521)	-	-	-
UDP (g)	813 (465)	863 (608)	613 (247)	697 (344)	-	-	-

ǂ Within rows, means not followed by same superscript letter differ significantly ($p < 0.05$).

ǂǂ Figures in brackets are the estimated daily protein requirements from ARC (1980).

Table 8.14 (continued) Mean Daily Intakes of Dry Matter and the Calculated Metabolisable Energy, RDP and UDP Intakes

	Treatments				SED		
	HF	HV	LF	LV	Pattern	Level	P x L
Period 3							
Silage DM (kg)	9.1[a][ǂ]	6.3[b]	9.8[a]	8.5[a]	0.61 **	0.61 *	0.86 NS
Concentrate DM (kg)	9.5	11.1	6.0	7.1	-	-	-
Total DM (kg)	18.6	17.4	15.8	15.6	0.64 NS	0.64 ***	0.90 NS
Total ME (MJ)	222	213	184	185	7.3 NS	7.3 ***	10.3 NS
RDP (g)	2271 (1732)[ǂǂ]	2193 (1661)	1866 (1435)	1878 (1443)	-	-	-
UDP (g)	801 (600)	821 (541)	614 (392)	645 (430)	-	-	-
Period 4							
Silage DM (kg)	8.5[a]	8.1[a]	8.7[a]	9.1[a]	0.44 NS	0.44 NS	0.63 NS
Concentrate DM (kg)	9.7	8.1	6.2	4.6	-	-	-
Total DM (kg)	18.2	16.2	14.9	13.7	0.53 **	0.53 ***	0.75 NS
Total ME (MJ)	215	189	171	154	6.0 **	6.0 ***	8.5 NS
RDP (g)	2235 (1677)	1973 (1474)	1777 (1334)	1599 (1201)	-	-	-
UDP (g)	797 (649)	692 (514)	596 (392)	513 (314)	-	-	-

ǂ Within rows, means not followed by same superscript letter differ significantly ($p < 0.05$).

ǂǂ Figures in brackets are the estimated daily protein requirements from ARC (1980).

Table 8.14 (continued) Mean Daily Intakes of Dry Matter and the Calculated Metabolisable Energy, RDP and UDP Intakes

	Treatments				SED		
	HF	HV	LF	LV	Pattern	Level	P x L
Period 5							
Silage DM (kg)	8.1[c‡]	9.5[ab]	8.5[bc]	10.5[a]	0.37 ***	0.37 NS	0.52 NS
Concentrate (kg)	9.7	6.2	6.4	2.9	-	-	-
Total DM (kg)	17.8	15.7	14.8	13.2	0.45 ***	0.45 ***	0.64 NS
Total ME (MJ)	211	180	171	145	5.2 ***	5.2 ***	7.3 NS
RDP (g)	2193 (1646)[‡‡]	1862 (1404)	1782 (1334)	1515 (1131)	-	-	-
UDP (g)	786 (532)	617 (295)	603 (370)	450 (156)	-	-	-
Mean of whole trial							
Silage DM (kg)	9.0[a]	7.1[b]	9.3[a]	8.9[a]	0.36 **	0.36 **	0.51 *
Concentrate DM (kg)	9.4	9.6	6.1	6.2	-	-	-
Total DM (kg)	18.5	16.7	15.4	15.1	0.45 *	0.45 ***	0.63 NS
Total ME (MJ)	219	201	179	175	5.2 *	5.2 ***	7.4 NS
RDP (g)	2248 (1711)	2072 (1565)	1827 (1395)	1798 (1368)	-	-	-
UDP (g)	792 (538)	754 (510)	606 (339)	602 (339)	-	-	-

‡ Within rows, means not folowed by same superscript letter differ significantly ($p < 0.05$).

‡‡ Figures in brackets are the estimated daily protein requirements from ARC (1980).

concentrate level on silage intake over the whole 25 weeks was small and the average substitution of concentrate for forage was 0.31 kg silage DM kg^{-1} concentrate DM. The effect of concentrate level on silage intake was only significant in periods 1 and 3 and for the mean of the whole experiment ($p < 0.01$). The low substitution of concentrate for silage resulted in the H levels of concentrate consistently, on average, increasing total dry matter intake and total ME intake in each period.

Pattern of concentrate allocation had significant effects on silage intake in each period apart from period 4. In periods 1, 2 and 3 the F treatments had significantly greater silage dry matter intakes than the V treatments. In period 5 the reverse situation occurred in that the V treatments had significantly greater silage intakes than the F treatments. Over the whole 25 weeks the F treatments ate significantly more silage dry matter than the V treatments. This difference was mainly attributable to the higher silage intake for treatment HF compared with HV (1.9 kg DM day^{-1}) whereas treatment LF only consumed 0.4 kg DM day^{-1} more silage than treatment LV. The interaction between the average treatment silage intake means over 25 weeks indicated that cows on treatment HV ate significantly less than treatments HF, LF and LV, which ate similar quantities of silage.

Pattern of concentrate allocation did not significantly affect total dry matter or ME intake in periods 1, 2 and 3. In period 1 and 2, however, as a result of a substitution rate of 0.68, the additional concentrates fed to treatment LV increased total dry matter and ME intake compared with treatment LF. The reverse occurred in periods 4 and 5 where a substitution rate of 0.41 resulted in treatment LF having an increased total dry matter and ME intake compared with treatment LV.

In the H levels of concentrate, additional concentrates in periods 1 and 2 for treatment HV compared to HF, did not result in increased total dry matter or ME intakes. Total dry matter and ME intakes were reduced as a result of the high substitution of concentrates for silage (1.8 kg silage DM kg^{-1} concentrate DM). In period 4 and 5 a similar effect to that in the L level was observed, in that the decrease in the level of concentrates for treatment HV compared to HF resulted in a lower total dry matter and ME intake (substitution rate 0.33).

Over the whole 25 weeks the V treatments had significantly ($p < 0.05$) lower total dry matter and ME intakes than the F treatments. This difference was mainly a consequence of the HV treatment having a much lower average total dry matter and ME intake than treatment HF. Treatments LV and LF had similar total dry matter and ME intakes.

The energy densities of the total diet differed over the four treatments and over the experiment. Table 8.15 illustrates the energy densities over the 25 weeks for each treatment in each period. The HF and LF treatments, group average, energy density was fairly constant over the experiment whereas the HV and LV treatments had higher energy density rations in periods 1 and 2 and lower energy density diets in periods 4 and 5 compared to treatments HF and LF.

The intakes of protein RDP and UDP were derived from the group intakes of silage and concentrate using degradability values of 0.8 for silage and 0.7 for concentrate (ARC, 1980). In all periods and within all treatments the intakes of protein satisfied the requirements laid down by (ARC, 1980).

Table 8.15 Energy Density of the Total Diet (MJ kg^{-1} DM) over the Experiment

Period	Treatment			
	HF	HV	LF	LV
1	11.9	12.2	11.7	11.9
2	11.9	12.4	11.7	12.0
3	11.9	12.2	11.7	11.9
4	11.8	11.7	11.5	11.2
5	11.9	11.5	11.6	11.0
Mean	11.9	12.0	11.6	11.6

Milk production

The mean daily milk yields for each period and for the whole experiment are presented in Table 8.16 and the lactation curves are illustrated in Figure 8.11. Peak milk yields, the time to reach peak yield, and the rate of decline per week as a % of peak yield are presented in Table 8.17.

Pattern of concentrate allocation did not significantly affect peak milk yield or the number of weeks to reach peak yield. Treatment HV did, however, have a longer period of time between calving and peak yield than the other treatments. Treatments HV and LV had significantly ($p < 0.001$) greater rates of decline from peak milk yield of 2.25% and 2.44% per week respectively compared with treatments HF and LF of 0.96% and 1.49% per week respectively. Pattern of concentrate allocation did not significantly affect milk yields in periods 1, 2 and 3 but treatments HV and LV produced significantly less milk during periods 4 and 5 compared with treatments HF and LF. The milk yield response to the additional concentrates fed to treatment HV compared with HF was negative and averaged -0.21 kg milk per kg increase in concentrate DM over periods 1 and 2 whereas the average response for treatment LV compared with LF over the same periods was positive and averaged +0.70 kg milk per kg increase in concentrate DM. During periods 4 and 5 the milk yield response to the additional concentrates fed to HF compared with HV was 1.6 kg milk per kg concentrate DM and the milk yield response between treatment LF and LV was +0.89 kg milk per kg concentrate DM. The negative milk yield response to additional concentrates for treatment HV in periods 1 and 2 combined with the positive response to additional concentrates for treatment HF in periods 4 and 5 resulted over the 25 weeks in 1.7 kg day^{-1} more milk for treatment HF compared with HV. In the low concentrate treatments the response to additional concentrates in periods 1 and 2 for treatment LV was compensated by the response to additional concentrates for treatment LF in periods 4 and 5 and over the 25 weeks treatments LF and LV produced similar amounts of milk per day. Over the 25 weeks pattern of concentrate allocation did not significantly affect mean daily milk yield.

The H treatments had significantly ($p < 0.05$) greater peak milk yields than the L treatments and produced significantly ($p < 0.001$) more milk in each period and over the whole experiment. The rate of decline from peak yield for the H treatments averaged 1.6% of peak milk yield and was significantly ($p < 0.05$) lower than the value of 2.0% of peak milk yield for the L treatments. The time to reach peak milk yield from calving for the H treatments averaged 7.2 weeks which was significantly ($p < 0.05$) longer than the average value of the L treatments of 5.7 weeks. This was caused by treatment HV having a value of 8.4 weeks whilst treatments HF, LF and LV had similar values of 6.0, 5.7 and 5.7 respectively (Table 8.17). The average milk yield response to concentrates over the experiment was 1.16 kg milk per kg increase in concentrate dry matter. The milk yield response between treatments LF and HF

Fig. 8.11 Mean daily milk yields for the four treatments over the 25 week experiment

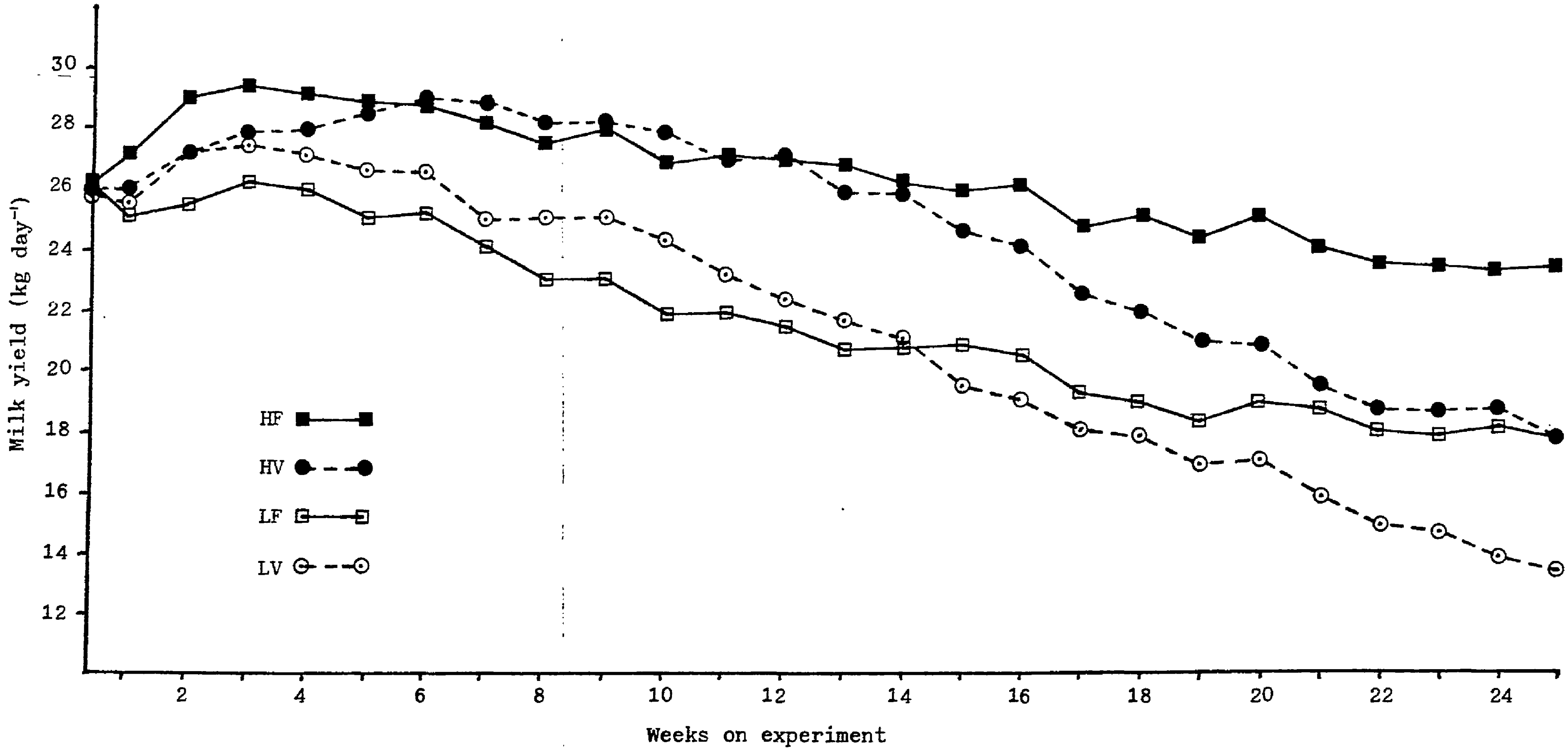


Table 8.16 Mean Daily Milk Yields for Each Period and for the Whole Trial (kg)

	Treatments				SED		
	HF	HV	LF	LV	Pattern	Level	P x L
Period 1	28.7	27.5	25.6	26.8	1.04 NS	1.04 NS	1.47 NS
	(28.5)[‡]	(27.5)	(25.6)	(27.0)	0.71 NS	0.71 *	1.00 NS
Period 2	27.9	28.4	23.5	25.1	1.09 NS	1.09 **	1.54 NS
	(27.7)	(28.4)	(23.5)	(25.3)	0.87 NS	0.87 ***	1.23 NS
Period 3	26.6	26.1	21.1	21.5	1.12 NS	1.12 ***	1.58 NS
	(26.4)	(26.1)	(21.1)	(21.7)	0.93 NS	0.93 ***	1.31 NS
Period 4	25.1	22.0	19.2	17.8	0.99 *	0.99 ***	1.41 NS
	(24.9)	(22.0)	(19.2)	(17.9)	0.85 *	0.85 ***	1.20 NS
Period 5	23.6	18.7	18.1	14.5	0.99 ***	0.99 ***	1.40 NS
	(23.4)	(18.7)	(18.1)	(14.7)	0.86 ***	0.86 ***	1.22 NS
Mean of whole trial	26.4	24.5	21.5	21.2	0.96 NS	0.96 ***	1.36 NS
	(26.2)[a][‡‡]	(24.5)[a]	(21.5)[b]	(21.3)[b]	0.75 NS	0.75 ***	1.05 NS

‡ Figures in brackets are adjusted by covariance analysis using 14-day milk yields as covariate.

‡‡ Within rows, means not followed by same superscript letter differ significantly ($p < 0.05$).

Table 8.17 Peak Milk Yields, Weeks to reach Peak Milk Yield from Calving and Rate of Decline per Week as % of Peak Milk Yield

	Treatments				SED		
	HF	HV	LF	LV	Pattern	Level	P x L
Peak milk yield (kg day^{-1})	31.1	31.3	28.1	29.1	1.14 NS	1.14 *	1.61 NS
Weeks to reach peak yield from calving	$6.0^{a‡}$	8.4^{b}	5.7^{a}	5.7^{a}	0.63 NS	0.63 *	0.89 NS
Rate of decline per week as % of peak yield	0.96	2.25	1.49	2.44	0.15 ***	0.15 *	0.22 NS
Coefficient of variation for milk yield over whole 25 weeks (%)	15.6	15.5	13.6	15.9	-	-	-

‡ Within rows, means not followed by the same superscript letter differ significantly ($p<0.05$)

of 1.42 kg milk per kg increase in concentrate DM was greater than the response between treatments LV and HV of 0.94 kg milk per kg additional concentrate DM.

Milk composition

The effects of pattern of concentrate allocation and level of concentrate on milk fat and protein content is illustrated in figures 8.12 and 8.13 respectively. On average, over the 25 weeks (Table 8.18) pattern of concentrate allocation had no significant effects on any aspect of milk composition. In period 2, however, the V treatments produced milk with significantly ($p < 0.05$) less milk fat content, which was a result of the severe depression in milk fat content observed for treatment HV in period 1 and 2, whereas treatment LV over the same period had a much smaller depression in milk fat content compared with treatment LF. The V treatments produced milk with a higher crude protein content than the F treatments in periods 1, 2 and 3 but these differences were not significant. In periods 4 and 5 treatment LF compensated for lower milk protein contents in periods 1, 2 and 3 compared to treatment LV by producing milk with a higher crude protein content than treatment LV, whilst treatments HV and HF had similar milk protein contents. On average over the experiment the H concentrate levels significantly ($p < 0.001$) decreased milk fat content, increased ($p < 0.05$) milk protein and solids-not-fat content but did not significantly affect milk lactose or total solids content (Table 8.18). The differences in milk fat content between the H and L concentrate levels were greatest in periods 1, 2 and 3 and in period 5 there were no significant differences between any of the four treatments. The significantly greater milk protein contents for the H concentrate levels were observed in periods 1, 2 and 3 and in periods 4 and 5 concentrate level had no significant effects.

Fig. 8.12 Milk fat content for each treatment over the 25 weeks

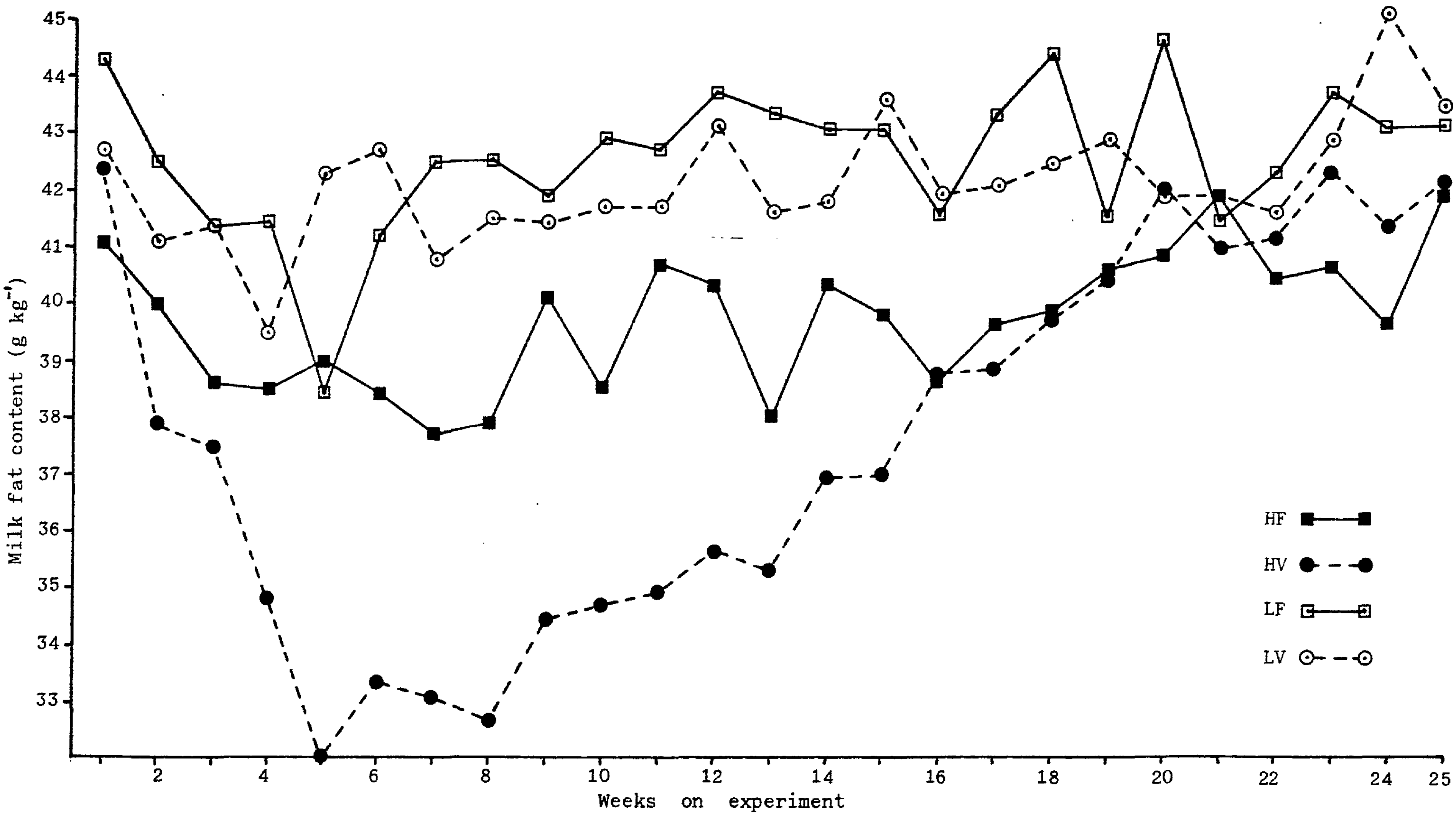


Fig. 8.13

Milk protein content for each treatment over the 25 weeks

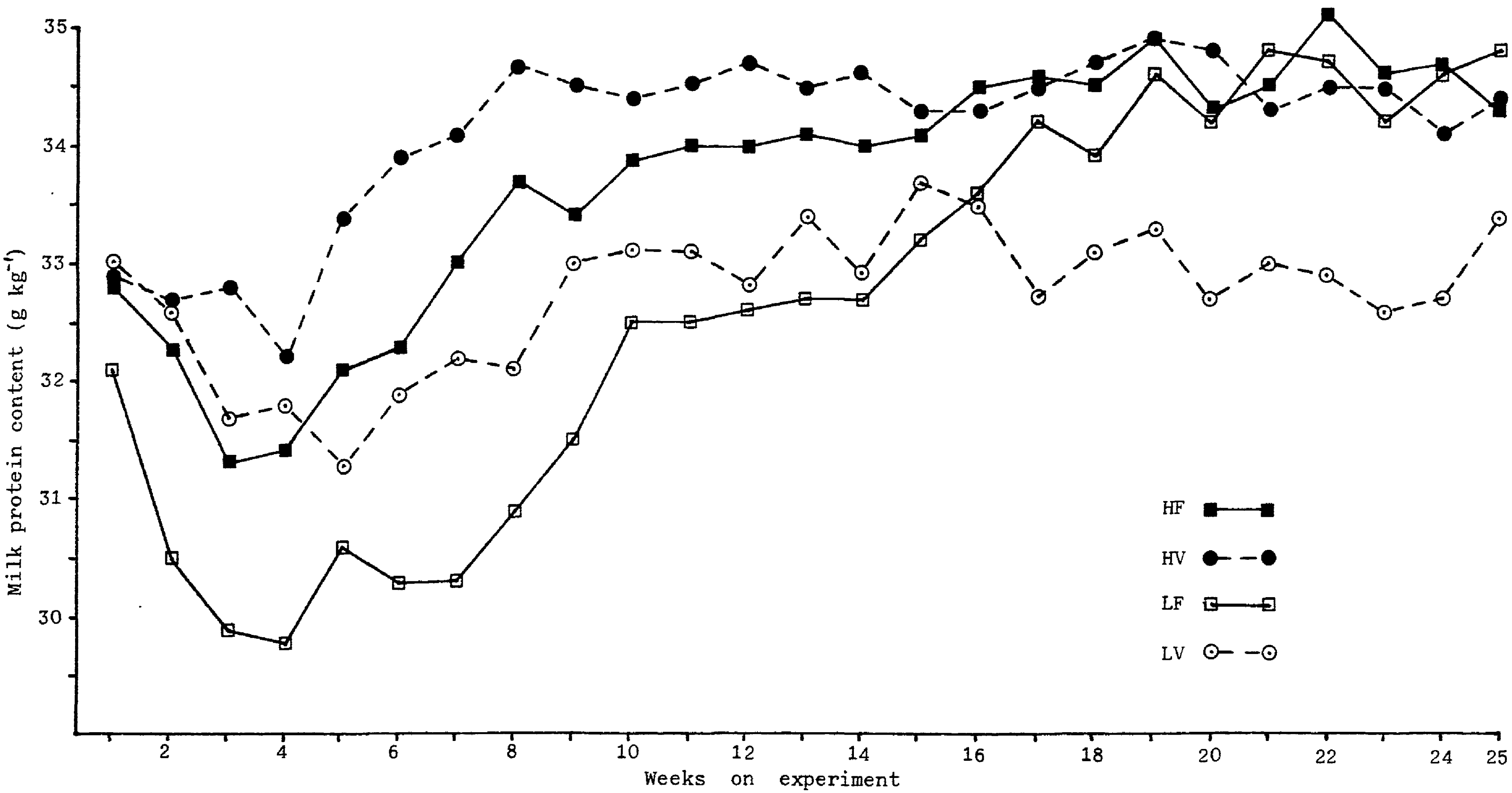


Table 8.18 Milk Composition for Each Period and the Mean for the Whole 25 Weeks (g kg^{-1})

	Treatments				SED		
	HF	HV	LV	LV	Pattern	Level	P x L
Period 1							
Milk fat content	$39.7^{ab\ddagger}$	37.2^{b}	41.6^{a}	41.6^{a}	1.06 NS	1.06 **	1.50 NS
Milk protein content	32.2	32.9	30.6	32.1	0.57 NS	0.57 *	0.80 NS
Period 2							
Milk fat content	39.0^{a}	34.2^{b}	42.2^{a}	41.7^{a}	1.26 *	1.26 ***	1.78 NS
Milk protein content	33.5	34.3	31.2	32.6	0.65 NS	0.65 **	0.92 NS
Period 3							
Milk fat content	40.2^{ab}	36.5^{b}	43.2^{a}	42.4^{a}	1.39 NS	1.39 **	1.96 NS
Milk protein content	34.3	34.6	32.8	33.3	0.64 NS	0.64 *	0.91 NS
Period 4							
Milk fat content	40.1	40.2	43.2	42.5	1.12 NS	1.12 *	1.58 NS
Milk protein content	34.9	34.8	34.2	33.1	0.60 NS	0.60 NS	0.85 NS

‡ Within rows, means not followed by the same superscript letter differ significantly ($p < 0.05$).

Table 8.18 (continued) Milk Composition for Each Period and the Mean for the Whole 25 Weeks ($g\ kg^{-1}$)

	Treatments				SED		
	HF	HV	LF	LV	Pattern	Level	P x L
Period 5							
Milk fat content	41.1	41.9	42.7	43.2	1.05 NS	1.05 NS	1.48 NS
Milk protein content	34.9	34.5	34.6	32.9	0.55 NS	0.55 NS	0.78 NS
Mean of whole experiment							
Milk fat content	$39.9^{a\ddagger}$	37.5^{b}	42.5^{a}	42.1^{a}	0.97 NS	0.97 ***	1.37 NS
Milk protein content	33.9^{ab}	34.1^{b}	32.5^{a}	32.8^{ab}	0.55 NS	0.55 *	0.78 NS
Milk lactose content	48.9	49.3	48.6	48.7	0.41 NS	0.41 NS	0.57 NS
Milk s-n-f content	90.3^{ab}	90.9^{a}	88.6^{b}	89.0^{ab}	0.78 NS	0.78 *	1.10 NS
Milk total solids content	130.2	128.4	131.1	131.1	1.40 NS	1.40 NS	1.99 NS

‡ Within rows, means not followed by the same superscript letter differ significantly ($P < 0.05$).

Liveweight and liveweight change

The liveweights and liveweight changes are tabulated in Table 8.19 and illustrated in figure 8.14. In periods 4 and 5 the V treatments on average had significantly ($p < 0.05$) lower liveweight gains than the F treatments. These differences were not large enough to influence the overall mean liveweight change or liveweights and therefore pattern of concentrate allocation had no significant effects on the mean liveweight and mean liveweight change over the 25 weeks. Treatment LF lost more liveweight during periods 1 and 2 compared to treatment LV, (as illustrated in figure 8.14) and regained this in periods 4 and 5 to finish with a similar mean liveweight to treatment LV at the end of 25 weeks. Treatment HV lost a similar amount of liveweight in periods 1 and 2 compared with treatment HF, but gained less liveweight in periods 4 and 5 and at the end of 25 weeks was on average 37 kg lighter than treatment HF.

The H treatments had on average significantly ($p < 0.05$) lower liveweight losses in period 2, compared to the L treatments, and over the 25 weeks they had significantly ($p < 0.01$) greater liveweight gains than the L treatments. This resulted in the H treatments having a significantly ($p < 0.05$) greater mean liveweight than the L treatments in period 5.

Condition score

Table 8.20 and figure 8.15 show the treatment effects on condition score over the 25 weeks. Pattern of concentrate allocation did not, in any period, significantly affect condition score and over the 25 weeks no effect on total condition change was observed. Level of concentrate significantly ($p < 0.05$) increased condition score change over the

Fig. 8.14 <u>Liveweights for the four treatments over the 25 weeks</u>

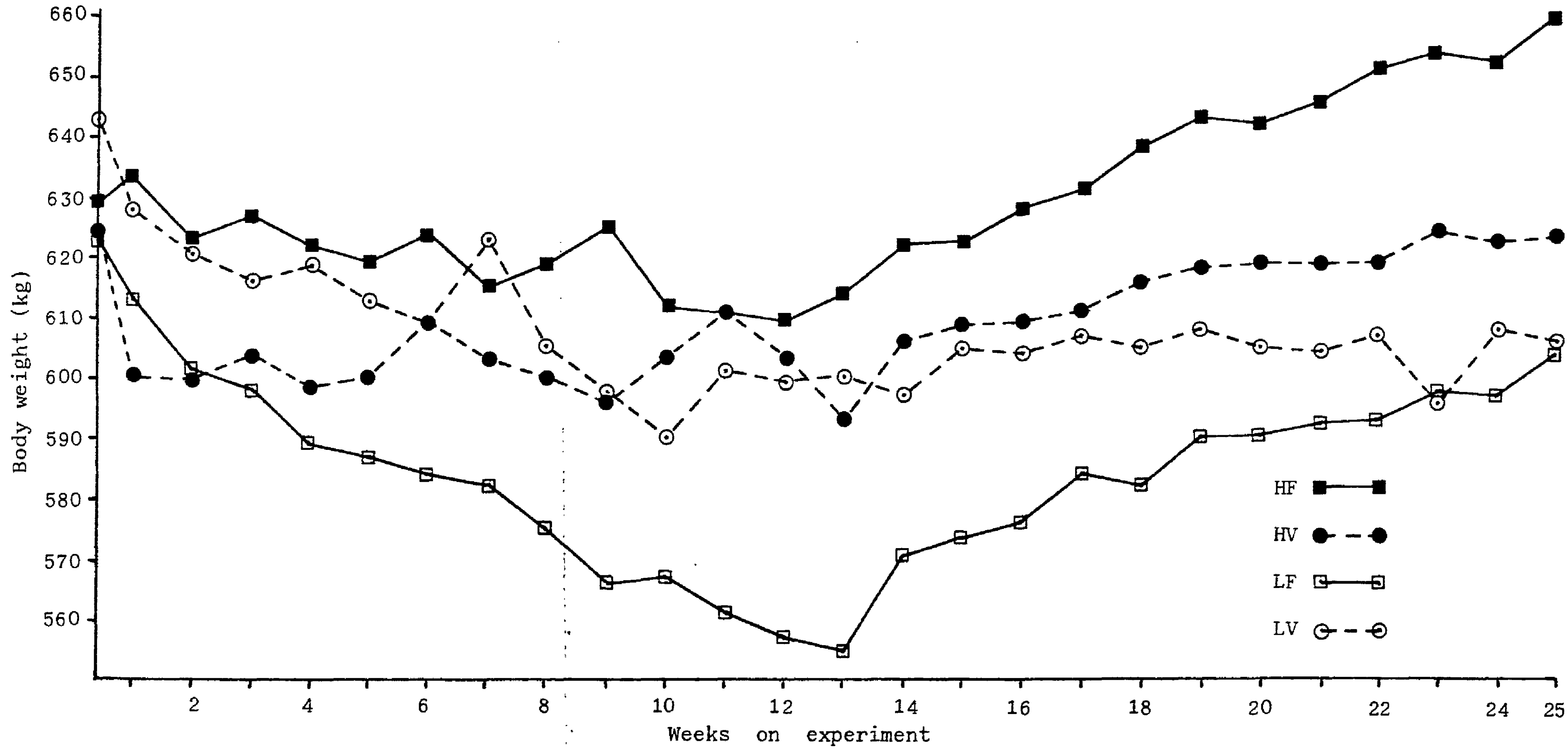


Table 8.19 Liveweight[‡] and Liveweight Change over the 25 Weeks

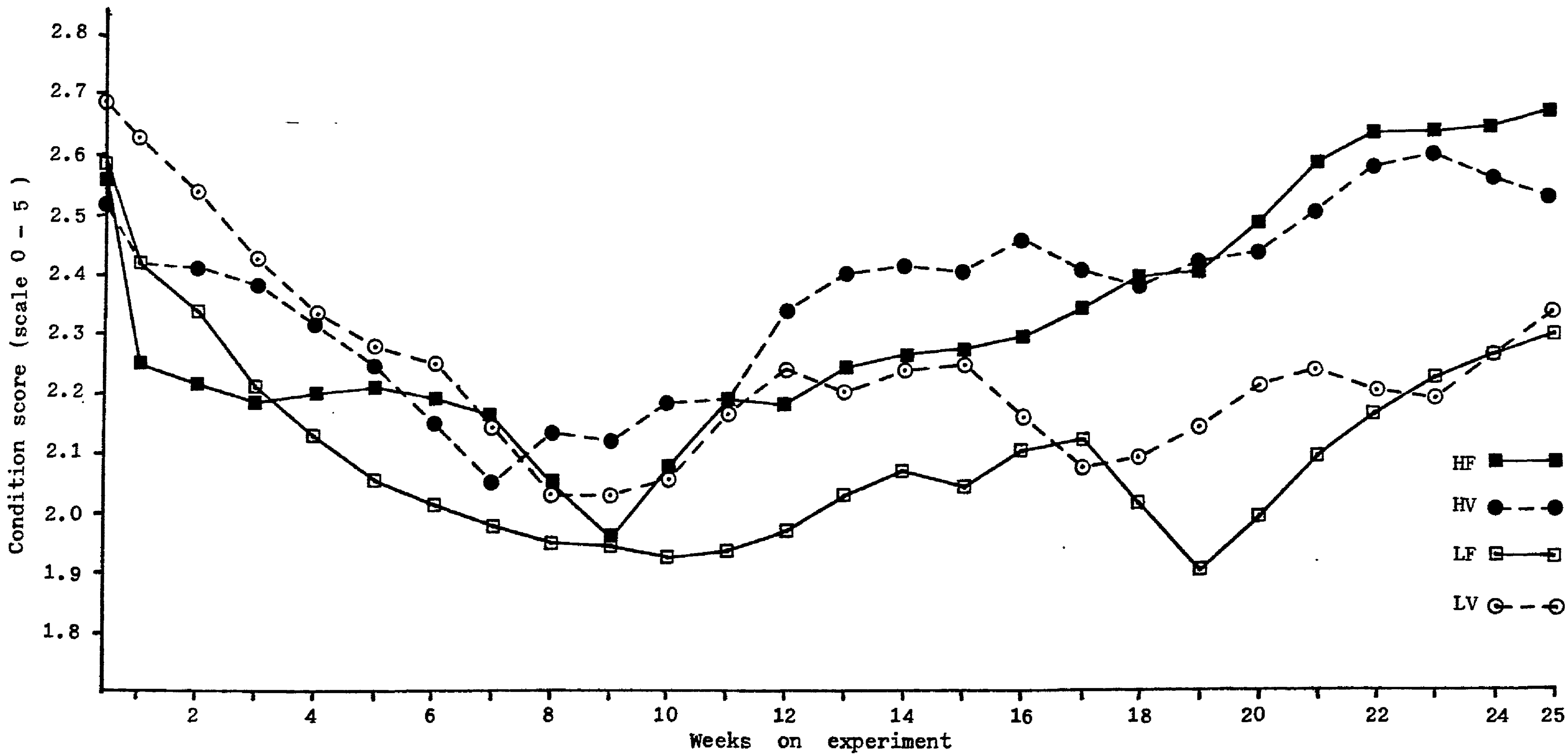
	Treatments				SED		
	HF	HV	LF	LV	Pattern	Level	P x L
Period 1							
Liveweight change (kg day^{-1})	-0.45	-0.05	-0.93	-0.46	0.29 NS	0.29 NS	0.42 NS
Period 2							
Liveweight change (kg day^{-1})	-0.12	-0.12	-0.65	-0.69	0.22 NS	0.22 *	0.31 NS
Period 3							
Liveweight change (kg day^{-1})	+0.36	+0.02	+0.27	+0.25	0.25 NS	0.25 NS	0.36 NS
Period 4							
Liveweight change (kg day^{-1})	+0.62	+0.31	+0.52	+0.03	0.18 *	0.18 NS	0.26 NS
Period 5							
Liveweight[‡] (kg)	653	622	597	602	18.4 NS	18.4 *	26.0 NS
Liveweight change (kg day^{-1})	+0.47	+0.16	+0.35	+0.03	0.12 *	0.12 NS	0.17 NS
Mean liveweight change Periods 1-5	+0.18	+0.07	-0.09	-0.05	0.07 NS	0.07 **	0.09 NS

‡ Liveweights are adjusted by covariance analysis using 14-day weights as covariates.

Table 8.20 Condition Scores for Each Treatment over the 25 Weeks

	Treatments				SED		
	HF	HV	LF	LV	Pattern	Level	P x L
Initial condition scores	2.6	2.5	2.6	2.7	-	-	-
Final condition scores at 25th week	2.7	2.6	2.3	2.3	0.15	0.15 *	0.21 NS
Total change	+0.1	0.0	-0.30	-0.40	0.15 NS	0.15 *	0.22 NS

Fig. 8.15 Condition scores for the four treatments over the 25 weeks



25 weeks and this resulted in the H treatments having a significantly greater mean condition score at the 25th week of 2.65 compared to that of the L treatments of 2.3.

Fertility and health

The cows had an average calving date of 21 September and serving did not begin until 22 November (62 days). Two out of the four bulls used during the first service period had semen of inferior quality and caused a low conception rate fo first service in the whole herd at Crichton Royal Farm. It is therefore doubtful whether any conclusions can be drawn from the fertility data tabulated in Table 8.21. There were no differences in predicted calving interval between treatments HF, HV and LF. Treatment LV had a shorter predicted calving interval but this was based on 7 animals out of 12 and 3 out of the remaining 5 were barren.

Table 8.21 Fertility Data for the Four Treatments

	HF	HV	LF	LV
Days to 1st service	75(12)*	81(12)	74(12)	67(11)
Days calving to successful service	102(10)	96(12)	104(11)	82 (8)
Conception rate to 1st service (%)	17($^{2}/12$)	58($^{7}/12$)	25($^{3}/12$)	55($^{6}/11$)
Number not served	0	0	0	1
Predicted calving interval	385(10)	380(12)	386(11)	363 (7)
Number barren	2	0	1	3

* Figures in brackets are the number of animals.

Two animals from LF and one from LV were treated for lameness. None of the data were removed for these animals. Many of the animals on the HV treatment refused concentrates during the first 10 weeks of the experiment but none of these animals exhibited or were treated for any metabolic disturbances. There were 5, 14, 4 and 14 cases of treated mastitis in treatments HF, HV, LF and LV respectively. There were two cases of coliform mastitis, one in treatment HV and one in LV. These animals recovered and the data for all animals were included in the final analysis.

Residual Period

The feeding of all the cows during the residual period weeks 27-43 of lactation was identical and is outlined in the experimental section. The concentrate used during the residual period was the same as that fed during the experimental period (Table 8.10). Table 8.22 shows the milk production during the residual period and the 305-day milk production for the four treatments. Two animals from treatment LV were culled before turnout, one due to persistent mastitis and low yield and the other due to lameness. Missing plots were used for these animals using the equation 6.10 described in Chapter 6. The data from all the remaining animals was used to calculate the values in Table 8.22.

There were no significant differences in the milk produced during the residual period of 16 weeks between the four treatment. The average 305-day milk yield of the H treatments was significantly ($p < 0.01$) higher than the average for the L treatments. Pattern of concentrate allocation did not significantly affect 305-day milk yields, although there was a trend for treatment HF to produce more milk at 305 days than treatment HV. Treatment LF and LV 305-day yields were similar. Although the H treatments had a significantly ($p < 0.05$) greater mean liveweight and condition score at the 25th week of the experimental period there were no significant differences in liveweights or condition scores between the 4 treatments when cows were dried off at 43 weeks post-calving.

Table 8.22 Milk Production during the Residual Period and 305-day Yields for the Four Treatment Groups

	Treatments				SED[‡]		
	HF	HV	LF	LV	Pattern	Level	P x L
Milk production during residual period (kg)	1929	1683	1604	1745	114.9 NS	114.9 NS	162.5 NS
305-day milk yield (kg)	6957[a]	6388[ab]	5737[b]	5901[b]	248.9 NS	248.8 **	352.0 NS

‡ 33 d f. for error.

‡‡ Within rows means with different superscripts differ significantly by at least ($p < 0.05$).

DISCUSSION

Treatment LV had a greater peak milk yield and a higher milk yield in period 1 and 2 compared with treatment LF, although these differences were not significant. This observation is similar to that reported in the previous experiment (Chapter 7) and other studies (Johnson, 1977; Steen and Gordon, 1980 a; Gordon, 1982) where high/low or to yield patterns of concentrate allocation gave greater peak milk yields than uniform patterns. This was not apparent in the H treatments and the average daily milk yields during periods 1 and 2 were similar for both treatments at 28.1 and 28.0 kg day^{-1} for treatments HF and HV respectively. Treatment HV had only a 0.2 kg day^{-1} increase in peak milk yield compared with treatment HF. The milk yield response to the additional concentrates fed to treatment LV compared with LF in periods 1 and 2 was +0.70 kg milk kg^{-1} concentrate DM, whilst the response between HF and HV over the same periods was -0.21 kg milk kg^{-1} concentrate DM. Other studies have reported that milk yield response to additional concentrates was lower at higher levels of concentrate feeding (Østergaard, 1979; Broster and Thomas, 1981; Gordon, 1981 a) and others (Ekern, 1972; Kincaid and Cronrath, 1982) have reported negative responses to additional concentrates at very high levels in early lactation. The extremely high energy density of the total diet of 12.3 MJ kg^{-1} DM for treatment HV during periods 1 and 2 compared with 11.9 MJ kg^{-1} DM for treatment HF may explain the lack of any milk yield response. Greenhalgh and Reid (1975, 1980) also concluded that complete diets with high energy densities did not produce worthwhile milk yield responses of 3% when fed to appetite even though animals ate 20% more. It is concluded, therefore, that there is little benefit to be obtained, in milk output, by feeding very high energy density rations in early lactation.

Table 8.23 Relationship between 14-day Milk Yield and Peak Yield and 305-day Yield and Peak Yield

	Treatment				SED		
	HF	HF	LF	LV	Pattern	Level	P x L
305-day milk yield (kg) ÷ peak milk yield (kg day^{-1})	224	206	206	203	6.3 NS	6.3 NS	8.9 NS
Peak milk yield (kg day^{-1}) ÷ 14-day milk yield (kg day^{-1})	1.19	1.21	1.08	1.14	0.03 NS	0.03 **	0.04 NS

From this (Table 8.23) and the previous experiments (Chapter 7 by calculation from Appendix 4, Table 7.15 and Chapter 6, Table 6.19) the ratio of peak milk yield ÷ 14-day milk yield has varied from 1.01 to 1.54, depending upon parity and the level of nutrition between 14 days and peak milk yield. For cows, over all three experiments, uniform patterns of concentrate allocation had, on average, a lower ratio, 1.1 compared with 1.2 for the variable patterns of concentrate allocation. Heifers (Table 6.19) had, on average, a greater ratio than cows of 1.4. Problems of predicting peak milk yield have been discussed by Johnson (1982).

The post-peak decline in milk yield (Table 8.17) was significantly ($p < 0.001$) greater for the V treatments compared with the F treatments which is a similar observation to that reported in experiment 1 and 2 (Chapter 6 and 7). Johnson (1977) and Steen and Gordon (1980 a) also reported much greater declines in milk yield for feeding to yield and stepped patterns of concentrate allocation.

The range in individual milk yield within treatment LV was greater than the range within treatment LF, and the overall means were similar. This is similar to the previous experiment (Table 7.21). However, the 6 highest yielding animals in treatment HV gave less than might have been expected (Table 8.24) which resulted in the overall mean yield of treatment HV being less than treatment HF.

Table 8.24 Average Milk Yields for the 6 Highest and 6 Lowest Yielders

	Treatment			
	HF	HV	LF	LV
Mean of 6 high yielders	29.46	27.52	23.57	24.01
Mean of 6 low yielders	23.28	21.57	19.39	18.30
Average	26.37	24.55	21.48	21.16

When intakes were expressed in terms of MJ of ME, a greater milk yield response was observed for the average of all the 6 highest milk yielders from each treatment, 0.14 kg milk per MJ of ME^{-1} compared with the 6 lowest yielders 0.10 kg milk per MJ of ME^{-1}. Other studies have also reported similar observations (Broster and Alderman, 1977; Wiktorsson, 1979; Thomas, 1980). Thomas (1980) reported values of 0.12 kg milk per MJ of ME^{-1} for high yielders and 0.08 kg milk per MJ of ME^{-1} for low yielders, which is good agreement with the present experiment.

The relationship between 14-day milk yield and the mean 25-week milk yield is given for treatments HF, HV, LF and LV in Equations 8.10, 8.11, 8.12 and 8.13 respectively. The V treatments had better correlations than the F treatments. This agrees with the observations from the previous experiment (Equations 7.10 to 7.13).

HF $y = -1.90 + 1.08\,x$ 8.12

$r = 0.80$

$b = 0.26$ RSD = 2.61 ($p < 0.01$)**

HV $y = 3.75 + 0.80\,x$ 8.13

$r = 0.83$

$b = 0.17$ RSD = 2.22 ($p < 0.001$)***

LF $y = 18.42 + 0.12\,x$ 8.14

$r = 0.10$

$b = 0.36$ RSD = 3.07 ($p > 0.05$) NS

LV $y = 6.45 + 0.57\,x$ 8.15

$r = 0.59$

$b = 0.25$ RSP = 2.87 ($p < 0.05$)*

Where: r = correlation coefficient; b = standard error of slope; RSD = residual standard deviation; y = mean daily milk yield over 25 weeks; x = 14-day milk yield.

The significant ($p < 0.001$) difference in milk yield between the H and L treatments corresponded to an average milk yield response of 1.16 kg milk kg^{-1} concentrate DM. This is greater than a value of 0.79 kg milk kg^{-1} concentrate DM reported by Thomas (1980) from a survey of 16 experiments and 0.80 from Chapter 2, Table 2.1. The difference can partly be explained by the higher sutstitution of concentrates for forage reported by Thomas (1980) of 0.50 kg silage DM kg^{-1} concentrate DM, whereas the present experiment had a much lower substitution rate of 0.31 kg silage DM kg^{-1} concentrate DM.

It is often suggested that a normal decline in milk yield is 2.5% per week of peak milk yield (Broster and Alderman, 1977) and many feeding regimes adjust rations accordingly to obtain this decline (Woodman, 1957; Johnson, 1977, 1979). It can be seen from Table 8.17 and the previous chapter (Table 7.15) that level of nutrition after peak milk yield can modify the post-peak decline in milk yield such that differences in peak milk yields can be compensated for totally. Johnson (1982) concluded that a lactation curve describes a specific feeding pattern rather than any innate biological lactation curve. Standard lactation curves are records of many thousands of individual lactation curves and merely reflect the methods and patterns of feed allocation used with these lactation curves (Wood, 1969, 1980).

Pattern of concentrate allocation did not significantly affect the mean milk fat or protein content over the 25 weeks. This agrees with the previous two experiments (Table 7.16 and 6.15) and other studies

(Johnson, 1977; Steen and Gordon, 1980 a; Moisey and Leaver, 1982) but not with Gordon (1982) who reported a significant increase in milk fat content with a uniform pattern of concentrate allocation with heifers. Treatment HF did, however, produce milk with a much higher milk fat content than treatment HV in this experiment. This difference was not observed in the L concentrate treatments (Table 8.18).

The proportion of concentrate in the total diet DM in periods 1 and 2 averaged 0.38 and 0.50 for treatments LF and LV respectively. These differences resulted in only a small depression in milk fat content, whereas a severe depression was observed over the same periods between treatments HF and HV where the proportion of concentrate in the diet DM averaged 0.48 and 0.66 respectively (Table 8.25 and Figure 8.12). Sutton (1980) concluded that depressions in milk fat content are relatively small until the proportion of concentrate is increased to 0.60, which would agree with this experiment's results where 0.6 concentrate was only ever observed in treatment HV (Table 8.25).

Milk fat yield over the whole 25 weeks was significantly ($p < 0.05$) greater for the F treatments (Table 8.26). This was mainly due to the low milk fat yield of treatment HV. The milk yield difference between

Table 8.25 Concentrate as a Proportion of the Total DM Intake (%)

	Treatment			
	HF	HV	LF	LV
Period 1	48	63	37	49
Period 2	48	69	38	50
Period 3	51	64	38	46
Period 4	53	50	42	34
Period 5	55	40	43	22
Average	51	57	40	40

treatments HF and HV became significant ($p < 0.05$) in favour of treatment HF, when the milk yields were corrected for total solids content, whereas treatments LF and LV had similar solids-corrected milk yields. The non-significant increase in milk fat yield between the mean of the H and L treatments indicated that the significant ($p < \cdot 0\ 01$) increase in milk yield associated with the additional concentrates was just able to compensate for the significant ($p < 0.001$) depression in milk fat content. A further increase in total concentrate levels would have almost certainly depressed milk fat yield (Oldham and Sutton, 1979; Broster *et al*, 1981). The large and significant ($p < 0.001$) increase in milk protein yield between the mean of the H and L treatments agrees with Oldham and Sutton (1979) who concluded that the main milk protein benefits from feeding higher concentrate levels is seen in milk protein yield and not milk protein contents. (Table 8.18 and 8.26 and Chapter 3).

The small substitution of concentrate for silage observed in this experiment of 0.31 kg silage DM kg^{-1} concentrate DM was smaller than a value of 0.41 from a survey of 28 experiments (Chapter 1), 0.5 (Thomas, 1980) from a survey of 16 experiments and 0.46 (Bertilsson, 1983). The enormous variation in substitution rates was discussed in Chapter 1.

The difference in the total quantity of milk produced between the average of the H and L treatments up to 25 weeks (Table 8.16), (745 kg), was slightly less than the difference obtained at 305 days (Table 8.22) (845 kg). The lack of any significant residual effect, even though the H treatments had a significant ($p < 0.05$) 2.6 kg day^{-1} higher average peak milk yield than the L treatments, confirms observations from the previous experiment (Chapter 7) and Thomas *et al* (1981). Residual effects on milk yield are not likely to occur at high planes of nutri-

Table 8.26 Milk Fat and Protein Yields and Solids-corrected Milk Yields per day for the Four Treatments

	Treatments				SED		
	HF	HV	LF	LV	Pattern	Level	P x L
Fat yield (g)	1045^{a} ‡	910^{b}	912^{b}	889^{b}	37.9 *	37.9 NS	53.5 NS
Protein yield (g)	888^{a}	836^{a}	695^{b}	692^{b}	32.7 NS	32.7 ***	46.2 NS
Solids-corrected milk (kg) ‡‡	26.3^{b}	24.0^{a}	22.1^{a}	21.8^{a}	0.75 NS	0.75 **	1.06 NS

‡ Within rows, means not followed by same superscript letter differ significantly ($p < 0.05$).

‡‡ S.C.M. calculated using SCM (kg) = 12.3 (F) + 6.56 (SNF) - 0.0752 (M), where SCM = solids-corrected milk having 750 kcal kg^{-1}. F, SNF and M = fat, solids-not-fat and milk respectively expressed in kg. (Maynard *et al*, 1969).

tion where high quality forage is available *ad libitum* (Chapter 2, Section 2.7). During the residual period of this and the previous experiment, cows were not restricted and were allowed access to *ad libitum* silage during the initial part of the residual period (average 3 weeks) and then grazed for 13 weeks where the grass heights averaged 6.0 cm using the MMB grassmeter (MMB).

There was a tendency for the HV cows, that were given very high energy density diets in early lactation, to produce less milk than the HF cows, during the residual period and over 305 days (Table 8.22). Chalmers *et al* (1979) also reported that cows allowed unrestricted concentrates in early lactation produced less milk at grass and over 305 days than cows that were given less and controlled amounts of concentrate in early lactation.

SUMMARY

In a 25-week experiment starting at 3 weeks post-partum two levels of concentrates were offered to 24 autumn calving dairy cows. Within each concentrate level two patterns of concentrate allocation were compared: a uniform pattern to all cows and a variable pattern based on an individual's milk yield 14 days post-calving. All the cows were offered the same 66 DOMD silage *ad libitum*.

The results indicated that at low concentrate levels, pattern of concentrate allocation did not significantly affect any aspects of animal performance during the experimental or residual period. Within the high concentrate level there was a significant ($p < 0.05$) increase in the solids-corrected milk yield for the uniform pattern of concentrate allocation, a result of a non-significant increase in mean daily milk yield for the uniform pattern and a non-significant depression in milk fat content for the variable pattern. It is concluded that a uniform pattern of concentrate allocation is better suited than a variable pattern, where a particular herd is fed a high total amount of concentrates.

CHAPTER 9

EXPERIMENT 4 THE EFFECT OF ADJUSTING THE LEVEL OF CONCENTRATES ON THE INTAKE OF SILAGE AND ON MILK PRODUCTION 1.

Introduction

The voluntary intake of silage by lactating dairy cows is usually reduced by the provision of concentrate supplements (Østergaard, 1979; Forbes, 1983; Harb and Campling, 1983; Chapter 1, Figure 1.5). The size of this reduction depends upon the amount and, in particular, the type of supplement (Castle, 1982, Chapter 1). Barley has a particularly marked effect on silage intake (Tayler and Aston, 1976) and in the four comparisons of Castle (1982) the mean reduction in silage DM intake was 0.51 kg kg^{-1} of barley DM, which agrees with a value of 0.50 kg kg^{-1} of barley DM reported by Harb and Campling (1983). Campling (1980) and Forbes (1983) suggested that there is an urgent need to obtain better quantitative information about substitution rates (r). Recent commercial concentrates contain a greater variety of by-products than formerly and much less straight cereal grains (Wilson *et al*, 1981) and these may have less of a depressing effect on silage DM intake than straight cereals such as barley (Campling, 1980).

In systems of concentrate allocation where allowances of concentrates are reduced as milk yields decline, it is important that the cow increases her silage DM intake to compensate for the removal of concentrates from the diet.

The objective of this experiment was to assess the responses in silage intake and milk yield when different levels of a commercial concentrate supplement were offered to dairy cows and heifers in mid-lactation when fed silage of moderate quality *ad libitum*.

MATERIALS AND METHODS

Twelve British Friesian cows and four heifers on average 21 weeks post-calving were divided into 4 groups of 4 animals. Within each group, the animals were allotted at random to 4 treatment sequences in a 4 x 4 balanced changeover design (Patterson and Lucas, 1962), each period lasting 21 days. There were four concentrate feeding treatments: A 8, B 7, C 6 and D 5 kg day^{-1} fresh weight of a 180 g kg^{-1} crude protein concentrate (Table 9.10) with the same physical ingredients as those given for the concentrate in experiment 1, Chapter 6. Statistical analysis was confined to the mean of the last 7 days of each 3 week period for feed intake and milk production and the mean of the last 3 consecutive days for milk compositions using the method outlined by Patterson and Lucas (1962) for balanced 4 x 4 changeover designs. The animal production data at the beginning of the experiment, 17 April 1981, can be seen in Appendix 6.

The animals were loose-housed and fed individually using Broadbent gates (Broadbent *et al*, 1970). Silage refusals were carried out daily for the 21 day periods at 0730 h and then half of the concentrate allowance was fed separately before fresh silage was weighed and fed at 0830 h approximately 10% in excess of their daily requirements. The remaining portion of the concentrate ration was placed on top of the silage whilst the cows were being milked at p.m. 1700 h. Concentrate refusals were negligible.

The silage was prepared from perennial ryegrass and was cut with a drum mower and harvested with a precision chop forage harvester applying formic acid (Add-F, BP Nutrition Ltd.) at the rate of 2.5 litres $tonne^{-1}$. The chemical composition of all the feeds is given in Table 9.10. The concentrate was in the form of a 9 mm pellet. The silage dry matter content was determined daily by oven-drying at 100°C. Milk yields were recorded weekly in the first 2 weeks of each period and daily for the last 7 days. Milk was sampled for the last 3 consecutive days of each period during the a.m. and p.m. milkings and analysed for milk fat, protein and lactose content by the methods described in experiment 1, Chapter 6. Liveweights were measured weekly after the Wednesday p.m. milking. Samples of feeds were taken for chemical analysis weekly. The equations and methods used to predict the ME value of the feeds are described in Appendix 2.

Table 9.10 Chemical Composition of the Feeds (g kg^{-1} DM)

	Silage	Concentrate
Oven dry matter (g kg^{-1})	165	872
Crude protein content	137	192
DOMD (*in vitro*)	600	748
Predicted ME content (MJ kg^{-1})	9.3	13.1*
Ammonia N as % of total N	14.2	-
pH	4.1	-

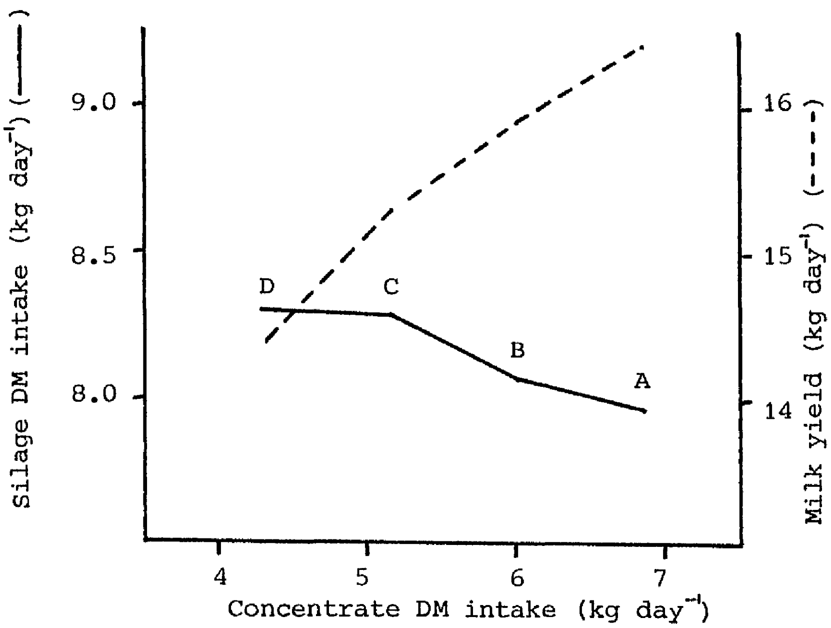
* Corrected ME assuming oil content of 50 g kg^{-1}.

RESULTS

Feed intake

The mean daily weights of DM consumed in each treatment and the total energy intakes (MJ day^{-1}) are given in Table 9.11. The silage intakes only increased slightly as the concentrates were reduced. The treatment A and B silage intakes were not significantly different and treatment B, C and D silage intakes were not significantly different. The only significant ($p < 0.05$) differences in silage DM intake were between treatment A compared with C and D. The mean substitution rate (r) was 0.17 kg silage DM kg^{-1} concentrate DM. As seen in Figure 9.10 there was virtually no depression in silage DM intake between treatments D and C. The main depression occurred between treatments C, B and A.

Fig.9.10 Milk yields and silage intakes for the four treatments



The small increase in silage DM intake observed between the 4 treatments as the levels of concentrate were reduced resulted in a large significant ($p < 0.001$) depression in total DM intake and metabolisable energy intake (MJ day^{-1}) between each of the 4 treatments.

Table 9.11 Mean Daily DM and ME Intakes

		Treatment				
		A	B	C	D	SED
Concentrate	(kg day^{-1})	6.88	6.02	5.16	4.30	-
Silage	(kg day^{-1})	$7.97^{a‡}$	8.07^{ab}	8.30^{b}	8.31^{b}	0.138 *
Total DM	(kg day^{-1})	$14.79^{a‡‡}$	14.07^{b}	13.48^{c}	12.67^{d}	0.134 ***
ME	(MJ day^{-1})	$164^{a‡‡}$	154^{b}	145^{c}	135^{d}	1.06 ***

‡ Within rows, means with different superscript letters differ significantly ($p < 0.05$).

‡‡ Within rows, means with different superscript letters differ significantly ($p < 0.001$).

Milk yield, composition and liveweight

The mean daily milk yields and compositions are given in Table 9.12. They showed a fairly linear decline from 16.39 kg day^{-1} for treatment A, the highest concentrate level, to 14.39 kg day^{-1} for treatment D, the lowest concentrate level (Figure 9.10). The mean milk yields of treatments B, C and D were significantly ($p < 0.05$) different from one another, whilst the mean milk yields of treatment A and B were not significantly different. The decline in milk yield averaged -0.84 kg milk kg^{-1} reduction in concentrate DM, over the 4 treatments.

Milk fat and milk protein contents were significantly increased as the level of concentrate supplementation increased for each of the 4 treatments. There were no significant treatment effects on milk lactose content. The significant increases in milk fat and protein contents resulted in significant ($p < 0.001$) increases in both milk fat and protein yields between each of the 4 treatments as the level of concentrate supplementation increased.

There were no significant treatment effects observed for liveweight or liveweight change although the liveweight changes were broadly in line with those expected from energy balance calculations using MAFF (1975). Liveweight gain tended to be greater as the level of concentrate supplement increased from treatment D to A.

Table 9.12 The Mean Daily Milk Yield, Milk Composition and Liveweight Data

	Treatment				
	A	B	C	D	SED‡
Milk yield (kg day^{-1})	16.39^{a} ‡	15.89^{a}	15.32^{b}	14.39^{c}	0.281 ***
Milk fat content (g kg^{-1})	40.2	38.7	38.5	38.0	0.59 **
Milk protein content (g kg^{-1})	32.5	32.0	31.7	31.0	0.31 ***
Milk lactose content (g kg^{-1})	46.7	46.3	46.4	46.3	0.26 NS
Milk fat yield (g)	658	615	589	545	10.3 ***
Milk protein yield (g)	531	507	484	446	7.8 ***
Liveweight (kg)	611	609	604	607	3.1 NS
Liveweight change (kg day^{-1})	0.31	0.32	-0.03	0.15	0.24 NS

‡ 30 d.f. for error.

‡ Within rows, means that have different superscript letters differ significantly by at least ($p < 0.05$).

DISCUSSION

The low substitution effect (r value) of concentrates for silage observed in this experiment (0.17) explains the large responses in milk yield and composition to the increases in concentrate input. This may have been a result of the low DM and moderately high ammonia nitrogen levels of the silage, as it has previously been reported (Wilkins *et al*, 1971; Demarquilly, 1973; Hermansen, 1980) that fermentation characteristics and the DM of the silage can have marked effects on the palatability and therefore intakes of silages. Blair *et al* (1982 b) reported a similar r value of 0.17 and a large milk yield response to concentrates with a similar type of silage.

The factors affecting the direct milk yield responses to concentrates have been discussed (Chapter 2: Thomas, 1980; Gordon, 1981 a; Johnson, 1982) and include quality of forage, its level of restriction, the level of concentrate supplementation, type of concentrate, stage of lactation and the yield potential of the animal. Gordon (1981 a) reported a mean response of 0.78 kg milk kg^{-1} concentrate DM and in a survey of 16 experiments Thomas (1980) found a mean response of 0.79 kg milk kg^{-1} increase in concentrate DM. The average milk yield response to additional concentrates obtained in this experiment 0.76 is therefore in good agreement with these previous studies (see Chapter 2, Table 2.1). Nevertheless, the animals in this experiment had been calved on average 21 weeks at the start of the experiment and the milk yield responses observed could be considered large at that stage.

The significant increase in milk fat content observed in this experiment is in apparent conflict with other work (Rohr *et al*, 1974; Sutton *et al*, 1977; Blair *et al*, 1982 a, Chapter 3, Table 3.1) where milk fat content was depressed as the concentrate portion of the total diet increased. This difference can partly be explained by the concentrate:forage ratio for the present experimental treatments which only reached a maximum of 47:53 for treatment A, whilst treatment D only had a concentrate:forage ratio of 34:66. Sutton (1980) concluded that depressions in milk fat content were relatively small until the proportion of forage in the diet is reduced to approximately 40% and Laird *et al* (1981) suggested that the progressive increase in milk fat content at low levels of concentrate supplementation, in their study, was in response to the increased energy intakes.

The increase in milk protein content and yield in this experiment agrees with the survey of 19 experiments, Table 3.3 (Chapter 3) and with Kaufman (1980) and Thomas, (1980 a,) and was probably the combined effect of the increase in energy intake and concentrate:forage ratio from treatments D to A.

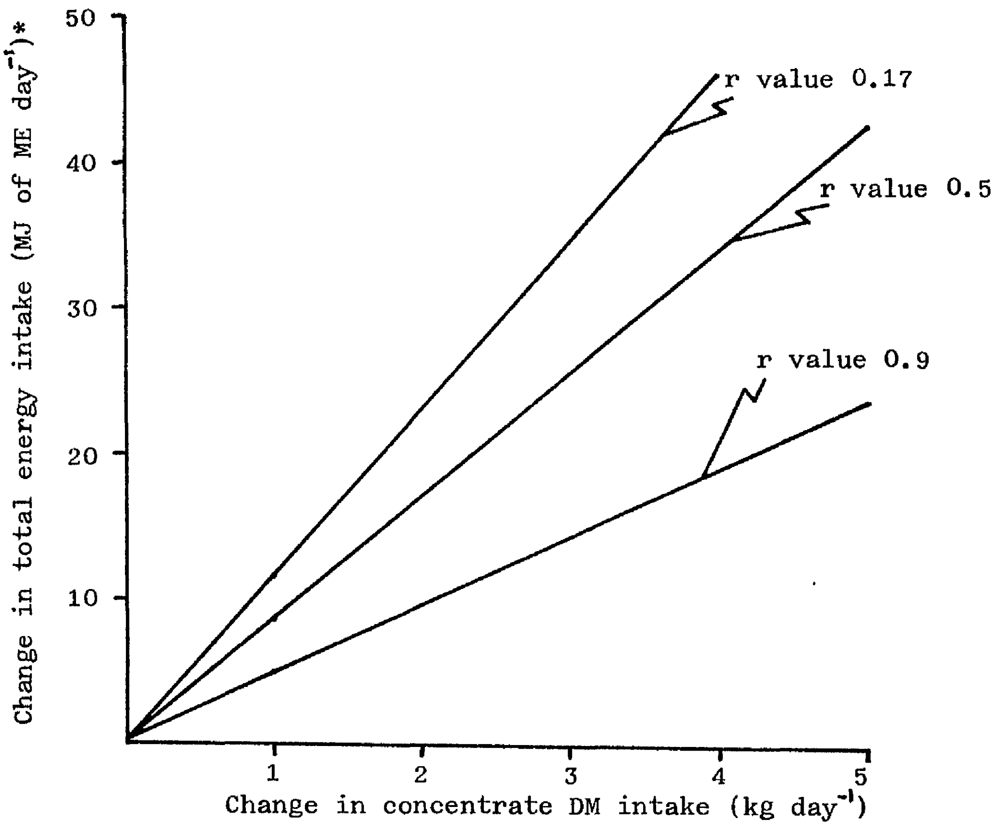
The lack of any significant effect on milk lactose content agrees with Peaker (1980) who concluded that, apart from extreme cases of underfeeding, nutritional changes have little or no effect on milk lactose content.

The liveweight and liveweight change results are difficult to discuss with any confidence, as the design of this experiment was such that gut fill and the relatively short periods of 21 days result in inadequate assessments of the true body weight changes (Altman, 1980).

The effect on total energy intake by increasing or decreasing the input of concentrate DM to dairy cows depends upon the r value of the silage, its ME content and the energy content of the concentrate. In the present experiment the average change in energy intake (MJ of ME day^{-1}) to a change of 1 kg day^{-1} of concentrate DM was 11.16 MJ of ME. Figure 9.11 illustrates graphically the theoretical changes in energy intake, positive or negative, to various changes in concentrate DM intake for different silage r values (assuming an ME content of 9.3 and 13.1 MJ kg^{-1} DM for silage and concentrate respectively). From Figure 9.11 the theoretical change in energy intake to a kg change in concentrate DM intake is 11.56 MJ, with an r value of 0.17. This figure compares reasonably with the actual value of 11.16 MJ obtained from the experimental results. If the r value had been 0.5 or 0.9 for the silage, instead of 0.17, it can be seen from Figure 9.11 that the change in energy intake would have been much smaller and animal production responses smaller.

These relationships have important implications on the consequences of reducing concentrates levels in mid-lactation. Reducing concentrate levels in mid-lactation will lead to accelerated declines in milk yield and composition as a result of poor responses in silage DM intake to compensate for the imposed reductions in concentrate levels. Moseley *et al* (1976) compared abrupt decreases in the energy content of complete feeds and concluded that this resulted in decreased energy intakes and milk yields and adaptation to the new diets took up to 15 days. They recommended that, in large herds, cows that calve within a narrow time interval could form a group that remained essentially intact the entire lactation with any dietary changes made gradually as lactation advanced.

Fig. 9.11 The effect of change in concentrate intake on the change in total energy intake for different substitution rates (r values).



* Using: 9.3 (MJ kg^{-1}DM) for silage.
13.1 (MJ kg^{-1}DM) for concentrate.

SUMMARY

Cows and heifers in mid-lactation were offered moderate quality silage *ad libitum* and either 8, 7, 6 and 5 kg day^{-1} of concentrate in a 4 x 4 balanced changeover experiment. Silage intakes were only increased by, on average 0.17 kg DM kg^{-1} reduction in concentrate DM. Milk yields were reduced by 0.84 kg kg^{-1} reduction in concentrate DM offered. The results indicate that with moderate quality silages and around 11.0 MJ kg^{-1} DM energy densities in the total diet, reducing concentrate levels in mid-lactation leads to accelerated declines in milk yield and reductions in milk composition.

CHAPTER 10

EXPERIMENT 5 THE EFFECT OF ADJUSTING THE LEVEL OF CONCENTRATE ON THE INTAKE OF SILAGE AND ON MILK PRODUCTION 2.

Introduction

In the previous experiment (Chapter 9) offering a range of concentrate levels (5-8 kg day^{-1} fresh weight) with a moderate quality silage offered *ad libitum*, resulted in a small average substitution of concentrate for silage (r value) of 0.17. It was suggested that, as a consequence of reducing the level of concentrates, within the range of concentrate levels compared, an accelerated decline in milk yield was likely to occur in mid-lactation. It has been reported from a survey of 28 experiments that r values can vary between 0.1 and 0.90 for silages (Table 1.1, Chapter 1) and increase as the level of concentrate supplement increases (Broster and Thomas, 1981). In the previous experiment the r value increased from 0.01 between the two lowest levels of supplementation, 5 and 6 kg day^{-1} fresh weight, to 0.19 between 6 and 8 kg day^{-1}, a fairly modest increase. The concentrate:forage ratio in the previous experiment was only 43:57 at the highest level of concentrate input. Higher levels of concentrate feeding above those compared in the previous experiment would result in higher concentrate:forage ratios and according to Broster and Thomas (1981) should lead to higher r values.

Previous studies (Castle, 1982; Harb and Campling, 1983) have compared only low levels of supplementation with very high quality silage. Little work has compared higher levels of supplementation with moderate quality forages.

The stage of lactation at the beginning of the experiment (17 weeks post-calving) was slightly earlier than in the previous experiment (21 weeks post-calving). This is still a stage of lactation associated with reducing concentrate levels in stepped and feeding to yield patterns of concentrate allocation.

The objective of this experiment was to compare a greater range of concentrate levels than in the previous experiment to study how r values and milk yields change at higher levels of concentrate intake in mid-lactation with moderate quality silage offered *ad libitum*.

MATERIALS AND METHODS

Twelve mature British Friesian cows, on average 17 weeks post-calving, were divided into 3 groups of 4 animals. Within each group, the animals were allotted at random to four treatment sequences in a 4 x 4 balanced changeover design (Patterson and Lucas, 1962) each period lasting 21 days. There were 4 concentrate feeding treatments: A 11, B 9, C 7 and D 5 kg day^{-1} fresh weight of a 170 g kg^{-1} crude protein concentrate (Table 10.10) with the same physical ingredients as those given for the concentrate in experiment 2, Chapter 7. Statistical analysis was confined to the mean of the last 7 days of each 3 week period for feed intake and milk production and the mean of the last 3 consecutive days for milk compositions (Patterson and Lucas, 1962). The animal production data at the beginning of the experiment, 3 March 1982, are given in Appendix 7.

The cows were loose-housed and fed individually using Broadbent gates (Broadbent *et al*, 1970). One kg of the treatment concentrate ration was fed to all animals at each of the two milkings in the parlour, the rest being fed through the Broadbent gates. Silage refusals were carried out daily for the 21 day periods at 0730 hrs. Half of the remaining concentrate ration, not fed in the parlour, was offered separately at 0800 hrs, before fresh silage was weighed and fed at 0830 hrs. approximately 10% in excess of their daily requirements. The remaining portion of the treatment concentrate ration was placed on top of the silage at 1700 hrs. whilst the cows were being milked at p.m. Concentrate refusals were negligible.

The preparation of the silage used was identical to that outlined in the previous experiment (Chapter 9). The concentrate used in this experiment was a smaller 6 mm pellet and fat coated compared with a 9 mm non fat coated pellet used in the previous experiment. The chemical composition of all the feeds is given in Table 10.10.

The silage DM content was determined daily by oven-drying at 100^{o}C. The procedures for milk recording, milk sampling and the sampling of the feeds are identical to those described in Chapter 9 for experiment 4. The cows were weighed twice weekly on Wednesday and Friday after p.m. milkings. The ME value of the feeds were predicted using the equations described in Appendix 2.

Table 10.10 Chemical Composition of the Feeds (g kg^{-1} DM)

	Silage	Concentrate
Oven dry matter (g kg^{-1})	202	868
Crude protein content	176	193
DOMD (*in vitro*)	648	763
Predicted ME content (MJ kg^{-1})	10.4	13.1*
Ammonia N as % of total N	14.5	-
pH	4.3	-

* Corrected ME assuming oil content of 45 g kg^{-1}.

RESULTS

Feed intake

The mean daily intakes of DM and energy for each treatment are given in Table 10.11.

Table 10.11 Mean Daily Intakes of Feed and Energy for the 4 Treatments

		Treatment				
		A	B	C	D	SED[‡]
Concentrate	(kg DM)	9.46	7.74	6.02	4.30	-
Silage	(kg DM)	$8.44^{a‡}$	9.15^{b}	9.34^{b}	9.65^{b}	0.337 *
Total	(kg DM)	17.78^{a}	16.94^{b}	15.31^{c}	14.06^{d}	0.338 ***
ME	(MJoules)	213^{a+}	200^{b}	177^{c}	159^{d}	3.3 ***

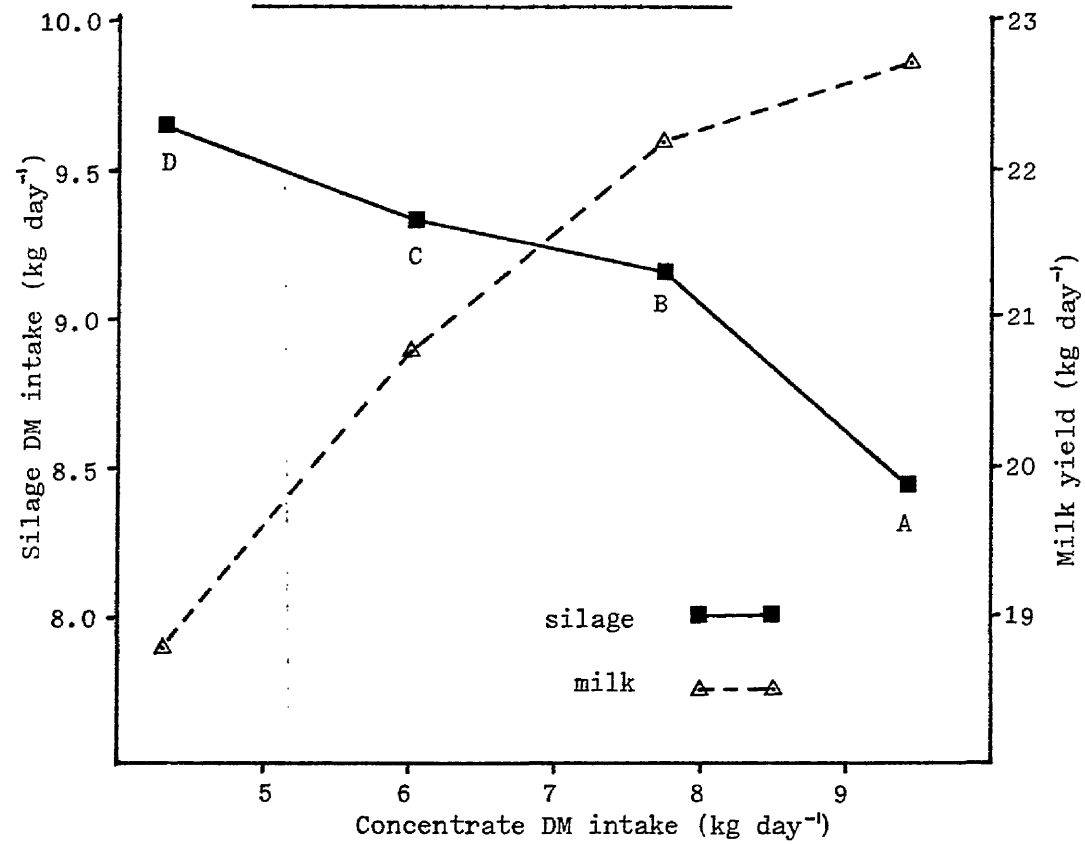
‡ 21 d.f. for error.

‡ Within rows, means with different superscript letters differ significantly by at least ($p < 0.05$).

+ Within rows, means with different superscript letters differ significantly by at least ($p < 0.01$).

The mean substitution rate (r value) was 0.22 kg silage DM kg^{-1} concentrate DM intake over the 4 treatments. Treatments B, C and D silage DM intakes were not significantly different. The r value between treatments B, C and D was 0.15. Treatment A was the only treatment in which the silage DM intake was significantly ($p < 0.05$) different from the other 3. The r value between treatment A and B was 0.41. Figure 10.10 illustrates, graphically, the small depression in silage intake that occurred between treatments D, C and B and the much greater depression in silage DM intake at the highest level of concentrate input, treatment A.

Fig. 10.10 Mean daily milk yields and silage DM intakes for the four treatments.



As a consequence of the relatively low overall r value the total DM and energy intakes were significantly different ($p < 0.05$ and $p < 0.01$ respectively).

Milk yield, milk composition and liveweight

The mean milk yields, milk compositions and liveweight data are given in Table 10.12. The milk yields are also illustrated in Figure 10.10. The average milk yield response to the additional concentrates fed over the 4 treatments was 0.76 kg milk kg^{-1} concentrate DM. The mean milk yields for treatments B, C and D were significantly different. Treatment A was not significantly different from treatment B. Figure 10.10 also illustrates that the average decrease in milk yield between treatments B, C and D (0.99 kg milk kg^{-1} concentrate DM) was much greater than the relatively small decrease (0.29 kg milk kg^{-1} concentrate DM) between treatments A and B.

Milk fat content was not significantly depressed by the additional concentrates. Milk protein contents were significantly increased as the concentrate levels increased, resulting in treatment A having a significantly ($p < 0.01$) higher value than the other 3 treatments. Treatments A and B had similar milk lactose contents which were significantly ($p < 0.05$) greater than treatment D.

Milk fat yields were consistently ($p < 0.05$) increased between treatments D, C and B up to 7.74 kg concentrate DM but the fat yield of treatment A (9.46 kg concentrate DM) was not significantly higher than that of treatment B. Each incremental increase in concentrate level resulted in a significant ($p < 0.05$) increase in milk protein yield.

Table 10.12 Mean Daily Milk Yields, Milk Composition and Liveweight Data for the 4 Treatments

	Treatment				
	A	B	C	D	SED‡
Milk yield (kg)	22.7^{a}‡‡	22.2^{a}	20.8^{b}	18.8^{c}	0.45 ***
Milk fat content ($g\ kg^{-1}$)	41.0	40.9	40.5	41.6	0.60 NS
Milk protein content ($g\ kg^{-1}$)	34.9^{a}	33.7^{b}	32.9^{bc}	32.5^{c}	0.40 ***
Milk lactose content ($g\ kg^{-1}$)	48.4^{a}	48.2^{a}	48.0^{ab}	47.5^{b}	0.28 *
Milk fat yield (g)	925^{a}	906^{a}	841^{b}	781^{c}	19.8 ***
Milk protein yield (g)	788^{a}	747^{b}	683^{c}	610^{d}	18.9 ***
Liveweight (kg)	652	655	644	625	5.8 ***
Liveweight change ($kg\ day^{-1}$)	0.68	0.17	0.48	-0.76	0.71 *

‡ 21 d.f. for error.

‡‡ Within rows, means with different superscript letters differ significantly by at least ($p < 0.05$).

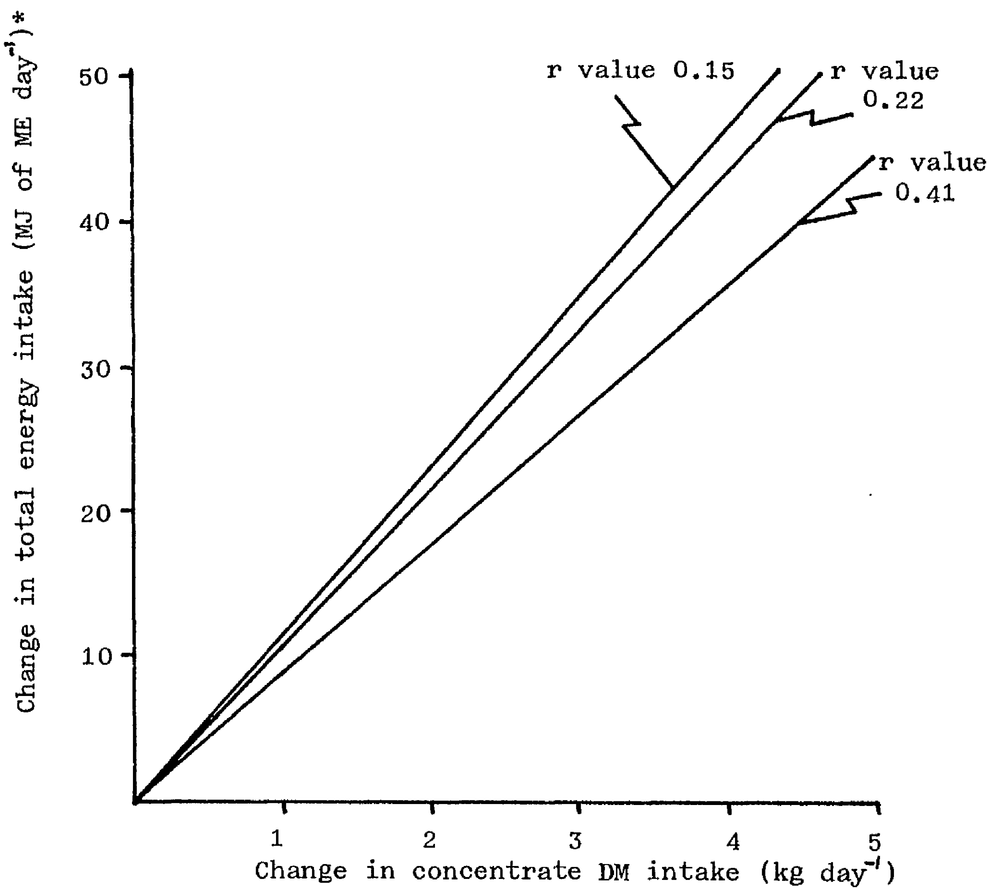
The liveweights and liveweight changes were significantly different and showed a general trend of being higher for the higher concentrate treatments A and B. As in the previous experiment (Chapter 9) liveweight changes could not be accurately assessed over the short 21 day periods.

DISCUSSION

In this experiment there was a general trend for the milk yield response to concentrates to be curvilinear, with the milk yield response decreasing at the higher levels of concentrate supplementation (Figure 10.10). These results agree with other reports (Broster and Thomas, 1981; Gordon, 1981 a, 1981 b). The reduced milk yield response to the additional concentrates offered between treatment B and A coincided with the only significant ($p < 0.05$) reduction in silage DM intake (Table 10.12). Broster and Thomas (1981) and Leaver (1980) suggested that high levels of concentrate supplementation may cause high r values and high energy density rations with consequently little change in total energy intake.

In the present experiment the average decrease in total energy intake was 10.8 MJ of ME day^{-1} kg^{-1} decrease in concentrate DM. Figure 10.11 plots the change in energy intake from a change in concentrate DM intake, using the average r value of 0.22 and ME contents of the silage and concentrate of 10.4 and 13.1 MJ kg^{-1} DM respectively from this study. As the r value gets larger (e.g. between treatments B and A of 0.41 kg silage DM kg^{-1} concentrate DM) the change in energy intake from a constant change in concentrate intake diminishes. This explains the small change in animal performance and, therefore, the less severe effect of reducing concentrate intakes at high levels of concentrate feeding, compared to the large change in animal performance and more severe effect of reducing concentrate levels at lower total intakes of concentrate supplementation. The size of the animal production response to a change in concentrate level is thus determined, to a great extent, by the degree of substitution the additional concentrates have for the silage, the energy content of the supplement and the energy density of the total diet.

Fig. 10.11 The effect of change in concentrate intake on the change in total energy intake for different substitution rates (r values).



* Using: 10.4 (MJ kg^{-1}DM) for silage.
13.1 (MJ kg^{-1}DM) for concentrate.

Where stepped or to yield patterns of concentrate allocation are practised in mid-lactation, cows must compensate for reductions in concentrate levels by eating more silage. The normal practice of feeding silage is to offer the best available, usually first cut, in early lactation and often there is a progressive change to poorer quality silage as lactation progresses. This results in silage of high r value being fed in early lactation and low r value in later lactation. With *ad libitum* silage feeding, therefore, the lowest total energy intake response to additional concentrate feeding will be observed in early lactation, as a result of the greater proportion of concentrates fed and the higher quality, higher r value silages offered. In mid-lactation when concentrate levels are reduced and silage quality progressively declines, one may expect large total energy intake responses to changes in level of supplementation, due to the combined effect of low total levels of concentrate and lower quality low r value silages offered.

There was no significant increase in milk fat content observed in this experiment as the level of concentrate supplementation increased. This is in contrast to the previous experiment where milk fat content was significantly increased with additional concentrates, and other studies where milk fat content was decreased with additional concentrates (Chapter 3, Table 3.1). The energy density of the total diet and proportion of concentrate in the total DM intake at the highest level of concentrate supplementation in this experiment (Treatment A 11.98 MJ kg^{-1} DM) was higher than in the previous experiment (Treatment A 11.09 MJ kg^{-1} DM) but may not have been high enough to cause a depression in milk fat content (Sutton, 1980). Variations in milk fat content from day-to-day and between animals were large and may be responsible for the inconsistent results for fat content in this and the previous experiment. Large variations in milk fat content that resulted in observed differences being non-significant were reported by Clapperton *et al* (1978) and Malestein *et al* 1981.

Milk protein content and yield were significantly increased with additional concentrates. This agrees with the previous experiment and others (Table 3.3, Chapter 3). The increase in milk protein yield of 34.8 g kg^{-1} increase in concentrate DM intake was greater than the increase in fat yield of 28.9 g kg^{-1} increase in concentrate DM intake. This agrees with that from a number of other studies listed in Tables 3.1 and 3.3 (Chapter 3).

SUMMARY

Cows in mid-lactation were offered moderate quality silage *ad libitum* and either 11, 9, 7 or 5 kg day^{-1} fresh weight of concentrate in a 4 x 4 balanced changeover experiment. Silage intakes only increased by an average of 0.22 kg DM kg^{-1} reduction in concentrate DM and milk yields were reduced by an average of 0.76 kg kg^{-1} reduction in concentrate DM. The results of this and the previous experiment (Chapter 9) indicate that in mid-lactation with moderate quality silages offered *ad libitum* the response in silage intake to a reduction in concentrate allowance between 5 and 9 kg day^{-1} fresh weight of concentrate is low, and due to the reduction in M/D in the total diet an accelerated decline in milk yield and composition is likely to occur.

GENERAL DISCUSSION

The major work in this thesis was designed to examine the effect of different patterns of concentrate allocation for dairy cows offered silage *ad libitum*. Two small experiments compared different levels of concentrate supplementation in mid-lactation with *ad libitum* silage. The review of literature discussed previous experimental results on concentrate supplementation, their effect on silage intake, milk yield and composition, and partition of energy as well as a study of previous work on pattern of concentrate allocation.

Feeding individual cows precise rationed quantities of forage and concentrates according to their daily requirements (Woodman, 1957) is impractical in today's management systems. With the progressive increase in average herd size, the move from byres to loose-housing, group feeding of forage and the increasing cost of labour, it has become uneconomic in all but the smallest of herds to continue individual rationing. A recent priority has been managerial convenience, rather than meeting all cows' exact nutrient requirements (Bines, 1980; Broster and Thomas, 1981). The adoption of group housing, easy feed or self-feed forage, has meant that individual control of the diet has been restricted to the concentrate portion of the diet fed in controlled amounts either in the parlour or through electronic out-of-parlour feed dispensers.

Earlier studies comparing different patterns of concentrate allocation (see Chapter 5) used restricted forage diets as the basal diet providing only 85% of the maintenance requirements (Broster *et al*, 1969; Strickland and Broster, 1981). They recommended that proportionately more concentrate should be fed to high yielders and proportionately more should be fed in early rather than in mid or late lactation. There were, however, no direct comparisons with uniform patterns of concentrate allocation in the studies of Broster *et al* (1969) and Gleeson (1970). They only compared a high/low pattern with a low/high pattern; the low/high being extremely restrictive in early lactation in both studies, with *ad libitum* silage only for the 'low' in the study of Gleeson (1970) and restricted forage providing 85% of the maintenance requirement for heifers plus 4.5 kg concentrate for the 'low' in the study of Broster *et al* (1969).

Recent studies have questioned the justification of feeding to yield with both restricted and *ad libitum* forage feeding (Johnson, 1977, Østergaard, 1979; Steen and Gordon, 1980 a; Gordon, 1982 a; Johnson, 1983). They argue that flat-rate patterns of concentrate allocation over a major part of the lactation will give as good an average performances as any other pattern of concentrate allocation.

The first experiment (Chapter 6) clarified that with high quality silage offered *ad libitum* and feeding the same total quantity of concentrate over the first 22 weeks of lactation, pattern of concentrate allocation, whether flat rate to all animals, stepped or fed to yield, did not significantly affect average performance over the 20 week experimental or 305-day lactation period.

It had been suggested (Taylor, 1979; Bines, 1980; MAFF, 1981) that the provision of *ad libitum* high quality forage was fundamental to the success of flat-rate feeding. There was, however, no evidence to support these statements other than that most of the previous studies with flat-rate feeding (Østergaard, 1979; Steen and Gordon, 1980 a) had used high quality silage offered *ad libitum*. There was therefore a need to clarify the importance of forage quality on the success of flat-rate feeding. The second experiment (Chapter 7) concluded that although forage quality *per se* had significant effects on performance, flat-rate feeding performed as well as the variable pattern of concentrate allocation (feeding proportionately more in early lactation and proportionately more to higher yielders) with 590 g digestible oragnic matter kg^{-1} DM (DOMD) and 650 g digestible organic matter kg^{-1} DM silage. In practice many dairy cows receive silage in excess of 59 DOMD and in these circumstances the adoption of flat-rate feeding would not have any adverse effect on average herd performance compared with any other pattern of concentrate allocation.

A popular question discussed is the optimum total level of concentrate to be fed to a herd (Gordon, 1980 a; Leaver, 1982; Doyle, 1983) which has been suggested as being of greater importance than pattern of allocation (Moisey and Leaver, 1982). The most suitable pattern of concentrate allocation may be different for high or low total levels of concentrate fed to a herd. A comparison was made, in experiment 3, Chapter 3, of two patterns of concentrate allocation, similar to experiment 2, Chapter 7, each with two different total quantities of concentrate fed over a period of 25 weeks. Animal performance was not significantly affected by pattern of concentrate allocation on the low concentrate input, whereas the flat-rate pattern within the high concentrate input gave a significantly better milk fat yield and solids-corrected milk yield during the 25 week experimental period and a non-significant increase in 305-day milk yield of 570 kg compared with a variable pattern of concentrate allocation. It is therefore argued that where a herd is to be fed a high total level of concentrate during a major part of lactation, in excess of 2.0 tonnes per cow, a uniform or flat-rate pattern of concentrate allocation will result in a better average performance through the avoidance of very high energy density diets in early lactation (>11.9 MJ kg^{-1} DM) that would be encountered on a variable or stepped pattern of concentrate allocation.

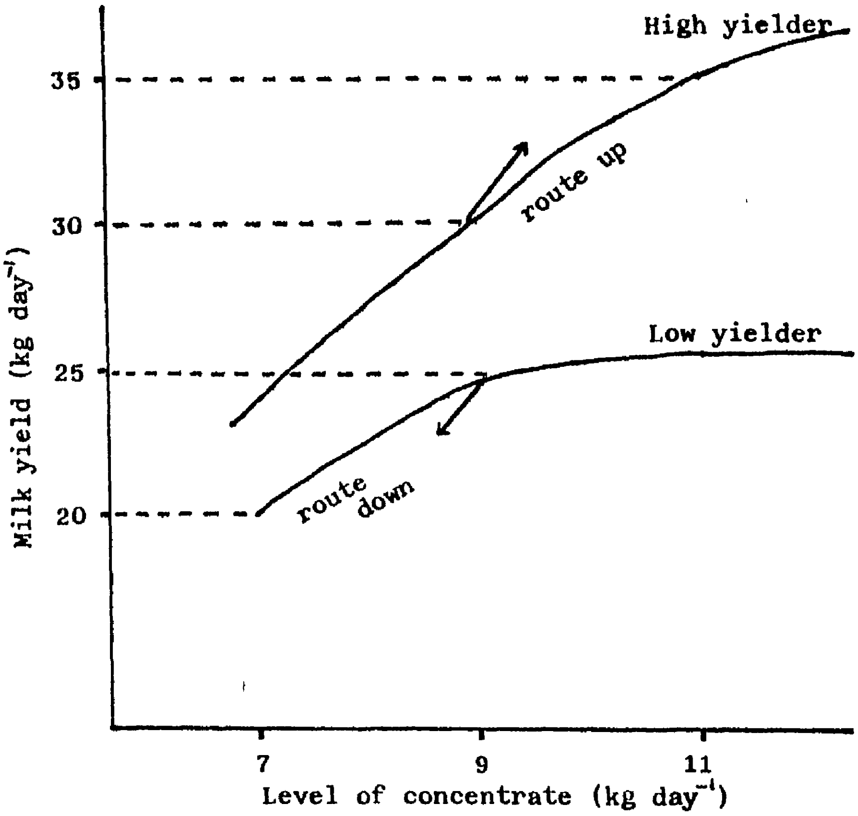
It has been shown in experiment 3 and by Leaver (1980) that the optimum energy density of the total diet in early lactation is between 11.5 and 11.9 MJ kg^{-1} DM. The next stage of lactation, 100 days plus, is a period in which many farmers consider reducing a cow's concentrate intake in an attempt to reduce the energy density of the total diet. When concentrate levels are reduced there is a need for the cow to compensate for this reduction in energy intake by consuming more forage. There is, however, an inevitable drop in energy intake as the extra forage consumed cannot compensate totally for the reduction in concentrate intake.

Results from experiments 4 and 5 indicate that in many circumstances, i.e. with diets consisting of low levels of concentrate supplementation and low quality forages, < 11.0 MJ kg^{-1} DM, reducing concentrate levels in mid-lactation will cause a severe decrease in the energy density of the total diet which results in an accelerated decline in milk yield. This is due primarily to the cow's inability to consume sufficient quantities of forage to compensate for the reduction in concentrate input. These results also explain the greater declines in milk yield observed on the variable patterns of concentrate allocation in the first 3 experiments.

Many cows, particularly those calving in autumn, are offered the highest quality forage available in early lactation (first cut) and then there is often a progressive change to a poorer quality forage as lactation progresses. Under such a system a variable pattern of concentrate allocation would be reducing concentrate levels to individual cows in addition to a progressive decline in forage quality. Cows should compensate by eating more forage but this becomes increasingly difficult when the forage is becoming of inferior quality. Future research should be directed towards the comparison of a flat-rate and a variable pattern of concentrate allocation where forage quality is progressively decreased in mid-lactation and this would illustrate what, in many circumstances, happens in practice on many dairy farms.

High yielding dairy cows have greater appetites than low yielders (Bines, 1980; Leaver, 1980) and will consume more forage, when available *ad libitum*, at a given level of concentrate intake. The ME intake of high yielding cows is therefore greater than low yielders with a similar level of concentrate supplement. It was therefore argued by Broster and Thomas (1981) (Figure 2.2) that both have similar milk yield responses to additional concentrates. What in fact may happen is not that both have similar milk yield responses to additional concentrates but that the high yielders' milk yield response to 1 increment extra of concentrate is identical to the low yielders' decrease in milk yield to 1 increment less of concentrate (see Figure 11.10). This happens when proportionately more of a given quantity (18 kg total) of concentrate is fed to a higher yielder, e.g. 11 kg day^{-1}, compared with 7 kg day^{-1}, to a lower yielder. Alternatively, both can get 9 kg day^{-1}. Therefore one must analyse the route up the milk yield response curve of the high milk yielder and the route down the milk yield response curve of the lower yielder (see Figure 11.10). These two marginal changes may be similar. This explanation would agree with the observations from the first 3 experiments where the mean daily milk yields over the experimental periods were similar for flat-rate and variable patterns of concentrate allocation but the range in individual milk yields within the variable patterns were much greater than for the flat-rate treatments.

Fig. 11.10 Milk yield response curve of high and low yielding cows.



Option:

1. Both(9kg day^{-1}) = 30 + 25 /27.5 average
2. High 11 and low 7 (kg day^{-1}) = 35 + 20/27.5 average

At any given concentrate level high yielder produces more milk than the low yielder. The milk yield response of the high yielder at high levels of concentrate is greater than the low yielder, but similar at low levels of concentrate.

There are still many uncertainties about the responses of high and low yielding cows to variations in feed input. Feeding a range of pre-determined levels of concentrate to pre-determined high and low yielding cows over a major part of lactation would provide information on substitution rates for high and low yielding cows and their respective milk yield responses to concentrates. Body condition at calving and its importance relative to flat rate or variable patterns of concentrate allocation should be considered as an area for future research, as should uncertainties about fertility where low levels of flat-rate feeding are adopted with relatively poorer quality forage.

Concentrate rationing of dairy cows is evolving in two directions: (a) Where concentrates are fed according to individual yield, where there is an ever increasing need to use expensive electronics and computers to enable individual cows within large herds to be fed pre-determined amounts of concentrate, in and out of the parlour, and (b) A simple approach where a fixed amount of concentrate or a fixed concentrate:forage ratio is offered to all animals within a herd or group. The decision on whether complex or simple patterns of concentrate allocation are desirable depends on future fixed costs, milk pricing and composition payments and the possible adoption of quotas to restrict total U.K. milk production.

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APPENDIX

Appendix 1 Initial Animal Production Data for Experiment 1 (14 day measurements)

	Treatments					
	Flat		Declining		To yield	
	Cows	Heifers	Cows	Heifers	Cows	Heifers
Milk yield (kg day^{-1})	27.5	15.5	25.7	14.9	26.5	16.8
Liveweights (kg day^{-1})	650	504	654	511	643	504
Condition Scores	2.50	2.47	2.56	2.70	2.69	2.41
Parity	4.3	1	4.3	1	4.3	1

APPENDIX 2

Equations used to predict the Metabolisable Energy Content of the Feeds

Equation number*

October 1980 to June 1982

1. Silage ME = $0.249 \times$ *in vitro* OMD (%) $- 0.00716 \times$ DM g kg^{-1} $- 4.21$ (MJ kg^{-1} DM)

2. Concentrate ME = $0.235 \times$ *in vitro* OMD (%) $- 4.45$ (MJ kg^{-1} DM)

July 1982 onwards

3. Silage ME = (*in vitro* OMD (%) $\times 0.907 + 6.03) \times \frac{\text{OM (g kg}^{-1})}{1000} \times 0.16$ (MJ kg^{-1} DM)

4. Concentrate ME = (*in vitro* OMD (%) $\times 1.207 - 10.21) \times \frac{\text{OM}}{1000} \times 0.16$

* The metabolisable energy content of the feeds in experiments 1, 2, 4 and 5 was predicted using equations 1 and 2 for silage and concentrate respectively. In experiment 3 equations 3 and 4 were used to predict the metabolisable energy content of the feeds.

APPENDIX 3

Method used to calculate individual silage DM intakes from weekly group silage intakes

1. Calculate the average ME output day^{-1} for each individual animal for the week in question using: milk yield, milk composition, liveweight and liveweight change and the equations described in MAFF (1975).

2. Add up the 24 average ME outputs for each individual cow in the group to get the mean ME output for the group for that week. Subtract from this the energy derived from the actual mean daily concentrates consumed in that week. This will give the energy contribution from the average amount of silage eaten for that week. Divide this by the ME content of the silage, which will give the theoretical mean silage DM intake for the group of 24 cows for that week.

3. Divide the mean actual quantity of silage DM eaten that week for the group by the theoretical amount eaten from 2 above. This will give a correction factor.

4. Calculate all 24 cows' individual theoretical silage DM intakes and correct these using the correction factor from 3 above. This will ensure that the mean of the 24 individual silage intakes corresponds exactly with the actual mean group intake for that week, measured from weights given and refused.

Appendix 4

Initial 14-day Animal Production Data for Experiment 2

	Treatments			
	HF	HV	LF	LV
Milk yield (kg day^{-1})	26.1	25.8	25.8	25.3
Liveweight (kg)	604	596	596	595
Condition score	2.4	2.4	2.5	2.5
Parity	3.5	3.7	3.9	3.7

APPENDIX 5

Initial 14 day Performance Data - Experiment 3

	Treatments			
	HF	HV	LF	LV
Milk yield (kg day^{-1})	26.2	26.0	26.0	25.8
Liveweight (kg)	629	624	623	643
Condition Score	2.6	2.5	2.6	2.7
Parity	4.3	3.5	3.4	4.0

APPENDIX 6

Initial Animal Production Data Experiment 4

	Group No. + Cow No.	Calving Date	Lactation Number	Liveweight (kg)	Condition Score	Milk Yield (kg day^{-1})
1.	713	21.10.80	1	500	2.00	15.5
	704	13.11.80	1	475	1.75	18.2
	452	30.11.80	1	525	2.50	14.5
	657	15.11.80	1	545	2.00	17.4
2.	538	17.11.80	2	650	2.50	16.2
	422	13.11.80	4	600	2.50	20.1
	395	13.11.80	4	645	2.50	20.8
	415	18.11.80	5	645	1.75	21.4
3.	434	24.11.80	4	585	1.75	23.2
	420	6.11.80	4	618	2.25	21.0
	541	10.11.80	2	635	2.00	18.6
	61	21.11.80	5	625	1.75	22.2
4.	696	12.11.80	3	635	2.50	21.4
	479	20.11.80	3	585	1.50	21.5
	404	22.11.80	5	620	1.75	23.4
	542	27.11.80	2	635	2.50	20.1

Started experiment on average 21 weeks after calving and finished 33 weeks after calving.

APPENDIX 7

Initial Animal Production Data for Experiment 5 (3 March 1982)

	Group and Cow No.	Calving Date	Lactation Number	Liveweight (kg)	Condition Score	Milk Yield (kg)
1.	624	27.10.81	3	575	1.75	20.3
	409	4.11.81	6	720	2.50	18.1
	538	28.10.81	3	680	3.00	21.0
	423	1.11.81	5	645	2.25	20.8
2.	350	13.11.81	6	640	1.50	24.4
	488	4.11.81	4	630	2.00	24.0
	420	11.11.81	5	585	1.50	23.1
	415	12.11.81	6	655	1.50	24.6
3.	619	12.11.81	3	615	1.50	26.2
	366	8.11.81	6	590	1.50	25.0
	434	30.11.81	5	625	1.25	25.6
	696	30.10.81	4	635	2.00	28.4

By 3 March 1982 the 12 animals had been calved, on average, 17 weeks.

The experiment finished, on average, 29 weeks after calving.