INDIVIDUAL FEED INTAKE BY RUMINANTS IN GROUP FEEDING SITUATIONS.

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SUMMARY

The main objectives of this thesis were to assess the variation in individual feed intake by ruminant livestock in group feeding situations, as influenced by animal (e.g., disease, rank-order position), feed (e.g., physical form, quantity allocated) and management (e.g., method of feed presentation) factors. Determination of individual feed intake in group feeding situations by complete faecal collection was not usually practicable and therefore in Section 1 an indigestible faecal marker technique for assessment of individual feed intake was successfully developed and evaluated.

In Section 2 calibration equations of the form $y = c + mx$ (where y = feed DM intake and x = faecal chromium concentrations from grab samples) were computed to facilitate the determination of individual feed intake of ewes in early lactation and to assess the influence of method of feed presentation on the variation in feed intake. The calibration equations successfully predicted the individual feed intake of the ewes and the method of feed presentation (either from troughs, behind a feed barrier or from a feedring) did not appear to markedly influence the uniformity of individual feed intake in the group of ewes.

In Section 3 the influence of the physical form of the diet (a bulky complete diet compared with a conventional hay and concentrates diet) and the quantity allocated on the variation in individual feed intake of ewes in late pregnancy was investigated using complete faecal collections. Plasma ketone bodies and non-esterified fatty acids were also determined to assess the ME status of the ewes. The bulky complete diet promoted a marginally more uniform intake of ME compared with the more conventional hay and concentrates diet. An increase in the quantity of feed allocated to the ewes did not markedly alter the variation in intake in the group and it was concluded that the increment was not sufficiently large to do so.

In Section 4 aspects of palatability of pelleted compounds were investigated in dry non-pregnant ewes and in ewes in late pregnancy. Incorporation of ingredients into the pelleted compound feed at or beyond their normal inclusion levels promoted greater uniformity of

individual feed intake in the group of dry, non-pregnant ewes, compared with allocation of a more acceptable compound feed which was readily consumed by a similar group of ewes. This effect was not repeated with similar ewes in late pregnancy possibly due to increased physiological demand which may have encouraged ready consumption of compound feed, irrespective of ingredient inclusion.

The influence of physical form, quantity allocated, method of presentation and frequency of feeding of compound feeds on the variation in individual compound feed intake by cattle was investigated in Section 5. The physical form of the compound feed on offer was particularly noted to influence the variation in compound feed intake in the group. The possible influence of ostertagiasis on the variation in the intake of hay (indoors) and compound feed (at grass) was investigated in steers. The group of steers which had been most deleteriously afflicted by ostertagiasis demonstrated greater variation in individual intake than the control groups.

In Section 6 the individual intake of grass silage by dairy cows was measured under different methods of access (i.e., self-feed versus easy-feed). Easy-feed access was observed to encourage greater uniformity of silage intake in the herds investigated, particularly between the cows and first-calving heifers.

In Section 7 the individual intake of pelleted compound feeds by the dairy herds (Section 6) were determined. First-calving heifers were observed to consume less than the cows within the herd. A comparison was also undertaken between the variation in individual intake of a novel loose compound meal and a pelleted compound feed by dairy cows. Possible influences on milk yield and composition were also investigated. When the novel loose meal was offered the first-calving heifers consumed significantly less compound dry matter than the cows. This was not repeated when the pelleted compound feed was offered. There were no marked influences on milk yield and composition.

It was concluded that variation in the individual intake of group fed roughages tended to be less than that of compound feeds. Nevertheless accurate individual allocation of compound feeds, particularly in the dairy herd, may not be worthwhile where the roughage component of the diet is group fed.

Factors influencing individual feed intake in group feeding situations

In practical on-farm group feeding situations unique conditions for food competition, in the ethological sense (Wilson, 1975) have been created. The appropriate design of feeding systems so that each animal in the group has an equal opportunity to consume adequate amounts of feed or, indeed, to maximise feed intake in a given situation, requires information on the eating behaviour of the animals. There are very limited quantitative data on behavioural aspects of feeding in ruminants. Such information would be valuable in the design and use of facilities for group feeding of animals (Chase et al., 1976)

The ability of ruminant livestock to control feed intake on either a long term or a short term basis by physical or physiological regulation has been well documented by many authors (e.g. Bines, 1976; Church, 1976; Forbes, 1979). Analysis of the mechanisms which control feed intake have usually been undertaken with ruminants which are individually fed under ad libitum unrestricted access conditions.

On a daily basis, the control of individual feed intake in group feeding situations is related directly to the feeding behaviour of the animals in the group (Chase et al., 1976). The individual feeding behaviour of the animals in group feeding situations, as well as being directly related to physiological demands (maintenance and production metabolisable energy requirements), is influenced by animal factors per se (e.g. differences in the inherent rates of consumption between the animals, rank position in the dominance-subordinate hierarchy within the group), feed factors (e.g. palatability, physical form of the diet influencing rate of consumption) and management factors (e.g. access time, differences in the physical method of allocation of the feed, i.e. from troughs or behind a barrier). This is a rather simplistic approach in view of the probable interactions between the animal, feed and management factors to determine the individual feed intakes of the animals in any given group feeding situation. However, the influence of (a) animal factors and (b) feed and management factors (which will be discussed together) on the variation of individual feed intake in a group feeding situation will now be examined, a summary of which is presented in Table 1.

Table 1 Factors influencing individual daily feed intake attained in group feeding situations.

ANIMAL	FEEDSTUFF	MANAGEMENT
Physiological demands	Palatability	Trough space allowance
Disease/disability	Rate of feed consumption	Design of feeding place
Rate of feed consumption	Substitution of roughages by concentrate feeds	
Rank order position		Frequency of feeding
		Time of access

ANIMAL FACTORS

In a given group feeding situation, on any given day, where the feed on offer is the only source of nutrients available (e.g. complete diet feeding to fattening cattle or dairy cows), animal factors per se under otherwise constant conditions will influence the feeding behaviour of the animals in the group and thereby determine the variation in individual feed intake of the cattle (for example) in the group.

There is inherent genotypic variation in the capacity of ruminants to consume feed, although it is difficult to reliably estimate the extent of the genetic variation (Weston, 1982). Nevertheless, estimates of heritability of feed intake of between 0.35 and 0.76 have been cited by Preston and Willis (1976) for beef cattle and Miller et al., (1972) calculated an heritability estimate of 0.42 $\pm$ 0.1 for the net energy consumption of lactating cows.

Under optimal conditions of the diet and environment, feed intake should be determined by the genetic potential of the animal to use energy; therefore differences in the genetic potential to use energy between animals in any group should be reflected by variation in feed intake (Weston, 1982). Indeed, by removing the influence of

liveweight, the coefficient of variation for voluntary feed consumption per unit of body weight was 4.8% in a study by Blaxter et al. (1966) using six breeds of wether sheep. Therefore, within a group of ruminant animals, under otherwise constant conditions, e.g. similar liveweight and production levels, there is an inherent difference in the capacity of the animals to consume feed which may be expressed in variation in feed intake under ad libitum or, indeed, restricted feeding conditions.

Inherent differences in the rate of feed consumption

The individual feed intake achieved by animals in group feeding situations is likely to be influenced by possible variation in the rate of feed consumption between the animals in the group, irrespective of the influences of diet and quantity allocated on consumption rate (which will be discussed under 'Feed Factors'). Variation in the rate of consumption between the animals may be particularly important in influencing the individual feed intake of the animals where the feed is allocated under restricted feeding conditions (e.g. compound feed), i.e. either time of access and/or quantity of feed offered. It is difficult to ascertain inherent differences between animals in the rate of consumption of feed due to the confounding influences of type of feed and quantity offered to the animals. Nevertheless, several authors (e.g. Stoddard, 1969; Jones et al., 1966) have observed differences in the rate of feed consumption by animals under individual feeding conditions.

Stoddard (1969) observed a large variation in the individual consumption rates of dairy cows which were individually offered grain. However, the number of cows used in the trial was not specified. When 4.5 kg grain was allocated to cows of similar liveweight and milk production, the mean consumption rate was 2.9 minutes/kg with a range of 1.9 to 3.4 minutes/kg.

Jones et al. (1966) measured the rate of consumption of 1.82 kg of meal/head by 42 dairy cows. The mean rate of consumption was 3.57 $\pm$ 0.978 minutes/kg. The coefficient of variation (as defined by the standard deviation divided by the mean of the population) of the consumption rate was 27.4%. It is possible, therefore, that the individual feed intake in a group feeding situation will be directly related to the rate of consumption of the feed on offer, particularly under restricted feeding conditions. Nevertheless, Jones et al.

(1966) did not specify whether or not the cows were of similar milk yield, liveweight or whether they received an otherwise similar diet in terms of dry matter intake. Indeed, Jones et al. (1966) cited work by Stallcup, Bostain and Bieworth (1959) which suggested that there were breed differences in the rate of feed consumption. When compound feed was offered to Holstein, Guernsey and Jersey cows in a cowshed, the rates of feed consumption were 4.82, 4.73 and 6.60 minutes per kg respectively. Nevertheless, the individual variation in consumption rate between cows within breeds was likely to be sufficiently great to question this trend, as indicated by Stoddard (1969), such that the difference between breeds is not likely to be significant.

Gill et al. (1966) offered 5 kg hay/head individually to six dry cows (five British Friesian and one Dairy Shorthorn; one cow was pregnant). The mean rate of consumption was 13.96 ± 2.72 minutes per kg (coefficient of variation 19.5%). There were consistent differences between the rates of consumption by these cows over the three day observation period.

The mean rate of consumption of ten dry heifers (mainly British Friesian) which were individually offered ad libitum hay (Campling, 1966a) was observed to be 54.6 ± 10.26 minutes/kg (coefficient of variation 18.8%). The mean hay intake over the recording days was 8.4 ± 0.72 kg fresh matter. The influence of level of feed allocation is illustrated by these latter two examples and will be further discussed in the subsection dealing with the influence of feed factors on rate of consumption.

Suzuki (1969) observed a coefficient of variation of 25.6% in the mean rate of consumption for six cows offered silage at a rate of 2.2% of their respective liveweights (i.e. restricted). The mean rate of consumption was 2.36 ± 0.605 kg in 5 minutes. A significant difference was observed in the cows in the rate of consumption. Cows 215 and 151 were dry and non-pregnant and the mean rates of consumption (kg/5 minutes) were:

Cow number	131	193	206	229	215	151
Consumption rate	3.0^{a}	3.2^{a}	2.3^{b}	2.1^{b}	1.9^{b}	1.7^{b}

Means with different superscripts were significantly different

a, b $P < 0.05$

Stoddard (1969) also noticed the effect of physiological energy demands (i.e. milk production) on the rate of feed consumption, under otherwise constant conditions. Cows which yielded more than 22.7 kg milk/day had a mean grain consumption rate of 2.6 mins per kg (allocated 4.5 kg grain/head) compared with cows which yielded less than 16.0 kg milk/day where the mean rate of consumption was 3.2 mins/kg. Nevertheless, it was suggested that the individual variation in consumption rate was sufficiently large to question this trend.

Liveweight has also been observed to influence the rate of feed consumption under otherwise constant conditions. Putnam et al. (1964a) indicated that 38% of the variation in the rate of feed consumption could be attributed to body weight in an experiment with 12 steers offered ad libitum access to a complete diet. Stoddard (1969) also indicated the influence of liveweight on the rate of feed consumption in dairy cows. Smaller cows (450-500 kg liveweight) required 3.5 mins/kg to consume 4.5 kg grain and cows of 600-650 kg liveweight required 2.9 minutes/kg to consume 4.5 kg grain. Indeed, with each 50 kg increment in increased liveweight, the rate of feed consumption was reduced by 0.2 mins/kg. Nevertheless, Stoddard did not specify whether or not these observations had been taken under otherwise constant conditions, particularly in terms of milk yield which was also implicated in influencing the rate of feed consumption.

The possible influence of liveweight on the rate of feed consumption, under otherwise constant conditions, has particular implications in group feeding situations where the group of animals is heterogeneous in terms of liveweight. This is more likely to be the case in dairy herds and ewe flocks than in groups of animals which are housed for store or fattening purposes (e.g. steers and wether sheep) where the liveweight is likely to be fairly uniform between the animals in the group.

Indeed, the observations on the rate of feed consumption, which have just been discussed, have usually been made under individual feeding conditions. An indication of the effects of group feeding on the rate of feed consumption of the animals has been provided by Putnam et al. (1964b) and Putnam and Bond (1971). When steers were either penned individually and fed individually or penned in pairs and fed individually (Putnam et al., 1964b), an increase of 17% ($P < 0.05$) in the consumption rate of a pelleted ration was observed by the steers which were penned in pairs and fed individually. The actual consumption

rates were not specified (abstract). Further work by Putnam and Bond (1971) with heifers from a beef herd indicated that the consumption rate of a complete diet was 3.3 kg feed/hr when the heifers were individually penned and fed, and 4.4 kg feed/hr when the heifers were penned in pairs and individually fed. The average feed consumption was 12.2 kg DM/day and 11.5 kg DM/day for the individually penned and pair-penned heifers respectively. Nevertheless, the feed consumed per unit time at the feeder was considerably greater for the pair-penned heifers.

Therefore, it is possible that under group feeding conditions the rate of feed consumption will be greater than under individual feeding conditions and the possible influence of liveweight and production parameters on the rate of consumption will be exaggerated.

Physiological demands

The specific hunger drive, i.e. appetite (Church, 1976) of the animals in the group will be influenced by physiological demands related to the energy requirements for maintenance and production. Maintenance energy requirements have been related to body size in dairy and beef cattle by the equation for maintenance metabolisable energy requirements in Technical Bulletin 433 (MAFF 1984), i.e. maintenance energy requirements = 8.3 + 0.091 W, where W is liveweight (kg). Metabolisable energy requirements for productive output by the animal, i.e. in terms of milk yield or daily liveweight gain, have similarly been defined by MAFF (1984) (e.g. the metabolisable energy (MJ ME/kg milk) allowance for the production of milk is related to the net energy value (EV) of the milk (EV (MJ/kg) = 0.0386 butterfat (g/kg) + 0.0205 solids not fat (g/kg) - 0.236, (MAFF 1984)) by the equation M_l=1.694 EV MJ/kg milk). Nevertheless, specific metabolisable energy demands may not be fully met due to limitations of dry matter intake, particularly on a high roughage diet. The limits to dry matter intake (DMI) in the dairy cow have been defined by DMI = 0.025 W + 0.1 Y, where W is liveweight (kg) and Y is milk yield (kg) (MAFF 1984). This is a rather simplistic approach in view of the depression in dry matter intake in early lactation which is associated with peak milk yield and, therefore, in effect, this imposes limitation to the effects of milk yield potential (i.e. Y) on feed intake (Broster et al., 1978). Also differences in body weight (W) may not truly indicate differences in body composition in terms of fat content. High abdominal fat content

may physically depress potential rumen capacity and accordingly feed intake (Weston, 1982). However, Forbes (1980) indicated that metabolic changes may accompany increases in body fat content and these, in turn, may affect voluntary consumption.

Therefore, it may be expected that the physiological energy demands of the animals in a group may be expressed directly in terms of individual feed intake, given that there is ad libitum access to feed and there are no restrictions in terms of voluntary intake (i.e. restrictions due to reduced abdominal capacity in late pregnancy, for example). Indeed, it may also be possible, under restricted feeding conditions, that the animals in the group with the greater physiological energy demands will also consume the largest quantities of feed, under otherwise constant conditions.

Disease

The current disease status of the animals is also likely to influence the variation in individual feed intake in the group. Individual feed intake may be altered by different degrees depending on the presence of parasitic infections or metabolic diseases in the group (Church, 1976; Weston, 1982). Localised infection of the mouths and/or feet of the animals in the group may physically hinder feed acquisition and, therefore, contribute to the range of individual feed intake observed in the group, if otherwise constant conditions are present.

Parasitic infection of cattle and sheep have been particularly associated with reduced feed intake (e.g. Entrocasso, 1984). The abomasal parasite Ostertagia circumcincta, for example, caused a reduction of 6-20% of feed intake in sheep, where the larval intakes ranged from 1,000 to 17,000/day (e.g. Sykes and Coop, 1977). The magnitude of the reduction is related to the severity of the infection and it seems that there is a threshold level of exposure below which there is no significant depression of appetite (Steel, 1978).

Elevated concentrations of the gastrointestinal hormone, cholecystokinin in infected animals have been implicated in the depression of voluntary intake (Entrocasso, 1984).

The variation in individual hay intake (during winter housing) and supplementary compound feed intake (at grass) by three groups of steers, which differed in the level of ostertagiasis infection, was examined in Experiment 5.6 of this thesis.

Social hierarchy

The rank position of an animal in the established hierarchy of the herd or group may influence its individual feed intake. There are various recognised forms of social relationships within groups of cattle or sheep (although not so well defined for sheep which will be discussed later), as described by various authors (e.g. Hafez, 1975; Syme and Syme, 1979). The group of animals may be organised in a social hierarchy where the dominance-subordination relationships are particularly relevant in the present context of variation in individual feed intake. If, for example, previously unacquainted cows are grouped together, a learnt dominance-submission relationship is established (Bryant, 1975). The formation of these relationships determines the form of the dominance orders or hierarchies in the group. Cattle have been observed to establish social hierarchies which are linear, linear-tending or complex (Hafez, 1975).

The dominance value of an animal is usually calculated from the arc sine transformation of the average proportion of 'wins' each animal has against all other animals in the group (Beilharz and Mylrea, 1963). These measurements are usually determined under fairly controlled conditions.

Indeed, the formation of a dominance hierarchy reduces the level of aggression and social tension within a group. As soon as the dominance-subordination relationship is established physical aggression is restricted to threat rituals from which the subordinate animal readily retreats (Rowell, 1974) having accepted its position in the social order. It has been suggested (Bryant, 1975) that the resulting social stability may be associated with an improvement in production parameters when compared to groups where a state of social instability is maintained.

The function of the dominance hierarchy operates when there are scarce resources, e.g. feed and/or water, so that the high ranking individual receives precedence over the low ranking individuals. The more severe the constraint, e.g. quantity of feed, time of access, the greater the proportion of individuals within the dominance hierarchy affected.

The particular characteristics of the animals which have been implicated by several authors (e.g. Bryant, 1975; Syme and Syme, 1979; Coppock et al., 1981) in determining the rank position of the animals have included age, liveweight, seniority in the herd, chest girth,

withers height, breed, possession of horns, aggressiveness and agility. For example, Coppock et al. (1981) cited work by Guhl and Arkeson (1959) which indicated a correlation coefficient of 0.84 between age and dominance rank order. McPhee et al. (1967) observed that withers height was the only body measurement to show a significant relation to social rank in seven groups of six steers offered hay or silage on an ad libitum basis. The partial regression coefficient for social rank position (scale of 1 to 6 where 1 was the most dominant animal) related to withers height was - 0.668 ($P < 0.01$). Measurement of weight and girth did not indicate significant relationships with social rank position.

In established herds, where the additions to the group are always heifers, it is likely that age and seniority in the herd are the main factors which confer dominance (Bryant, 1975).

Social hierachies have not been so well defined in sheep. 'Social dominance' has been associated with studies on sheep behaviour (e.g. Dove et al., 1974) even although social rank is not as obvious in this as in other domestic species (Syme and Syme, 1979). Social hierarchies, if they are observed, tend to be bi-directional, i.e. dominance of one sheep over another is not absolute (Dove et al., 1974). Nevertheless, it has been suggested (Ewbank, 1973) that social dominance may be more readily observed to influence feeding behaviour in intensive sheep production systems (e.g. housed ewes prior to parturition, intensive fattening of lambs).

Few studies have investigated the individual characteristics of dominant sheep. Syme and Syme (1979) cited work by Scott (1945) where there was a direct relationship between social rank and age. Dove et al. (1974) found statistically significant correlation coefficients ($P < 0.05$) between social rank and liveweight (0.62), social rank and height at withers (0.57) and social rank and height at hocks (0.67) in 20-month old wethers.

The influence of rank position in the established dominance hierarchy on feed intake has been widely investigated in cattle and, to a lesser extent, in sheep and several examples of this type of investigation will now be discussed.

Influence of rank position in the dominance hierarchy on feed intake in cattle

Early work by Wagnon (1963) cited by Syme and Syme (1979) indicated that two year old cows kept on the same range pasture as older, more dominant cows were driven away from the supplement feeding troughs by these more dominant older animals and consequently the two year old cows gained less weight than comparable two year olds grazed separately.

Observations by McPhee et al. (1967) where 42 steers were divided into groups which were allocated either ad libitum hay or 75% of the amount of hay eaten ad libitum or ad libitum sorghum silage, indicated that animals of higher social rank spent more time feeding (i.e. 611 $\pm$ 19.5 minutes) compared with animals of lower social rank 546 $\pm$ 19.4 minutes) over a 60-hour observation period. The difference in the time spent eating was statistically significant ($P < 0.05$). Individual feed intake was not recorded.

Further observations on the relationship between time spent feeding and social rank were made by Friend and Polan (1974). Twenty-one Holstein cows were given access to hay and concentrates from troughs and the correlation coefficient between social rank and time spent feeding was 0.59. Again, individual feed intake was not recorded.

The influence of rank order position on individual feed intake has been assessed in several studies by Krohn and Konggaard (e.g. 1976, 1979) with Danish Black dairy cows. Cows in their first lactation, with few exceptions, held the lowest position in the hierarchical system. Krohn and Konggaard (1976) allocated silage (ad libitum) and fodder beets (restricted to 12 kg FM/head) to a group of 60 cows of mixed age. Both feeds were offered from a feed bunker and individual feed intake was assessed by chromium analysis, as described by Krohn and Konggaard (1976). For both silage and fodder beet, the cows of higher ranking order consumed significantly more ($P < 0.05$) than the cows of lower rank order (Table 2). The result reflected the close relationship between rank position and liveweight (which was not recorded) and, indeed, was probably a corollary between liveweight and intake capacity of the animals. Expression of feed intake per kg liveweight may have removed the effect of rank order.

Table 2 The effects of rank position on feed intake and production performance (Krohn and Konggaard, 1976).

	RANK POSITION			
	Older cows			Cows in first lactation
	Low	Medium	High	Low
Number of cows	13	13	14	20
Fodder beet intake (kg)	13.6	13.2	16.6	11.9
Grass silage intake (kg DM)	8.8	9.9	11.1	7.3
Fat corrected milk production kg (130 days post partum)	2976	3050	2842	2219

Nevertheless, milk production among the older cows was not related to rank position. This was also observed by Friend and Polan (1978) where dominance, in terms of competitive order, in time spent eating was not well correlated with milk production, although in this example the apparent lack of correlation between time spent feeding and milk production may be explained by differences in the rate of consumption between the cows. Therefore, cows of low rank position may consume the feed on offer at a greater rate than those of higher rank and, consequently, even although the time spent eating may be less for the former group, the quantity of feed consumed may be greater than for the cows of higher rank.

Further work by Krohn and Konggaard (1979) demonstrated that separation of cows in their first lactation from older cows resulted in an increase in the milk production of the former animals of between 5 and 10%. First lactation cows which were placed in a group isolated from older cows spent, on average, 10-15% more time eating fodder beet and silage than first lactation cows grouped with older cows. Consequently, 20% more feed dry matter was consumed by the separated first lactation cows compared with the first lactation cows grouped with the older cows. Indeed, Konggaard (1983) recommended that first lactation cows should be grouped on their own when present in herds of 100 cows or more.

In more recent work (Harb et al.,1985) with 10 group fed late lactation dairy cows offered ad libitum grass silage, there was a

significant correlation coefficient ($r = 0.55$, $P < 0.05$) between the time spent eating silage and rank position which suggested that when competing for silage, dominant cows tended to eat for longer than submissive cows. However, rank position was not significantly correlated with the amount of silage eaten (mean intake 8.9 $\pm$ 0.92 kg DM/day) and this may suggest that submissive cows increased their rate of consumption more than the dominant cows. Indeed, 72% of the variation in silage intake was attributed to milk production, body weight, dominance value, eating time and day in milk. Milk production was observed to be the most important independent variable, even although the mean milk yield was only 5.0 $\pm$ 4.9 kg per day. Friend and Polan (1978) also indicated that production variables were more important than dominance rank in explaining access to feed, which was offered on a restricted basis.

Therefore, dominance/subordination relationships in cattle appear to influence access to the feed supply, in that dominant cattle may spend a greater amount of time at the feeding trough under ad libitum access and they may be able to assert their position under restricted access conditions. Nevertheless, the dominance values of cattle are not consistently related to actual feed intake (Harb et al., 1985) or production parameters (Friend and Polan, 1978). However, the extent of the influence of dominance/subordination relationships on the access to the feed supply may be influenced by quantity of feed available, time feed is available, trough space and trough design (Bryant, 1975).

Influence of rank position in the dominance hierarchy on feed intake in sheep

There is no clear-cut evidence for sheep that dominance is related to priority of access during feeding, although restricted feeding has been used to facilitate aggressive behaviour (Arnold and Maller, 1974; Ewbank, 1973). Bi-directional dominance relationships have been observed in sheep (Dove et al., 1974) whereby the effects of dominance on feeding may be reliable in terms of the successful animals. However, the effects of dominance may vary considerably in terms of the degree of success in paired encounters achieved by subordinates. Therefore, a dominant sheep is one which wins more than 50% of the time rather than one which exhibits absolute dominance.

FEED AND MANAGEMENT FACTORS

Palatability

Palatability is defined as the perceptive response of an animal to a feed depending upon taste, smell, flavour and texture (Church, 1976) and has been variously rated as a determinant of feed intake (e.g. Baumgardt, 1970; Marten, 1978). The palatability of a feed is usually assessed on a free choice or, more usually, two-choice basis (e.g. Greenhaulgh and Reid, 1971; Coppock et al., 1974; Marten, 1978; Owen, 1979), whereby a feed is said to be palatable if it is selected in preference to the other food(s) offered simultaneously. However, it is perhaps unreasonable for such a rating to be associated with the intake properties of the same feeds when given as a whole or part of a single diet offered without choice (Owen, 1979). Where the feed is offered without choice, it is perhaps applicable to assess the phenomenon of palatability in terms of whether an animal may or may not find a specific feed to be acceptable (Marten, 1978).

The palatability of a feed, due to its physical and/or chemical properties which may invoke a selective response by the animal, may influence individual feed intake in a group feeding situation, under otherwise constant conditions. This may be observed where, for example, a compound feed is introduced on a restricted basis without choice to a group of fairly hungry animals which would have perhaps selected against, i.e. rejected, this feed in a two-choice preference test. The relative unacceptability of the compound feed may cause a large variation in intake by the animals in the group, both during its introductory allocations and perhaps later in the long term when the animals have become accustomed to the feed. This effect may contrast markedly with the variation in feed intake in the group had the compound feed been relatively more acceptable (i.e. preferentially selected in a two-choice test situation).

The responses of ruminants to chemicals (bitter, sour, salty and sweet) indicated that cattle responded to (i.e. rejected) lower concentrations in an ascending series of concentrations more than did sheep (Goatcher and Church, 1970). Sheep required relatively high concentrations before responding. These results suggest that the possible influence of relatively unacceptable feed on the variation in individual feed intake in group feeding situations may be more readily observed in cattle than in sheep.

The acidity of silage has been implicated by various authors (e.g. Hutchison and Wilkins, 1971; Church, 1976) in relation to the level of intake attained, where the total dry matter consumed is less when the forage is offered as silage compared with hay. McLeod et al. (1970) demonstrated that by increasing the pH of grass silage from 4 to 5.4 (by addition of sodium bicarbonate) silage consumption was increased by 10-20%. When lactic acid was added the pH was reduced from 5.4 to 3.8 and dry matter consumption was observed to be reduced by 22%. There is an apparent conflict then, between palatability or acceptability of silage and one of the appropriate characteristics of a good fermentation (i.e. pH 4). It is possible then that silages which have similar characteristics, except for pH, and are offered separately to one group of animals, may produce different intake characteristics which may be responsible for influencing the range of individual dry matter intakes attained by the group under otherwise constant conditions.

Flavour and texture have been demonstrated as important characteristics of concentrate feeds offered to early weaned lambs (28 days old) (Davies et al., 1974). Eight feeds were offered simultaneously to individually penned lambs and feed intake was measured every four days. Soya bean meal, barley and two types of concentrate pellets (of low energy concentration and high energy concentration) were the most popular. Shredded sugar beet pulp, fishmeal, flaked maize and whole oats were the least popular. Therefore, coarse feeds and those which tasted of fishmeal were found to be unpopular.

It is possible that the results of such comparative tests may depend on the previous familiarity of the animals with the particular (or comparable) feeds investigated.

Adverse physical and chemical aspects of the feed may, therefore, be more likely to promote variation in individual feed intake in group feeding situations compared with more favourable aspects of the feed.

Variation within species has been observed in the preference expressed in two-choice or free choice tests of palatability. The mean intake of corn silage expressed as a percentage of the total forage dry matter consumed in a two-choice preference test between corn silage and hay crop silage, using 30 lactating Holstein cows (Coppock et al., 1974), was 58.7% with a coefficient of variation of 33.3%. The possible influences of lactation, age and size were removed by the

Latin square experimental design. However, the authors suggested that social dominance may have contributed to the preferences expressed (individually fed animals, penned in groups).

Considerable difference in preferences for concentrate feeds, e.g. soya bean meal, rolled barley (Davies et al., 1974) were also observed between artificially weaned lambs. Therefore, there may be differences between animals within species in tolerance for certain feeds which may influence the individual feed intake attained in group feeding conditions, where there is no choice of feed and under otherwise constant conditions.

The preference for, or acceptability of feeds may be altered in a given situation by animal or plant (with reference to grazing animals particularly) related factors. It has been suggested (Church, 1976) that the effects of palatability are more likely to be observed where feed is abundant compared to where feed is in short supply. Church (1976) was referring to grazing situations where selective grazing is likely to be more apparent under conditions of high herbage availability than under low herbage availability. Nevertheless, the influence of quantity of feed available on the expression of palatability effects may be observed, for example, where conserved forage allocated on an ad libitum basis has been substituted by concentrate feeds. Therefore, even although there is a large quantity of conserved forage, e.g. silage, available, adverse aspects of palatability (e.g. acidity) of the silage may be more noticeable under liberal concentrate allocation than under conditions of more restricted concentrate feed allocation, where the substitution rate may not be so apparent.

The variation in feed intake in a group of animals, as possibly influenced by aspects of palatability, may also be influenced by differences in the hunger drive, i.e. appetite (Church, 1976) between animals. When animals have an increased energy demand, e.g. in pregnancy and lactation, there may be less selection or rejection of feed compared with dry, non-pregnant animals. However, McManus (1968) did not find any difference in grazing preference in dry, pregnant or lactating ewes.

Nevertheless, it would be expected that hunger causes animals to eat more rapidly and be less selective. It may therefore, be anticipated that variation in individual intake in group feeding situations, as affected by palatability aspects, may be more readily

observed in relatively unproductive animals, e.g. dry, non-pregnant ewes, store cattle and sheep.

Aspects of palatability related to compound feed allocation to ewes at various stages of production (e.g. dry, non-pregnant and late pregnancy) were pursued in Experiments 4.1, 4.2 and 4.3. The influence of acceptability on the individual intake of a compound feed allocated to dry, pregnant suckler cows was examined in Experiment 5.2.

Influence of type of feed on rate of feed consumption

The physical form of the diet on offer has been implicated in determining the extent of variation in individual feed intake, in group feeding situations, through its effects on the rate of consumption of the feed (Foot and Russel, 1973). These workers observed a greater variation in dry matter intake by group fed ewes on a mainly pelleted diet (dried grass) where the mean dry matter intake was 621 g and coefficient of variation 22.3%, compared with a mainly roughage diet (84.3% hay and 15.7% oat pellets). The mean dry matter intake of the mainly roughage diet was 756 g and the coefficient of variation was 13.3%. The ewes on the mainly pelleted diet ingested their allocation of feed more quickly than those ewes allocated the mainly roughage diet. Indeed, the oat pellets component of the mainly roughage diet was also observed to be consumed very rapidly in comparison with the hay component and, consequently, the coefficients of variation for the oat pellets (mean intake 101 g) and the hay (mean intake 637 g) were 35.8% and 12.9% respectively.

It is possible, then, that feeds which are consumed relatively more rapidly (e.g. energy dense, moist and/or pelleted feeds (Campling and Morgan, 1981)) may promote a larger variation in individual feed intake in group feeding situations than feeds of a fibrous, bulky and dry nature. Since pelleted, energy rich diets are usually more expensive than bulky fibrous diets, it is perhaps particularly important to ensure uniformity of intake of such diets in group feeding situations to ensure efficient use of feed resources.

The rate of consumption of various individually offered feeds by cattle, allocated either on an ad libitum or a restricted basis, are presented in Table 3. Pelleted concentrate feeds were consistently consumed more rapidly than forages (e.g. Bailey, 1959; Jones et al., 1966; Balch, 1971; Clough, 1972) and were usually consumed within 2-10 minutes/kg DM. Pelleted ground roughages were also consumed more

rapidly than the equivalent roughage in its original form (e.g. Putnam and Davies, 1963; Freer and Campling, 1965; Campling and Freer, 1966; Balch, 1971). Silage was not consistently consumed at a faster rate than hay (Balch, 1971; Castle et al., 1979) which may have been influenced by different palatability aspects of the silage between sources, i.e. silage may not be as consistent a product as hay. However, short chop silage tended to be consumed at a faster rate than long or medium chop silage (Castle et al., 1979, 1981).

The addition of urea (or compound feeds) to diets of poor quality roughages has been observed to increase the rate of feed consumption (and to increase the total dry matter intake). Campling and Freer (1966) observed an increase in rate of consumption from 21.8 minutes/kg DM to 16.4 minutes/kg DM when 150 g of urea was additionally offered with ground pelleted oat straw. Similarly, addition of urea to oat straw allocated to dairy cows (Balch, 1971) improved the rate of consumption from a range of 41-58 minutes/kg DM when only oat straw was fed to 23-40 minutes/kg DM. Therefore, diet composition will influence the rate of feed consumption of the components of the diet, with possible consequent effects on the variation in individual feed intake in a group feeding situation.

Data on the feeding behaviour of sheep are considerably less extensive than those on cattle. The rate of feed consumption (grass hay, chopped dried grass and ground pelleted dried grass) in a group of 18 individually fed dry ewes was observed by Forbes et al. (1972). The feeds were allocated at a rate of 15% in excess of voluntary intake and the rates of feed consumption were 137 minutes/kg, 106 minutes/kg and 93 minutes/kg respectively. The rate of consumption was significantly less ($P < 0.01$) for the pelleted dried grass compared with the hay. The ewes had full 24-hour access to the feeds on offer and it may be possible that such relatively low consumption rates would not be apparent under more restricted and competitive feeding or access conditions.

Table 3 Influence of the type of feed offered on the rate of feed consumption (minutes/kg DM) in cattle.

Animals	n	Feed	Av. rate of consumption	Source
Dairy cows	4	Pelleted conc.+	2.8	Bailey (1959)
		Fresh grass	3.5	
		Silage	4.0	
		Dried grass	12.1	
		Hay	14.3	
Steers	12	Complete diet:		Putnam and Davies (1963)
		(a) 60% concentrate		
		coarsely ground	24.2	
		pelleted	27.1	
		(b) 89% roughage		
		coarsely ground	42.7	
		pelleted	23.5	
Dairy cows	7	Pelleted dried grass	4.5	Freer and Campling (1965)
		Dried long grass+	8.1	
Dairy cows	3	Long oat straw	47.2	Campling and Freer (1966)
		Ground pelleted oat straw	21.8	
		Ground pelleted oat straw + 150 g urea	16.4	
Dairy cows	NA	Cubed concentrate+	2.6	Jones et al. (1966)
		Concentrate meal+	3.9	
Dairy cows	6	Silage+	10.6	Suzuki et al. (1969)
		Hay+	27.8	

Table 3 contd.

Animals	n	Feed	Av. rate of consumption	Source
Calves	6	Pelleted dred grass	60	Hodgson (1971)
		Hay	240	
			Range	
Dairy cows	5	Oat straw+	41-58	Balch (1971)
		Medium quality hay+	20-40	
		Grass silage+	31-58	
		Pelleted concs.+	4-10	
		Pelleted oat straw+	11-24	
Dairy cows	NA	Concentrate meal in water +	0.6	Clough (1972)
		Pelleted concentrate (dry)+	2.2	
Dairy cows	4	Silage (72 mm)	52.8	Castle et al. (1979)
		Silage (17.4 mm)	47.4	
		Silage (9.4mm)	35.6	
		Hay	44.2	
		(s.e difference between two means)	(5.0)	
Dairy cows	4	Silage (18.2mm)	36.5	Castle et al. (1981)
		Silage (11.6mm)	28.0	
		(s.e. difference between two means	8.5	

NA No data available

\+ Feed allocated on an ad libitum basis apart from those marked with +.

Hay and haylage (85.0% DM and 51.8% DM respectively) were separately allocated on an individual ad libitum basis to 24 wether sheep (Peterson et al., 1974). The mean rates of consumption were 476 minutes/kg (expressed as 2.10 g/minute by the authors) for the hay and 373 minutes/kg (2.68g/minute) for the haylage. The difference was not significant on an ad libitum basis but may have been significant under more restricted feeding conditions. The possibility of a relationship between the bulk density of the diet and the rate of dry matter consumption was investigated by these workers. A statistically significant correlation coefficient ($r = 0.929$, $P< 0.01$) was found between bulk density and rates of dry matter consumption in 8 forage diets (crown vetch and alfalfa of different maturities and types of preservation). It was hypothesised that for forage diets, volume itself may be limiting the rate of ingestion once eating has been initiated.

Earlier survey work on nine dairy herds (Weidlich and Wulff, 1961) also indicated that the rate of feed consumption depended more on the volume of the feed (fodder beet and hay) than on the types of feed.

Therefore, the physical form of the feed available, and possibly its bulk volume characteristics, have been observed to influence the rate of feed consumption by animals, even although differences between animals in the rate of consumption may also be apparent (as indicated earlier in this review), with consequent implications in terms of variation in individual feed intake in group feeding situations. The influence of feeds which differed in their physical forms on the variation in feed intake in group feeding situations has been pursued in Experiments 3.1, 5.3, 5.4 and 7.4.

In Experiment 3.1 the individual intake of a conventional hay and concentrates diet compared with a bulky complete diet was assessed in two groups of pregnant ewes. In Experiments 5.3 and 5.4, the variation in intake of compound nuts or compound cobs was examined in a group of lactating suckler cows at grass in the spring and autumn respectively. The individual intakes of the respective compound feeds were illustrated by reference to the concentration of markers (i.e. magnesium and chromium, which had been incorporated into the compound feeds) in faecal grab samples.

In Experiment 7.4, the individual intakes of a novel sugar beet pulp loose mix was compared with the individual intakes of a proprietary pelleted compound feed in a herd of dairy cows. Possible differences in milk yield and composition were also examined.

Influence of the quantity of feed offered on the rate of feed consumption

The quantity of feed offered to animals has also been implicated in determining the extent of the variation in individual feed intake in group fed animals, particularly if the feed is in a physical form which can be rapidly ingested (Foot and Russel, 1973). The large variation (coefficient of variation 35.8%) in the individual intake of pelleted oats by group fed sheep (Foot and Russel, 1973) was considered to be due to the small quantity offered (101 g DM/head) as well as the physical form of this diet component. Further work by Foot et al. (1973) indicated that allocation of a pelleted compound feed at 10.4 g digestible dry matter/kg $W^{0.75}$/day to sheep, on a group basis, reduced the coefficient of variation of intake from 51.1% to 13.2%, when 3.8 g digestible dry matter/kg $W^{0.75}$/day was offered. The hay allocation was similar during both experimental period (734 g DM/head/day).

Allocation of either 84, 252 or 504 g DM/head/day of a pelleted compound feed containing chromic oxide to pregnant Greyface ewes given a fairly generous trough space allowance of 530 mm/head (measured on both sides) produced coefficients of variation of faecal chromium concentration (from grab samples) of 45.9%, 36.7% and 26.8% respectively (Kendall et al., 1980) (the standard deviations of the mean faecal chromium concentrations were $\pm$ 55.1, $\pm$ 142.4 and $\pm$ 190.3 g/100 kg DM respectively).

It is possible, therefore, that the allocation of large quantities of feeds which can be rapidly consumed by animals (e.g. compound feeds, pelleted roughages) may promote a more uniform intake of the feed in a group compared with small quantities of the same feed. This trend is probably mediated through differences in the rate of feed consumption, whereby there is an increase in the rate of ingestion by the animal when small compared with large quantities of feed are offered.

The influence of the quantity of feed offered on the rate of feed consumption in cattle and sheep has been studied by various workers, usually under individual feeding conditions (Table 4). When forages

were allocated (dried pelleted grass, hay, silage or dried pelleted ground oat straw) on a restricted basis followed by a more liberal regimen (i.e. ad libitum), e.g. Freer and Campling (1965); Campling (1966b); Campling and Freer (1966); Gill et al. (1966); Forbes (1972) and Harb et al. (1985), the rate of forage consumption was greater under restricted allocation compared with ad libitum feeding. Indeed, analysis of variance (Forbes, 1972) indicated that the ewes ate significantly faster ($P < 0.05$) when fed on a restricted compared with an ad libitum basis.

The variation in the group intake of silage was observed to increase from 47.2% (mean silage DM intake 7.4 kg/day) to 56.2% (mean silage DM intake 6.5 kg/day) when 11 cows were offered silage on an ad libitum basis compared with 80% of the quantity consumed on an ad libitum basis respectively (Harb and Campling, 1985). The average rate of consumption of the silage was improved from 22.2 minutes/kg DM to 16.7 minutes/kg DM respectively which may have contributed to the larger variation in intake under 80% ad libitum access.

When concentrate cubes were allocated to dairy cows (Jones et al., 1966) the rate of feed consumption was increased from 1.6 minutes/kg DM to 1.1 minutes/kg DM as the quantity offered was increased from 1.0 to 4.0 kg/day. The authors explained this on the basis that the cows would have to put in more effort to scoop up the cubes, which would be thinly spread when allocated at 1.0 kg/day, from the bottom of the feed trough compared with the allocation of 4.0 kg/day. Nevertheless, the difference in the rate of consumption was fairly small and was probably not significant, although this data was not available. In contrast, Stoddard (1969) indicated that grain fed to dairy cows was more rapidly ingested (3.0 minutes/kg DM) when allocated in smaller quantities (e.g. 4.5 kg/day) compared with larger quantities (ingestion rate of 3.5 minutes/kg DM when 5.5 kg/day offered). It has been suggested that saliva production may be a limiting factor in ingestion rate when large quantities of feed (particularly those of a dry nature) are offered (Church, 1976).

Table 4 Influence of the quantity of feed offered (kg/day) on the rate of feed consumption (minutes/kg DM) in cattle and sheep.

Animal	n	Feed	Quantity allocated	Rate of consumption	Source
Dairy cows	7	Pelleted dried grass	4.5	4.5	Freer and Campling (1965)
			Ad lib	10.7	
Dairy cows	3	Silage	7.5	32.3	Campling (1966b)
			9.9	58.1	
Dairy cows	3	Hay	9.5	30.1	"
			11.3	37.7	
Dairy cows	3	Pelleted oat straw	4.4	9.4	Campling and Freer (1966)
			Ad lib	21.8	
Dairy cows	NA*	Concentrate cubes	1.0	1.6	Jones et al. (1966)
			4.0	1.1	
Dairy cows	6	Hay	5.0	14.0	Gill et al. (1966)
			7.5	18.3	
Dairy cows	NA*	Grain	4.5	3.0	Stoddard (1969)
			5.5	3.5	
Ewes	18	Hay	Ad lib	113.2	Forbes (1972)
			66% ad lib	101.7	
Dairy cows	11	Silage	Ad lib	22.2	Harb et al. (1985)
			80% ad lib	16.7	

* NA Data not available

The rate of feed consumption has been observed to increase as the meal size increases under ad libitum feeding conditions where specific measurements of meal size and time of feeding have been taken, e.g. Chase et al. (1976). Five steers were individually fed a complete diet available under ad libitum access throughout the day. Eating rate was observed to vary with meal size, whereby meal sizes of 65 g, 390 g, 776 g and 1037 g were consumed at a rate of 17.6 g/minute, 30.4 g/minute, 40.3 g/minutes and 48.7 g/minute respectively. Meals of greater than 1200 g were consumed at a rate of 41.9 g/minute. Therefore the rate of consumption tended to increase with meal size up to 1200 g when the rate of consumption began to decline.

However, determination of the influence of the quantity of feed allocated on the rate of consumption is probably more valid under restricted feeding conditions where discrete meals are allocated at various levels of allocation.

Time of access and frequency of feeding

The quantity of feed allocated may, in effect, be a function of access time (e.g. Campling, 1966b). Therefore, the rate of feed consumption (and consequent effects on the variation in feed intake) may be influenced by time of access. A significant reduction in the mean intake of silage from 8.77 to 8.14 kg organic matter/day ($P < 0.01$) was observed in 14 pregnant British Friesian heifers (18 months old and of mean liveweight 348 kg) when the access time to silage was reduced from 5 hours/day to 3 hours/day respectively (Leaver and Yarrow, 1977). The space allowance at the silage pit was the same during both experimental periods, i.e. 0.5 m/head. The coefficients of variation of silage intake were 9.0% and 15.4% for 5 hours and 3 hours of access respectively, which indicated a larger variation in individual silage intake in the group of heifers under 3 hours access compared with 5 hours access. Indeed, the authors emphasised the importance with any method of restriction, of not only monitoring changes in mean intake but also examining the effects of between animal variation. The rates of silage consumption were 47.5 g organic matter/minute and 53.9 g organic matter/minute for 5 hours and 3 hours access respectively. The difference in the rate of consumption (6.4 g OM/minute) was statistically significant ($P < 0.05$). The measurements of intake and the behavioural observations were taken after an 8-day introductory period.

Therefore, the heifers probably adapted, during the 8-day introductory period, to the restrictions in access to the silage (i.e. 3 hours/day compared with 5 hours) by significantly increasing their rate of silage consumption. The increased rate of consumption possibly contributed to the larger variation in silage intake under 3 hours of access compared with 5 hours of access.

The quantity of feed consumed is usually reduced by restricting the time of access to the feed and the extent of the reduction usually depends on the composition of the ration (Broster et al., 1978). Under conditions of full 24-hour voluntary access to silage (Wilson and Flynn, 1974), it was observed that beef cows usually consumed their daily maximum voluntary intake in about 6 hours. Nevertheless, when the time of access to silage was reduced from 24 hours to 5 hours using 3 dry dairy cows (Campling, 1966b), the voluntary intake of silage decreased from 9.9 kg DM to 7.5 kg DM and the rates of silage consumption improved from 58.1 minutes/kg DM to 32.3 minutes/kg DM under 24 hours access and 5 hour access respectively. Under more restricted conditions of access to roughage feeds, intake is likely to be regulated by physical feedback mechanisms.

The influence of the composition of the ration on the effect of access time on feed intake was observed by Bines and Davey (1970). Two complete diets, which differed in the percentage roughage contents (diet 1 contained 50% straw; diet 2 contained 0% straw) were allocated to 2 dry non-pregnant cows. The intake of diet 1 (50% straw) was increased from 12.34 kg DM to 12.95 kg DM (increase of 5%) for 5 hour and 24 hour access respectively. The intake of diet 2 (0% straw) was increased from 8.98 kg DM to 13.31 kg DM (increase of 48%) for 5 hours and 24 hours access respectively. The rates of feed consumption were not measured. Larger increases in intake of high concentrate rations, compared with roughage rations, by extending the time of access may be expected due to reduced influence of metabolic feedback mechanisms which may have inhibited individual feed intake when large quantities of concentrate feeds were offered for only a short period of time each day.

Other examples of the influence of time of access on feed intake are given by Freer et al. (1962) and Harb and Campling (1983) where reduction in the time of access was observed to reduce hay and silage intake respectively.

Therefore, time of access to feed has been observed to influence

the quantity of feed consumed and there is evidence that rate of feed consumption is also affected. It is possible then, that a larger variation in individual feed intake in a group feeding situation may be observed (and indeed was observed by Leaver and Yarrow (1977)) when the time of access to the feed is restricted, which is probably mediated through effects on the rate of consumption as well as the reduced quantity of feed which can, in effect, be consumed. Reduction of the time of access of 14 British Friesian heifers to maize silage from 5 hours to 3 hours significantly reduced the mean intake of silage from 8.77 kg OM/day to 8.14 kg OM/day ($P < 0.01$). The coefficients of variation for organic matter intake increased from 9.0% to 15.4% respectively and the rate of consumption increased from 47.5 to 53.9 g OM/minute respectively.

The frequency of feed allocation is related to access time and thereby to the quantity of feed which can, in effect, be consumed each day. If a constant allocation of concentrate feed is offered in small meals several times during the day, it is possible that the coefficient of variation of intake will be larger compared with allocation of the same total quantity in, for example, one or two meals where relatively larger quantities of concentrate are offered. This trend may be mediated through effects on the rate of consumption. After a period of adjustment, the rate of feed consumption may be expected to increase when several small meals are given during the day compared with one or two large meals.

The influence of frequency of feeding on the rate of consumption of silage (20 kg/day) and hay (6 kg/day) was investigated using only two dry, non-pregnant dairy cows which were individually fed (Suzuki et al., 1969), in two, three, four or five meals per day. The observations were taken after a preliminary period of only 3 days which may account for the absence of any influence on the rate of consumption by manipulating the frequency of feeding.

Gill and Castle (1983) observed a significant deterioration in the mean eating rate in four dry, pregnant dairy cows allocated 5 kg concentrates/head/day in either two meals (at 05.30 and 14.30 h) or twenty-two meals (every hour except 06.00 and 15.00 h) from 19.2 minutes/kg DM to 22.2 minutes/kg DM ($P < 0.05$) respectively. Silage was available on an ad libitum basis for approximately 20 hours per day.

Nevertheless, access time and frequency of feeding are closely

related and it is possible that they may exert an influence on the rate of feed consumption and thereby effect the variation in individual feed intake in a group.

The influence of frequently feeding a given quantity of a pelleted compound feed on the variation in individual intake in a group of suckler cows was investigated in Experiment 5.2.

Substitution Rate

The intake of forage attained by animals under ad libitum access conditions (usually dairy cows, newly-weaned young stock and fattening animals) can be markedly influenced by the provision of concentrate supplements. The change in the intake of the forage produced by a unit change in the intake of the supplement is termed the substitution rate (Broster and Thomas, 1981). The substitution rate is usually negative, i.e. the intake of forage is depressed by the addition of a concentrate supplement and is influenced by the digestibility of the forage on offer (e.g. Leaver, 1973), the conservation method, chemical composition of the forage and by the type (Castle, 1982) and level of the concentrate itself (Broster and Thomas, 1981).

The concept of substitution has important consequences on the response of the animal to concentrate feeding in that the effect on total energy intake may be less than the additional energy supplied by the concentrate. Indeed, at high levels of concentrate intake, further supplementation may produce very little change in the total energy intake if the relationship is curvilinear (Broster and Thomas, 1981). This may occur in early lactation when forage of high digestibility is offered as well as high concentrate inputs (Ekern, 1972).

The forage:concentrate ratio is ultimately affected by the substitution of forage by concentrates which may have deleterious consequences, in dairy cows, on the ratio of acetate to propionate in the rumen with possible acidosis and low milk fat problems (e.g. Bines, 1979).

Various substitution rates have been defined, e.g. 1 kg of concentrate added to a forage will depress the intake of a poor quality forage by 0.4 kg DM and up to 0.8 kg DM for a good quality forage (Broster, 1980). More precise definition of the concentrate supplement, particularly in terms of its protein content, is required before comparisons can be made between defined rates of substitution (Castle, 1982). The substitution rate is, however, usually greater for

high quality roughages (high digestibility) than for low quality roughages (low digestibility) (Leaver, 1973). Indeed, where the quality of the basal diet is poor and of low protein concentration, the addition of small amounts of concentrate will increase roughage intake, unless the protein content of the concentrates is also poor (Bines, 1979). This effect is probably mediated through promotion of cellulolytic microbial activity in the rumen.

The influence of supplementary concentrates on the voluntary intake of barley straw (DOMD 41.7%), hay (DOMD 67.3%) and silage (DOMD 60.3%) by 10 week old British Friesian female calves was observed by Leaver (1973). Three groups of 30 calves were offered ad libitum access (individually fed) to either barley straw or hay or silage. A pelleted barley, groundnut concentrate feed (18% crude protein) was offered at either 1.2 kg, 2.0 kg or 2.8 kg/head/day. The mean intakes were:-

	Intake (kg DM)			
Concentrate allocated (kg/h/day)	1.2	2.0	2.8	Effect of concentrate -
Barley Straw	0.67	0.53	0.45	N.S
Hay	2.08	1.58	1.16	$P < 0.01$
Silage	1.80	1.37	1.08	$P < 0.05$

Additional concentrates significantly depressed the voluntary intake of hay ($P < 0.01$) and silage ($P < 0.05$) which were both of greater DOMD% (67.3% and 60.3%) than the barley straw (41.7%). The voluntary intake of the barley straw, albeit very small quantities, was not influenced by additional concentrate intake. Indeed, an improvement in the intake of the barley straw may have been observed had the crude protein concentration of the concentrate been greater than 18% (e.g. 22-24%).

Further examples of substitution rate are presented in Table 5. The reduction in intake of roughages by additional concentrates was more marked for roughages of higher quality, e.g. maize silage and, in particular, spring grass where the substitution rate was 1.00 (Broster, 1975).

The influence of the type of supplement on the voluntary intake of forage has been studied by Castle (1982) with particular reference to grass silage (Table 6).

Table 5 Reduction in intake of roughages per unit of additional concentrates (kg/kg of DM or OM) given to lactating cows.

Roughage	DOM	DOMD	Substitution rate	Source
Poor hay	44.9%	-	0.17	Marsh et al (1971)
Lucerne hay	NA		0.44	Ward and Kelley (1969)
Dried grass	66.2%	-	0.55	Marsh et al (1971)
Maize silage	-	66.0%	0.63	Phipps and Cramp (1978)
Spring grass	NA		1.00	Broster (1975)

DOM = Digestibility of OM; DOMD = Digestibility of OM in DM

NA = Not available

Table 6 Changes in the intake of silage dry matter with different supplementary feeds (Castle, 1982).

Supplement	Changes in silage intake (kg DM per kg supplement DM)
Hay	-0.84
Barley	-0.51
Dried grass cubes	-0.36
Barley and groundnut	-0.32
Sugar beet pulp	-0.40
Soya	+0.06
Groundnut	+0.13

+ Denotes an increase and - denotes a decrease in intake

Supplements of high starch content (e.g. barley) have a marked effect on silage intake which is probably mediated through the suppression of cellulolytic microbial activity in the rumen due to the depression in the rumen pH brought about by elevated propionate levels. The depression of silage intake brought about by barley was observed to be less marked when groundnut was included in the concentrate ration (depression of 0.32 kg DM per kg supplement DM) which suggests that the protein content of the supplement has a beneficial effect on silage intake in addition to the effect that would result from the supplement having a reduced starch content. Indeed, supplements of soya and groundnut meal per se increased the intake of silage and indicates that the supply of protein to dairy cows fed silage based diets may be limiting total dry matter intake and, in effect, milk production.

Animals show a variable response in substitution rate to allocation of additional concentrate supplements. Twenty-four British Friesian cows, 159 days into lactation (Harb and Campling, 1983) individually allocated either 4.6 kg or 7.2 kg of rolled barley per day with access to silage for 2.5 hours/day, indicated a mean substitution rate of 0.5 kg silage DM per kg of barley DM. The range of substitution rates was between a decrease of 2.03 kg silage DM per kg or barley to an increase of 0.2 kg silage DM per kg of barley DM. The coefficient of variation of substitution rate was 131% (i.e. standard deviation of $\pm$ 0.66). The cows were at a similar stage of lactation

and liveweight and it is therefore possible that their potential dry matter intakes would be similar. A considerable difference in the substitution rate was also observed with 22 hour access to silage, where the mean depression in silage intake was 0.53 kg DM per kg of barley. The coefficient of variation was 109%.

Therefore, even although the cows (Harb and Campling, 1983) were individually fed, it may be anticipated that a variable substitution rate would also be observed in a group feeding situation, under otherwise constant feeding conditions. In effect, a large variation in the forage intake (under ad libitum access) may be observed in the group.

Influence of trough space allowance and type of feeding barrier or trough design on feeding behaviour of group fed animals

Competition for food is likely to occur when the feed supply is spatially limited (Wilson, 1975). Under such conditions, individual animals may defend their interests there and may probably be aggressive or change their rate of ingestion of the feed in order to obtain as much food as they want or need (Metz, 1983).

Group feeding conditions in housed situations, or indeed trough feeding at grass, where an adequate quantity of feed may be available in a limited area and the number of competitors is potentially high, have created unique conditions for feed competition in the ethological sense (Wilson, 1975).

Spatial parameters which influence competition for feed in a group feeding situations have been defined as the total feeding space available and the physical structure of the feeding area (Metz, 1983). Where the trough space allowance is generous such that all the animals can consume the feed at one time (Cermak, 1984), the food supplied will be more dispersed and competition for the food will be reduced (Metz, 1983) compared with conditions which prevent the animals from eating at one time, i.e. reduced trough space (Cermak, 1984). The critical length of the trough below which competition will occur will depend on the length of time that the feed is in the trough. The presence of trough divisions may affect the eating behaviour of submissive animals, enabling them to eat for a longer time (e.g. Bouissou and Signoret, 1971).

Trough space allowance

Definitions of trough space allowances are influenced by the quantity of feed which is allocated and the time during which it is available. A more generous space allowance is required under restricted feeding compared with ad libitum feeding conditions (Scottish Agricultural Colleges Farm Management Handbook 1984/1985). Examples of trough space allowances are presented in Table 7.

Table 7 Trough spaces allowance for cattle and sheep (from Farm Management Handbook SCAC 1984/85)

Cattle

Controlled feeding	Allowance (mm/head)
Cows	600-750
Store cattle	450-550
Finishing cattle	450-650
Ad libitum bunker feeding	100-200
Self-feed silage	150-250

Sheep

Ewe hogg (23-32kg)	300
Ewe	450-500

The relationship between trough space allowance and feeding behaviour has been experimentally investigated, usually with dairy cattle. Konggaard (1983) and Cermak (1984) have both recommended 700 mm trough space allowance for cows allocated feeds in restricted quantities at a feed bunker (i.e. trough/manger). The minimum space needed if cattle are fed complete diets ad libitum or have free access to a basal ration of roughages and concentrates allocated elsewhere, has not yet been defined (Konggaard, 1983).

Allocation of good quality hay on an ad libitum basis to 17 dairy heifers (Metz and Mekking, 1978, cited by Metz, 1983) from 17 feeding spaces (assumed to be 700 mm/head) or from 6 feeding spaces (when all the animals were prevented from eating at the same time) resulted in extra aggression in the herd. There was an increased number of chasings away from the feeding rack when the number of feeding spaces was reduced. Low ranking heifers were observed to eat for shorter periods when the number of feeding spaces was reduced to 6 and it was assumed that, in effect, food intake was reduced in these heifers, even although this was not measured. Indeed, the low ranking heifers may have compensated by increasing their rate of hay consumption and, consequently, their mean hay intake may have been similar to the mean hay intake of the more dominant heifers.

Successive reductions of trough space allowance from 500 mm to 100 mm/head (in steps of 100 mm/head) in an experiment with 12 Holstein cows in early lactation (Friend et al., 1977) given continuous access to a complete mixed ration reduced the average daily feed intake (based on herd refusals) from 37.3 kg/head, at 500 mm/head, to 33.2 kg/head at 100 mm/head. The reduction in intake was particularly marked for 100 mm/head space allowance. Time spent at the feed bunker was also reduced under 100 mm/head space allowance to 2.57 ± 0.80 hours per day (compared with 3.82 ± 0.97 hours per day with 500 mm/head space allowance). The correlation coefficients of time spent at the feed bunker and dominance value for 500 mm, 400 mm, 300 mm, 200 mm and 100 mm/head space allowance were 0.46, 0.32, 0.30, 0.67 ($P < 0.05$) and 0.71 ($P < 0.01$) respectively. As competition for feed increased (by reduction in trough space allowance to 200 mm and 100 mm/head) the heifers of greater dominance value spent significantly more time at the feed trough compared with the more subordinate animals in the group. Individual feed intake was not measured and it may be possible that the more subordinate heifers increased their rate of feed consumption and, in effect, consumed similar quantities of feed as the more dominant heifers.

Indeed, if the more subordinate animals do not adapt to reduced feeding space by increasing the rate of feed consumption, the recommended trough space allowance of 100-200 mm/head (SCAC 1984/85, Table 7) for ad libitum bunker feeding of cattle would, therefore, appear (from the results of Friend et al., 1977) to give rise to more competition for feed than is perhaps desirable.

An increase in the rate of maize silage consumption was observed in a group of 20 pregnant Friesian heifers (350 kg liveweight and 17 months old) under conditions of reduced feeding space (Leaver and Yarrow, 1977). The heifers had access to silage for 7 hours per day with a trouch space allowance of either 400 mm or 200 mm. Individual silage intake were measured and the rate of consumption was determined (Table 8).

Table 8 Influence of trough space allowance on maize silage intake and rate of consumption (Leaver and Yarrow, 1977)

Space Allowance (mm)	Silage Intake (kg OM/day) (± S. dev.)	Rate of Consumption (g OM/minute)
400	8.86 ± 0.771	39.7
200	8.35 ± 0.685	52.7
Difference	$P < 0.01$	$P < 0.001$

Reduction in the width of the feed face from 400 mm to 200 mm/head brought about a 4% reduction in silage intake which was statistically significant ($P < 0.01$). 80% of the heifers were able to feed at one time when 400 mm/head allowance compared with 40% of the heifers when the allowance was 200 mm/head. Feeding activity was more evenly distributed throughout the 7 hour access period under 200 mm/head space allowance compared with 400 mm/head space allowance when the feeding activity declined rapidly after the first hour of access.

The rate of silage consumption significantly increased by 33% (from 39.7 to 52.7 g OM/minute) when the space allowance was reduced from 400 mm to 200 mm/head respectively. The coefficients of variation for the silage intake (kg OM) were 8.7% and 8.2% for 400 mm and 200 mm space allowance respectively which indicates that there was little pressure on individuals by restricting feed face width when access to silage was 7 hours. Alteration in the time of access (i.e. reduction

to less than 7 hours) may have promoted a greater range of silage intake by reducing the feed face width, which may have been mediated by an increased rate of silage consumption.

Allocation of a complete diet, on an ad libitum 24 hour basis, to 60 dairy cows under a reduced space allowance (250 mm/cow compared with 680 mm/cow) reduced the eating time to 232 ± 25 minutes per cow from 298 ± 59 minutes/cow (Konggaard, 1983). The quantities of feed consumed in each experimental period were similar (not indicated in text) and the speed of consumption was observed to increase when the feeding space was reduced. Subjective observations indicated that during the first few hours after the feed had been allocated, there was more unrest and aggressive behaviour when the trough space allowance was reduced to 250 mm/cow.

The variation in individual silage intake was observed to particularly increase by reducing the number of mangers from which silage was available to 11 lactating British Friesian cows (mean days in milk 140) by Harb et al. (1985). Silage was offered at a rate of 80% of the quantity which would be consumed under ad libitum access for 7 hours per day from either 11 or 6 mangers (dimensions not available) in two consecutive experimental periods. A pelleted compound feed containing chromic oxide was individually offered, at a rate of 5.86 kg DM/head/day, to the cows in both periods. The mean intakes of silage were 6.5 ± 3.65 kg DM (coefficient of variation 56.2%) and 5.8 ± 5.58 kg DM (coefficient of variation 96.2%) for access from 11 and 6 mangers respectively, and the mean rates of silage consumption were 60 g silage DM/minute and 81 g silage DM/minute respectively. There was an increase in fighting between cows when only 6 mangers were available.

The increased competition between the cows observed in this latter experiment, when the number of mangers from which silage was available was reduced, was therefore illustrated by an increase in the rate of feed consumption by the cows and a substantial increase in the variation in individual silage intakes in the group (coefficient of variation 96.2%). The mean intake of silage was also reduced.

One of the few examples of experimental work with sheep on the influence of trough space allowance on the variation in feed intake was carried out by Kendall et al. (1980). Pregnant Greyface ewes were allocated 252 kg DM/head/day of a pelleted compound feed containing chromic oxide with trough space allowances (measuring both sides) of

either 530, 400 or 330 mm/head during three consecutive experimental periods, each of eight days duration. The coefficients of variation for faecal chromium concentrations (from grab samples) were 36.7%, 37.2% and 42.9% respectively, which suggested that the coefficient of variation increased with restrictions of trough space (i.e. 330 mm/head). A more marked effect was observed when only 84 g DM/head/day of the compound feed was allocated in a further experimental period when the coefficients of variation of faecal chromium concentration were 45.9%, 57.8% and 73.6% for trough space allowances of 540, 400 and 330 mm/head respectively. The influence of trough space allowance on the variation in compound feed intake (as indicated by faecal chromium concentration) was therefore more acute under more restricted feeding conditions.

Therefore, a reduction in spatial limitations in terms of trough space allowance does promote increased competition for the feed available which is demonstrated by dominant animals spending greater time at the feeding area, an increased rate of feed consumption and greater variation in individual feed intake in the group. The adequacy of trough space allowance under conditions of restricted feeding is particularly important to ensure a sufficiently uniform intake of feed by the animals in the group.

Influence of type of feeding barrier or trough design on feeding behaviour

For a given trough space/feeding space allowance the design of the feeding place (e.g. trough, manger, box, fixed barrier) is likely to determine how much the subordinate individual is protected from attack while eating and thus whether or not true competition is allowed (Metz, 1983). Physical barriers between animals at the given feeding place may strongly affect the competition process and it is possible to diminish the number of aggressive interactions during feeding by modifications of the feeding place (Metz, 1983).

Work by Bouissou (1970), cited by Bryant (1975), indicated how various types of division of a feeding trough can influence the time spent feeding by a subordinate animal in the presence of a dominant animal. For example, when feed from the trough was available and there was no division along the trough, the dominant cow consumed feed for 2 minutes 57 seconds. The subordinate cows (in the paired encounter) consumed feed for only 7 seconds. When various physical divisions were

alternately put in place along the trough, the subordinate cow consumed feed for a greater period, e.g. a simple horizontal metal strip across the trough enabled the subordinate cow to consume feed for 1 minute and 24 seconds (dominant cow 2 minutes 58 seconds).

Further examples of this effect were observed by Metz and Mekking (1978) when 17 heifers were fed concentrates either at a feeding rack (no divisions between animals) or in feed cubicles (divisions between animals). In the cubicles eating time of the low-ranking animals was similar to that of the dominant animals (e.g. 10 minutes and 13 minutes respectively). When the concentrates were offered from the feed rack, the dominant animals consumed the concentrate allocation for 10 to 15 mninutes, compared with the low ranking animals which consumed concentrates for only 1 to 6 minutes. Again, the subordinate animals may have adapted to the situation by increasing their rates of feed consumption and, in effect, have consumed similar quantities as the dominant animals. Very little quantitative work has been carried out on the influence of the design of the feeding place on feeding behaviour (in terms of rates of consumption and variation in feed intake).

Examples of feed bunker (i.e. trough or mangers) designs include the feeding box, the neck rail, the tombstone barrier, the locking gates barrier and diagonal or vertical bars along a barrier (e.g. Poldenvale equipment). If partition between the feed bunker and the standing area consists of a neck bar only, dominant animals are more likely to disturb neighbouring, and possibly more subordinate, animals (Konggaard, 1983). Consequently, younger animals and those of lower rank order may be reluctant to eat when the more dominant animals are present.

A tombstone arrangement allows some physical separation of the animals and may encourage the more subordinate animals to consume their feed in the presence of more dominant animals. Feed barriers with diagonal or vertical bars may have a similar effect. However, fixed feeding barriers have been criticised (Zappavigna, 1983) because of the possibility of attacks by aggressive animals on the weaker ones.

An effective solution, in terms of preventing dominant/subordinate interactions between the animals, has been suggested by Konggaard (1983) and is the locking-gate system of feed barriers where the animals are locked up while restricted amounts of feed are being offered. In order to make full use of such an expensive barrier, it is

indicated that a treatment area for insemination or blood sampling or pregnancy checks, for example, is also provided .

The variation in individual intake of a bulky complete diet by lactating ewes, as influenced by a neck rail barrier, or an oval feedring (Poldenvale) or ordinary troughs, was investigated in Experiment 2.3. Allocation of a compound feed to suckler cows from cattle troughs or a feedring was carried out in Experiment 5.1 to determine the variation in individual compound feed intake by each method.

GENERAL OBJECTIVES OF THESIS

Studies of feed intake and feeding behaviour have tended to examine parameters, e.g. feed intake, time spent feeding, consumption rate under individual feeding conditions where feeds are usually allocated under ad libitum access for 20-24 hours (e.g. extensive work by Castle and co-authors on silage intake at the Hannah Research Institute). Studies of individual feed intake in group feeding situations which have been conducted (e.g. Foot and Russel, 1973) have tended to use small numbers of animals where individual feed intake has been assessed by complete faecal collection methods.

Feeds are allocated on a group basis under either ad libitum (usually forages) or restricted (usually compound feeds) conditions with the assumption that the animals in the group will consume their voluntary intake of forages, for example, or maximum intake during the given time of access, and a uniform intake of restricted feeds, i.e. compound feeds, respectively. Uniform individual intake of a restricted compound feed in a group of animals of similar physiological demands (in terms of metabolisable energy for maintenance and production) is particularly important to ensure an adequate intake of metabolisable energy and protein (and minerals) when either low quality or high quality forages are also on offer. The intake of low quality roughages, offered under ad libitum access, may be reduced if the animal consumes inadequate quantities of compound feed such that only small quantities of metabolisable energy, and particularly protein, are supplied to the rumen, thereby reducing the scope of microbial fermentation. Indeed, should the intake of the compound feed by several animals in the group be much larger than the mean compound feed intake, where high quality forages are also allocated to the group under ad libitum access, the forage component of the diet may be substituted by the compound feed intake. Therefore, it is possible that the total metabolisable energy intake of the animal is not improved by allocation of compound feeds. The substitution of forages by concentrates may also have a deleterious effect on milk composition.

Uniform intake of the compound feed allocated to the group of animals may also ensure an adequate intake of, for example, mineral inclusion in the compound feed, such as magnesium, which may have been incorporated into the compound feed as a prophylactic treatment against hypomagnesaemic tetany. Indeed, an inadequate intake of other

minerals, such as potassium, manganese, zinc (Baile and Forbes, 1974) may depress total feed intake. Growth promoting substances may also be incorporated into compound feeds at a particular rate of inclusion and in order to produce a growth promoting effect, the compound feed will need to be consumed in appropriate, and often well-defined, amounts by the animals in the group, otherwise toxicity might arise.

Examination of the factors which influence the variation in feed intake in group feeding situations is particularly relevant to ensure that animals in a group obtain an adequate amount of feed, as under - or over-feeding may results in inefficiencies of food utilisation. It may be possible to manipulate these factors to achieve uniform individual feed intake by a group of animals.

In practical group feeding conditions, a large number of animals may be involved which is likely to prohibit the use of complete faecal collections in order to assess individual feed intake. The applicability of assessing feed intake from the concentrations of indigestible markers in grab samples was investigated in Section 1 to establish an appropriate technique for dealing with large numbers of animals.

Various possible factors which may influence intake in group feeding situations were examined in the experimental work (Sections 2, 3, 4 and 5), e.g. physical form of feed, quantity allocated (time of access, frequency of feeding), palatability, type of feed presentation, parasitological influences, the possible effects of which have been discussed in the General Introduction and Literature Review.

Assessment of the individual intake of self-feed and easy-feed silage in three dairy herds was also carried out (Section 6) to determine the influence of social hierarchy (i.e. comparison of intake by heifers and cows), liveweight and milk production on individual silage intake under the given on-farm feeding conditions. The individual intake of compound feeds allocated behind feed barriers by the same three herds of dairy cows was examined in Section 7, to assess whether or not uniform intake was achieved. These results may have particular significance in view of out-of-parlour allocation of compound feeds and may ultimately influence decisions about group size or segregation of first-calving heifers from cows in the herd.

GENERAL MATERIALS AND METHODS

Measurement of individual feed intake in group feeding situations

Several methods were employed in this thesis for the measurement of individual feed intake in group feeding situations.

1. Complete faecal collections were undertaken in sheep studies only, usually where the dry matter digestibility of the diet or dietary components (either a complete diet or a more conventional forage and concentrate diet) had been determined separately using wether sheep in cages (Appendix 1). Where the diet consisted of forage and concentrate components, both of which were group fed, an indigestible marker (usually chromium as chromic oxide) was incorporated into the concentrate component, thereby facilitating the determination of the individual intake of the concentrate using the following equation:-
Individual intake of chromic oxide containing food (g) =

$$\frac{\text{Mean daily faecal DM output (g)} \times \text{Concentration of chromium in faeces (g/kgDM)}}{\text{Concentration of chromium in feed (g/kgDM)}} \times \text{Recovery rate}$$

Recovery rate assumed to be unity.

The indigestible fraction of the individual concentrate intake was subsequently calculated (the dry matter digestibility coefficient of the concentrate had been determined separately using wether sheep), thereby facilitating the apportionment of the total measured faeces output into the components from individual concentrate and forage intake respectively. The indigestible fraction from the individual forage intake was therefore used to determine the individual intake of forage using the known, previously established dry matter digestibility coefficient:-

$$\text{Intake of forage dry matter (kg)} = \frac{\text{Faeces dry matter from forage (kg)}}{\text{1-dry matter digestibility coefficient}}$$

2. Complete faecal collections were not practicable in every group feeding situation where the aim was, for example, to determine the individual intake of group fed silage in a commercial dairy herd. In these situations each animal received a known input of chromic oxide incorporated into the concentrate ration which was allocated individually to the animals in known quantities, thereby facilitating an estimation of total faeces output from the concentration of chromium in faecal grab samples, using the equation:-

$$\text{Faecal dry matter output (kg)} = \frac{\text{Weight of chromium given (g)}}{\text{Mean concentration of chromium in faeces (g/kgDM)}} \times \text{Recovery rate}$$

Recovery rate asssumed to be unity.

The total faeces output per animal was apportioned to that from concentrates, the individual allocation and dry matter digestibility of which were known, and that from the component of the diet under investigation, e.g. group fed silage. The individual silage intake was thence calculated using the dry matter digestibility coefficient of the silage $\frac{\text{(Faeces DM from silage)}}{\text{(1 - DMD coefficient)}}$.

Faecal grab samples were taken at the same time each day during the collection period, which usually lasted between five and seven days. However, in commercial situations, e.g. dairy herds, it was usually impractical to take more than one or two grab samples, particularly under self-feed silage conditions where the silage intake behaviour of the animals may have been disturbed by more frequent handling in order to obtain rectal grab samples of faeces.

Preliminary work with suckler cows was carried out to investigate the correlation of faecal chromium concentrations of one or two grab samples compared with combinations of 15 to 35 grab samples over a seven day collection period (to be described in Experiment 1.3.1). The determined correlation coefficient, for example, between the faecal chromium concentrations of single grab samples compared with 35 samples over a seven day collection period was 0.966 ($n=16$, $P< 0.001$). This indicated that where determination of the faecal chromium concentration was required, there was no special advantage in obtaining 35 faecal

grab samples compared with one faecal grab sample.

This result is similar to that recorded by Kendall (1977) who investigated the relationship between the concentration of chromic oxide in a single grab sample of faeces and the estimated feedblock intake of a group of 22 suckler cows, derived from the chromium content of a 24-hour total collection of faeces. The individual faecal chromium concentrations of the faecal grab samples were positively correlated ($r = 0.93$, $P < 0.001$) with feedblock intakes estimated from 24-hour collection. It was concluded that the chromium content of single rectal grab samples were useful indicators of the relative intakes of the chromic oxide-containing feeds.

3. Individual feed intake in group feeding situations was also estimated from established calibration equations in the form $y = a + mx$, which related feed intake (y) to faecal chromium concentrations (x) from grab samples. The diet under investigation was individually allocated at various levels anticipated to include the possible range of dry matter intake which may be observed when the same or a similar group of animals was group fed. The animals were also given a constant quantity of chromic oxide per day over a period of usually 7-10 days, and faecal grab samples were taken during and/or towards the end of the 7-10 day period. The chromium in the faecal grab samples was thereby differentially diluted according to the various feed input levels. Calibration equations were then computed between the given inputs of feed under investigation (y) and the corresponding faecal chromium concentrations from one or more grab samples (x). In a subsequent experimental period, the same or a similar larger group of animals was allocated the diet under investigation on a group basis, and individually given a constant quantity of chromic oxide for a period of 7-10 days. Faecal grab samples were taken during or towards the end of the 7-10 day period. The faecal chromium concentrations (x) of the grab samples were then substituted into the established calibration equations ($y = a + mx$) and the individual feed intakes (y) were thence calculated. The use of calibration equations to determine individual feed intake, in group feeding situations, is further described in Experiments 1.4 and 2.3.

Inaccuracies associated with the use of chromic oxide in feed intake studies

The use of chromic oxide in nutritional studies has been reviewed by Kotb and Luckey (1972) and Kendall (1977). Where feed intake has been determined either by using chromic oxide in conjunction with a complete faecal collection method or in methods involving grab sampling of faeces, the results need to be interpreted with some caution in view of the errors associated with the use of chromic oxide.

Where the collection of chromic oxide is fully quantitative in a complete faeces collection, or where the faeces DM output is estimated from the concentration of the chromium in rectal grab samples of faeces, the appropriate extrapolation to estimate individual feed intake involves the assumption that the recovery rate of the chromic oxide is 100%.

$$\text{Recovery rate} = \frac{\text{Total weight of chromic oxide excreted in faeces}}{\text{Total weight of chromic oxide given.}}$$

Indeed, this assumption is particularly pertinent where the total weight of chromic oxide given is not known, i.e. where the animals have been group fed the chromic oxide-containing component of the diet. Nevertheless, the need to check, wherever possible, the recovery rate of the chromic oxide of the animals on the experimental treatments has been advocated by Le Du and Penning (1982) in order to adjust the faeces production, if necessary, for recovery rate.

Factors which may contribute to the incomplete (i.e. < 100%) recovery of chromic oxide include (a) an inaccurate estimate of the quantity of chromic oxide given to each animal (if given individually), (b) possible regurgitation of chromic oxide-containing gelatin capsules or chromic oxide-impregnated paper (where used), (c) absorption of soluble chromates, (d) retention of chromic oxide in the alimentary tract, (e) incomplete collection of faeces, (f) losses in the grinding of faecal samples, due to the higher density of chromic oxide compared with faecal DM, which may result in separation (Stevenson, 1962) and (g) analytical errors.

A wide range of recovery rates has been obtained by various authors (Table 9) using different methods of administration of chromic oxide (e.g. impregnated paper, capsules, incorporation into feed). There appear to be inconsistencies in the absolute recovery rate of the chromic oxide which have been influenced by the different methods of chromic oxide administration. Curran et al (1967) concluded that it is preferable to administer chromic oxide in the feed wherever possible in view of the high recovery rates (not significantly different from 100%) achieved when chromic oxide was given in the feed, compared to when given in purchased gelatin capsules.

Estimation of faecal dry matter output from the concentration of chromic oxide in faecal grab samples may be subject to error due to the possible diurnal excretion pattern of chromic oxide which has been recognised by several workers (e.g. Kane et al., 1952; Hardison and Reid, 1953; Hardison et al., 1956; Balch et al., 1957; Wilkinson and Prescott, 1970). Hardison and Reid (1953), for example, found a variation in apparent recovery rate of chromic oxide of 0.55 at 12.00 h to 1.8 at 18.00 h for housed steers which were dosed once daily with 10g of chromic oxide. The diurnal excretion pattern has been attributed to some intrinsic physiological mechanism (Bloom et al., 1957; Edin et al., 1944) rather than the effect of time, frequency or method of dosing in relation to the pattern and level of feed intake, as proposed by Raymond and Minson (1955) and Pigden and Brisson (1956). Indeed, Brisson (1960) suggested the need to define possible sources of variation in chromic oxide excretion for each set of experimental conditions, indicating that the diurnal excretion pattern of chromic oxide is specific to each experiment. Furthermore, where animals have ad libitum access to the forage component of the diet (fresh or conserved) the pattern of forage intake for each animals during the day may well be dissimilar, thereby imposing specific diurnal excretion patterns of chromic oxide for each animal within the experiment.

Le Du and Penning (1982) concluded that the substances used as carriers for the chromic oxide and the patterns of dosing and sampling of the animals need to be designed to minimise or take into account these fluctuations in chromic oxide excretion.

Table 9 Absolute recovery rates of chromic oxide

Animals	Method of administration of chromic oxide	Diet	Absolute recovery rate %	Authors
Wether Sheep	Feed constituent in powder form	Pelleted alfalfa	84.8	Johnson, Dinusson and Bolin (1964)
	Impregnated paper	Pelleted alfalfa	91.3	
Sheep	Chromic oxide dental plaster pellet	Long roughage diets	85–90	Troelsen (1965)
Beef cows	Incorporated into pelleted concentrate	Hay + concs	97.3–103.1 (total faecal collection) 95.4–106.4 (rectal grab samples)	Curran et al (1967)
Beef cows	Two gelatin capsules per head given at 07.15 h and 15.15 h	Hay + concs	82.8–93.5 (total faecal collection) 77.2–109.7 (rectal grab samples)	ditto
Sheep	Two capsules/head dosed once/day at 15.30 h	Grass	83.2–93.5 (total faecal collection)	ditto
Sheep	Incorporated into cubed concentrate given once/day	Grass	90.8–113.9 (complete collection)	ditto

Before the faeces samples are taken, a preliminary dosing period is required to ensure that the chromic oxide has equilibrated throughout the alimentary tract. The time for equilibrium conditions to be attained is influenced by the level of intake and by characteristics of the feed in relation to rate of passage through the digestive tract. Usually a minimum period of seven days is recommended (Le Du and Penning, 1982).

The timing of faeces sampling is therefore critical in influencing the error associated with the subsequent determination of the total faecal output from the faecal chromic oxide concentration. Le Du and Penning (1982) advocate that faecal samples should be taken at a time when the concentration of the chromic oxide is similar to the mean daily value. Lambourne (1957) concluded that an unbiased estimate of the mean chromic oxide marker concentration was obtained by dosing the animals and taking samples of faeces at 9 and 15 hour intervals. Confirmation of this procedure was put forward by Coop and Hill (1962), whereby the chromic oxide concentration was within 1% of the mean concentration, whereas faeces samples taken at two hour intervals showed a diurnal variation of 12% of the mean.

More frequent administration of the chromic oxide serves to reduce or eliminate possible diurnal variation of the marker concentration in the faeces. The concentration of chromic oxide in the faeces of grazing animals was observed to be uniform throughout the day, when the marker was administered in gelatin capsules every four hours (Pigden and Brisson, 1956). However, this frequency of dosing would be impractical without undue disturbances of the animals.

The diurnal variation of faecal chromic oxide excretion therefore introduces a short term error component which influences the accuracy of the estimation of faecal DM output. The diurnal excretion pattern can be attributed to a variety of factors including daily dosing pattern, method of dosing in relation to the pattern and level of feed intake and the physical nature of the diet. The hypothesis put forward by Kane et al. (1952) and Bloom et al. (1957) that the excretion of chromic oxide may be regulated by a physiological mechanism which is independent of feed intake pattern and dosing interval, whereby surplus and unusable substances are removed from the body, may also contribute to the periodicity of chromic oxide excretion. Therefore the diurnal excretion pattern needs to be accounted for in each experiment to enable the faecal DM output, calculated from the chromic oxide

concentration of grab samples, taken at various times, to be adjusted. Selection of sampling times where the chromic oxide concentration of the grab sample is closest to the mean concentration during the day is perhaps more efficient where diurnal excretion curves have been established.

Furthermore, the inter-day variation in chromic oxide excretion may contribute to a possible short term error in the grab sampling technique where faecal DM output is estimated. The day-to-day variation in faecal chromic oxide concentration was between 6.2% and 9.9% (Wilkinson and Prescott, 1970) over a four-day sampling period (two faecal samples per day at 09.15 h and 17.00 h) where Friesian steers were given grass silage ad libitum and two levels of barley (1.8 or 3.6 kgDM/day). Chromic oxide was given in two feeds at 09.00 h and 16.30 h in the form of shredded paper before each meal. Wilkinson and Prescott (1970) advocated the use of as long a sampling period as possible in order to minimise the inter-day variation in chromic oxide excretion and recovery.

It has been postulated (Kameoka et al. 1956) that the inter-day variation in faecal chromium excretion was a normal occurrence and may be due to possible variation in the faecal dry matter output (range of 10-15%). Also the possible accumulation of chromic oxide in some parts of the digestive tract of ruminants with consequent irregular excretion may produce abnormal concentrations from day to day.

Conclusion

In view of the short term errors (diurnal variation and inter-day variation in faecal output due to variation in faecal chromic oxide concentration) and long term errors (absolute recovery of chromic oxide may well be <100%) associated with the use of chromic oxide to estimate individual feed intake (by complete faecal collections or grab sampling techniques), it is necessary to minimise the potential sources of error in the experimental design. Therefore, for example, selection of the most efficacious method of administering chromic oxide and the use of grab sampling times which make an allowance for the periodicity of chromic oxide excretion, as well as the adoption of a sampling period over as many days as is possible, may reduce the inherent errors of the technique. Indeed, Le Du and Penning (1982) concluded that the use of chromic oxide as a marker will usually estimate faeces output to within ±6%.

In this thesis, in order to make an allowance for the periodicity of chromic oxide excretion where repeated observations have been made over a period of time, it has been the practice for faecal grab samples to be taken at a constant time (or times) each day, from all the animals in a particular experiment.

Where the total intake of feed (the individual intake of which was being determined) by the group was known, it was possible to apportion the total intake to individual animals in relation to their respective faecal chromium concentrations, and thereby remove the sources of error associated with using chromium as an indigestible marker when faecal grab samples were taken (Appendix 3).

Possible alternative faecal markers to chromium, particularly those which are normally included, or naturally occurring in the diets of ruminants, e.g. magnesium as magnesium oxide and copper as copper sulphate, were investigated in Experiment 1.3.3 with respect to their ability to illustrate possible variations in feed intake between animals in a group feeding situation.

SECTION 1 ESTABLISHMENT OF ANIMAL TECHNIQUE

Experiment 1.1 Uniformity of dry matter digestibility of feeds between animals assessed by complete collection of faeces

Introduction

Determination of individual intake in group feeding situations, either directly from complete faecal collection or indirectly using indigestible markers (to estimate total faeces dry matter produced), involve the assumption that the between-animal variation in digestibility is minimal. In Experiment 1.1.1 - 1.1.6, the uniformity of dry matter digestibility between animals was investigated using either wether sheep or Friesian steers in metabolism cages, where the animals were allocated various types of feed and complete faecal collections were carried out.

Materials and Methods

The experimental procedure involved individual allocation of the respective rations in two equal feeds (at 07.30 h and 16.00 h) for a six-day preliminary period, followed by a six-day complete faecal collection period. At the end of the collection period the total faeces produced by each animal was weighed and a subsample was taken which was dried, thereby permitting an estimation of the total faeces dry matter produced over the collection period.

In Experiment 1.1.1 twenty wether sheep were individually allocated 1 kg FM of dried grass (0.91 kg DM) per day. The dry matter digestibility of the dried grass was estimated, as previously indicated, and the experimental procedure was completely repeated with the same group of sheep, thus producing two parallel sets of data of the dry matter digestibility of dried grass.

In Experiment 1.1.2, eight wether sheep were individually allocated 0.33 kg FM of dried grass (0.31 kg DM) and 0.67 kg FM of a proprietary dairy concentrate (0.58 kg DM) per day. The overall diet dry matter digestibility was determined and the dry matter digestibility of the dairy concentrate was estimated by difference as the dry matter digestibility of the dried grass had been previously established in Experiment 1.1.1.

In both Experiments 1.1.3 and 1.1.4 six wether sheep were

individually allocated 3 kg FM of silage A or silage B (0.71 kg DM and 0.79 kg DM respectively). The dry matter digestibility of each silage was determined by complete faecal collection.

In Experiment 1.1.5 fifteen wether sheep were individually allocated a complete ration which consisted of 0.26 kg FM barley husk siftings, 0.22 kg FM of unmolassed sugar beet pulp and 0.48 kg FM of molassed sugar beet pulp (0.96 kg FM in total per day equivalent to 0.85 kg DM per head per day). The dry matter digestibility of the diet was determined as previously indicated.

In Experiment 1.1.6 ten Friesian steers (150 kg liveweight) were individually allocated 4 kg FM/head/day in two equal feeds of a pelleted complete diet (consisting of mainly barley, dried grass and oats). The dry matter digestibility of the pelleted feed was determined by complete faecal collection.

Results

The mean dry matter digestibility of the respective feeds, presented in Table 10, ranged from 610.2 $\pm$ 15.26 g/kg for dried grass to 783.0 $\pm$ 7.28 g/kg for silage A. In Experiment 1.1.2, the dry matter digestibility of the dairy concentrate was greater than that of the overall diet dry matter digestibility, which may have been expected as the dry matter digestibility of the dairy concentrate was obtained by difference using a constant value for the dry matter digestibility of the dried grass (i.e. 612.1 g/kg which was the mean of 40 observations).

The distribution of the individual dry matter digestibility figures around the mean was fairly compact for each set of data, with coefficients of variation of 0.93% (silage A) to 6.91% (complete pelleted diet to steers). The relatively larger coefficient of variation of the dairy concentrate (4.43%) was probably the result of the errors associated with the determination of the overall diet dry matter digestibility and the determination of the dry matter digestibility of the dried grass, since the dry matter digestibility of the dairy concentrate had been estimated by difference. The small variation of the determined dry matter digestibility data, within the groups of wether sheep, indicated that the between-animal variation in dry matter digestibility was indeed minimal where feed has been individually offered to animals at a fairly restricted level (i.e. not ad libitum).

Table 10 Mean dry matter digestibility (± S. dev.) of the various feeds under investigation

Experiment	n	Dry matter digestibility (g/kg DM)	S. dev. ±	CV%*
1.1.1 Dried Grass	20	610.2	15.26	2.50
1.1.1 (repeat)	20	613.9	11.37	1.85
1.1.2 Whole diet	8	714.2	22.19	3.11
1.1.2 Dairy conc. (by difference)	8	767.2	33.99	4.43
1.1.3 Silage A	6	783.0	7.28	0.93
1.1.4 Silage B	6	742.8	19.09	2.57
1.1.5 Complete ration	15	695.0	15.08	2.17
1.1.6 Complete pelleted ration (steers)	10	645.0	44.57	6.91

CV%* = Coefficient of variation, defined as the standard deviation divided by the mean of the population.

The relatively larger variation (6.91%) of the determined dry matter digestibility data within the group of Friesian steers may indicate the increased difficulty of undertaking complete faecal collections in cattle where possible errors associated with the complete collection method (e.g. possible loss of faeces) may have contributed to the larger error term.

Discussion

The coefficients of variation of the dry matter digestibilities of the feeds under investigation were between 1% and 7% (although more usually between 1% and 3%) which compares well with the coefficient of variation of dry matter digestibility obtained by Entrocasso (1984) where nine Friesian steers were individually allocated 4.2 kg DM/head/day of hay and 2.6 kg DM/head/day of a proprietary beef compound feed. The mean dry matter digestibilty for the overall diet was 590.0 ± 15.34 g/kg and the corresponding coefficient of variation was 2.60%.

The relatively restricted levels of feed allocation in the present experiment, under which the variation in the diet dry matter digestibility between the animals was fairly minimal are comparable with conditions where, for example, concentrate feeds are usually allocated on a restricted basis to a group of animals. However, the between animal variation in dry matter digestibility may increase under more liberal forage feeding conditions (e.g. ad libitum self-feed silage) where the possibility of a large range of dry matter intakes may exist, which may produce widely different individual dry matter digestibilities within the group, due to a level of intake effect.

The coefficients of variation of 1-7% represent the minimal error caused by between-animal differences where there are no associated faecal sampling and no analytical errors (other than dry matter determination) in the complete faecal collection technique used in the present experiment. The use of chromic oxide as an indigestible marker in feed intake and digestibility studies has errors associated with faecal sampling and laboratory analyses, thereby compounding and increasing the basal error of the experiment compared to when faeces are completely collected. The determination of the basal variation of faecal chromium concentration of grab samples will be described in Experiment 1.3.1, where a group of suckler cows were individually given a constant diet of hay and a barley/urea compound containing chromic oxide. The coefficients of variation of faecal chromium concentration obtained were between 8.7% and 13.6% depending on the frequency of grab samples which represents the basal errors associated with faecal sampling and analytical method.

When animals are group fed concentrates, coefficients of variation of concentrate feed intake of, for example, 33.0% to 59.1% have been obtained in ewes (Kendall et al., 1980) of which less than 3% is

likely to be caused by basal between-animal variations. The variation in concentrate feed intake in the group of animals was therefore well described by the coefficients of variation of 33.0 - 59.1% in the latter example.

Experiment 1.2 Comparison between the ability of single faecal grab samples and measured outputs of faeces dry matter to accurately determine the faecal concentration of chromium, derived from dietary chromic oxide, in sheep

Introduction

The relationship between the concentration of chromium in single grab samples of faeces and the concentration of chromium and total faecal output from complete faecal collections in a group feeding situation can be readily determined with sheep which are more suitable for complete faecal collections than cattle. In the present experiment, complete faecal collections were conducted with two groups of ewes, fitted with harnesses and nylon 1 mm mesh collection bags, with two different methods of administration of dietary chromic oxide. The ewes in Group A were each given the same quantity of chromic oxide once per day, in gelatin capsules. The ewes in Group B consumed different quantities of chromic oxide as they were allocated, under group feeding conditions, a pelleted compound feed in which chromic oxide was incorporated.

Materials and Methods

Two groups of mainly Greyface ewes (Group A n = 20, three weeks into lactation with twin lambs at foot and Group B n = 16, dry, non-pregnant ewes) were each housed separately in open fronted accommodation with straw-bedded areas of $82m^2$ and $20m^2$ respectively. The ewes in Group A were allocated 2.35 kg FM/head/day of a complete ration (consisting of 1.29 kg of molassed sugar beet pulp, 0.63 kg of barley husk siftings and 0.43 kg of soya bean meal), in two approximately equal feeds at 07.30 h and 16.00 h, in three troughs behind a barrier (without impedence of dividing bars) allowing 0.43 m/head. After six days on the complete ration, the ewes in group A were each given one chromic oxide capsule per day at 09.00 h for six days.

The ewes in Group B were allocated, on a group basis at 07.30 h,

0.63 kg FM of a pelleted compounded ewe feed in two troughs, allowing 0.68 m/head trough space (measured on both sides). The pelleted compound feed contained chromic oxide at a rate of 2.5 kg/tonne of fresh matter. Additionally 0.66 kg FM/head of dried grass was individually given to the ewes at 16.00 h. The proximate analyses of the feeds offered in the present experiment are shown in Table 11.

Table 11 Proximate analyses of the complete ration (Group A), the pelleted compound feed and dried grass (Group B)

	Complete ration	Pelleted compound feed	Dried Grass
Dry matter (g/kg)	888	879	923
Composition of dry matter (g/kg)			
Crude Protein	160	174	134
Crude Fibre	154	159	268
Ether Extract	11	25	32
Soluble carbohydrate	601	548	507
Ash	74	94	73
Chromium	-	0.570	-

After six days on their respective rations, harnesses and 1 mm mesh nylon faecal collecting bags were fitted to each of the ewes in Group A and Group B. Complete faeces collections were made from each ewe during the following six days. The faeces were emptied from the collecting bags into individual plastic sacks, twice per day for Group A and once per day for Group B, and the faeces samples from each ewe were amalgamated over the collection period. Additionally, on day 6 of the collection period for each group, faecal grab samples per rectum were taken from each ewe at 09.00 h. The faeces samples from each ewe from the complete collection were weighed at the end of the collection period, mixed and subsampled prior to being dried and subsequently milled before analysis for chromium. The single faecal grab samples were dried, milled and analysed for chromium.

Correlation coefficients were computed between the faecal chromium concentrations of the single grab samples and (i) the faecal chromium

concentration of the total faeces output and (ii) the total faecal dry matter collected per day over the collection period, for Group A and Group B respectively.

Results

The ewes from both Group A and Group B came forward readily to consume their rations. The ewes from Group A usually consumed their allocation of the complete ration within 25-30 minutes. The ewes from Group B usually consumed their allocation of the pelleted compound ewe feed within 4-5 minutes. The dried grass allocation was usually consumed within 10-15 minutes. There were no obvious differences in the behaviour between the ewes within each group at feeding time.

The individual and mean faecal chromium concentrations from single grab samples and complete faecal collection and the corresponding faecal dry matter output for ewes in Group A and Group B are presented in Table 12 and Table 13 respectively.

In Group A, the mean faecal chromium concentration from single grab samples and complete faecal collections were 0.87 g/kg DM and 0.61 g/kg DM (n = 19) respectively (ewe 20 was empty when single grab samples were taken). The difference of 0.26 g/kg was statistically significant ($P < 0.01$) and reflects the periodicity of faecal chromium excretion. The faecal dry matter ouput (and extrapolation to individual feed intake) would be overestimated from the chromium concentration of single faecal grab samples compared with that of complete faecal collections. Nevertheless, the correlation coefficient between the faecal chromium concentration of single grab samples and the corresponding chromium concentration of the complete faecal output was 0.629 ($P < 0.01$), suggesting that even although the mean chromium concentrations were significantly different, the relative outputs of feaces would be indicated by the chromium concentration of single grab samples.

Table 12 Individual and mean faecal chromium concentration from single faecal grab samples and complete faecal collection, and faecal output per day, for ewes in Group A

Ewe Number	Faecal chromium concn. (g/kg DM) Single grab sample	Complete faecal collection	Faeces DM output per day (kg)
01	0.76	0.59	0.60
02	1.84	0.71	0.51
03	0.75	0.49	0.61
04	1.10	0.89	0.52
05	0.68	0.59	0.63
06	0.68	0.61	0.68
07	1.05	0.80	0.44
08	1.13	0.71	0.53
09	0.77	0.52	0.57
10	1.59	0.72	0.51
11	0.68	0.67	0.59
12	0.58	0.50	0.88
13	0.83	0.68	0.61
14	0.49	0.45	0.80
15	0.86	0.49	0.72
16	0.65	0.54	0.61
17	0.57	0.51	0.81
18	0.78	0.63	0.57
19	0.74	0.56	0.65
20	-	0.66	0.60
n	19	20 19	20 19
Mean	0.87	0.62 0.61	0.62 0.62
S.dev ±	0.346	0.115 0.117	0.111 0.114
CV%	39.8	18.6 19.2	17.9 18.4

Table 13 Individual and mean faecal chromium concentration from single faecal grab samples and complete faecal collection, and faecal output per day, for ewes in Group B

Ewe No.	Faecal chromium concn. (g/kg DM)		Faeces DM output per day (kg)	
	Single grab samples	Complete faecal collection		
21	0.41	0.52	0.54	
22	0.49	0.59	0.53	
23	-	0.60	0.57	
24	0.43	0.48	0.40	
25	0.39	0.51	0.47	
26	0.35	0.53	0.25	
27	0.36	0.49	0.36	
28	0.47	0.50	0.50	
29	0.51	0.68	0.55	
30	0.37	0.51	0.36	
31	-	0.56	0.25	
32	0.41	0.51	0.36	
33	-	0.52	0.54	
34	0.36	0.55	0.34	
35	0.39	0.53	0.49	
36	0.39	0.54	0.53	
n	13	16	13	16	13
Mean	0.41	0.54	0.53	0.44	0.44
S.dev.±	0.052	0.050	0.052	0.108	0.097
CV%	12.7	9.3	9.8	24.6	22.1

Indeed, the correlation coefficient between the concentration of chromium in one faeces grab sample compared with the corresponding measured output of faeces dry matter was -0.659 ($P < 0.01$), suggesting that the output of faeces dry matter was indicated by the faecal chromium concentration of single grab samples. The ewes in Group A consumed exactly the same quantity of chromic oxide per head (except perhaps where occasional regurgitation of the capsule may have occurred) and therefore a negative correlation coefficient existed between the concentration of chromium in one grab sample and the output of faeces due to a differential dilution effect of the faeces depending on how much feed was consumed (large quantity of feed consumed produced corresponding large output of faeces which diluted the chromium concentration in the faeces to a greater extent than when a relatively smaller quantity of feed was consumed).

In Group B, three of the ewes were empty when single grab samples were taken from the group. Therefore, the mean of the faecal chromium concentration of 13 grab samples (0.41 g/kg) was compared with the mean of the faecal chromium concentration of the corresponding complete faecal collections (0.53 g/kg). The difference of 0.12 g/kg was statistically significant ($P < 0.001$). Faecal dry matter output (and extrapolation to individual feed intake) would be underestimated from the faecal chromium concentration of single grab samples, compared with that of complete collection. The periodicity of faecal chromium excretion was again observed by the difference of 0.12 g/kg between the mean faecal chromium concentration of single grab samples and from complete collection respectively. Indeed, a different chromium excretion pattern has been imposed where the method of administration of chromic oxide in Group B was by incorporation into a pelleted compound feed, which was allocated once daily, compared with the administration of chromic oxide in gelatin capsules (Group A) which were also administered once daily, where the mean faecal chromium concentration from grab samples was significantly greater by 0.26 g/kg than the mean faecal chromium concentration from complete collection. The difference between the mean faecal chromium concentration from grab sampling and complete faecal collections was greater for Group A (chromic oxide in gelatin capsules) than for Group B (chromic oxide in compound feed), even although the pattern of grab sampling was similar in both groups in relation to the timing of administration of chromic oxide. This may have implications for the choice of method of chromic

oxide administration where faecal grab samples are taken, in that estimations of faecal dry matter output from the concentration of chromium in faecal grab samples may be more accurate where chromium is administered in the feed dry matter than where chromium is administered in gelatin capsules.

Nevertheless, the correlation coefficient between the faecal chromium concentrations of single grab samples and the corresponding faecal chromium concentration of completely collected faeces samples was 0.590 ($P < 0.05$) for which the respective mean faecal chromium concentrations were significantly different, again indicating that the relative outputs of faeces would be indicated by the chromium concentration of single grab samples. This was further substantiated by the statistically significant correlation coefficient of 0.698 ($P<0.01$) between the chromium concentration of one faeces grab sample compared with the corresponding output of faeces dry matter. The latter correlation coefficient was positive which is explained by the incorporation of chromic oxide into the pelleted compound feed offered to the ewes in Group B which promoted an increasing concentration of faecal chromium as more of the pelleted compound was consumed (and ewes consumed equivalent quantities of dried grass), therefore producing a positive correlation coefficient between faecal chromium concentration in one grab sample with the corresponding faecal dry matter output.

Discussion

The statistically significant correlation coefficients between the faecal chromium concentrations of single grab samples and (a) the faecal chromium concentration of completely collected faecal samples and (b) the corresponding faecal dry matter output, indicate the potential applicability of single grab samples (and the chromium concentrations thereof) to reflect faecal dry matter output, and consequent extrapolation to individual feed intake.

Nevertheless, the periodicity of faecal chromium excretion (as evidenced by the statistically different mean faecal chromium concentration from single grab samples and complete faecal collection in both Groups A and B) will influence the absolute determination of faecal dry matter output. The total faecal dry matter output may well be under-or-over-estimated where the single grab samples have not been taken at a time which will coincide with the mean daily faecal chromium concentration. However, allowances could be made for this factor, if

the total amount of feed (the individual intake of which is being determined) given to the group were known. An example of this is given in Experiment 5.1 (and Appendix 3).

Experiment 1.3 The intensity of faecal sampling required to indicate faecal dry matter output.

Experiment 1.3.1 The relative accuracy of single grab samples of faeces compared with repeated grab sampling over a period to determine the faecal concentration of chromium derived from a constant input of dietary chromic oxide and variable hay intake in suckler cows.

Introduction

In several experiments in this thesis, particularly those which involved estimating the individual intake of group fed concentrates or forages in commerical dairy herds, it was not possible to carry out complete faecal collections or, indeed, daily grab sampling of faeces over predetermined, possibly lengthy, collection periods. Interference with the intake of the dietary component which was being quantified may have occurred had more regular faecal sampling over a defined collection period taken placed, e.g. dairy cows with access to self-feed ad libitum silage. In these experiments it was hoped that, in order to indirectly estimate total faeces output of each animal, it might be possible to rely on the chromium concentration from single rectal grab samples, where the individual intake of chromic oxide was known.

Calculations of faecal dry matter output, which can be extrapolated to individual feed intake, from estimates of faecal chromium concentration from single rectal grab samples, may be inappropriate due to the errors associated with the use of chromic oxide which would probably be compounded by using only single rectal grab samples. Nevertheless, the concentration of chromium found in single grab samples has been shown to be significantly correlated ($r = 0.93$; $P < 0.001$) with estimates of individual feed intake from complete faecal collections in a group of suckler cows given access to two feedblocks (each containing chromic oxide at 7.89 g/kg DM) and allocated 4 kg FM/head/day of medium quality hay on a group basis (Kendall, 1977).

In Experiment 1.1.1 to 1.1.6 it was established that, under fairly restricted allocations of the respective feeds, the variation between animals in the dry matter digestibility of the individual feeds was low (coefficients of variation usually between 1 and 3%). The ability of the concentration of chromium in faeces grab samples, derived from dietary chromic oxide in group feeding situations, to reliably indicate a differential dilution effect, caused by variation in individual feed intake, depends on the uniformity of chromium excretion when animals are given a constant diet. In Period 1 of the present experiment, the uniformity of chromium excretion was investigated when suckler cows were individually given a constant diet containing chromic oxide.Grab samples were taken at various intensities. A basal level of variation of chromium concentration in the faeces of the group was therefore established.

In Period 2, information was obtained on the required intensity of faeces sampling (per rectum), in individually fed cattle, in order to produce representative faeces samples whose chromium concentration reflects the variation, within the group, of faecal dry matter output and therefore individual feed intake.

Materials and Methods

Sixteen pregnant suckler cows (mainly Hereford x Friesian) of mean liveweight 448 ± 49 kg were tied in individual standings in a byre, where each animal had separate access to a feed trough and hay rack.

In Period 1, each cow was allocated 1.5 kg FM/day of a cubed barley, urea and chromic oxide feed at 07.30 h. Hay was allocated at a rate of 5 kg FM/head/day in two equal feeds at 08.00 h and 16.30 h. The proximate analyses of the feeds are presented in Table 14.

Table 14 Proximate analyses of hay and barley/urea compound

	Hay	Barley/urea compound	
		Period 1	Period 2
Dry matter (g/kg)	845	877	880
Composition of dry matter (g/kg)			
Crude protein	73	234	223
Crude fibre	336	43	41
Ether extract	10	11	4
Sol. carbohydrates	525	652	641
Ash	56	60	91
Chromium	-	4.95	5.78

Table 15 Combinations of faecal grab samples

Samples taken and combined over 7 days	Time of sampling each day				
	07.00h	10.00h	13.00h	16.00h	19.00h
35	+	+	+	+	+
21	+		+		+
7			+		
2 (on 2 consecutive days only)				+	
1 (on one day only)				+	

After a preliminary period of seven days, faecal grab samples were taken per rectum as described in Table 15, for a period of seven days. Where more than one grab sample was taken, the faeces from each sampling time for each respective prerequisite number of grab samples over the collection period, were amalgamated for each animal in polythene bags. At the end of the seven day collection period, the faeces were subsampled, dried and milled prior to analysis for chromium. The single faecal grab samples were dried, milled and analysed for chromium.

In Period 2, the same group of 16 pregnant (mainly Hereford cross) suckler cows (Period 1) were divided into four subgroups such that the four animals in each subgroup had a mean overall liveweight equivalent to the group (n = 16) mean of 447 kg. The cows in each subgroup were individually allocated hay according to liveweight such that 3,4,6 or 7 kg fresh matter/head was offered in two approximately equal portions at 08.00 and 16.00 h in order of increasing liveweight. Additionally, 1.5 kg FM/head of a barley, urea, chromic oxide pelleted compound was given to each animal at 07.30 h. The proximate analyses of the hay and barley urea compound are shown in Table 14.

After a preliminary run-in period of seven days when the cows were allocated their respective rations, faecal grab samples were taken, as shown in Table 15, during the following seven days. The same procedure for the amalgamation of the faeces samples was followed as in Period 1 and, at the end of the seven day period, the faeces samples were dried, milled and analysed for chromium.

Correlation coefficients were computed between the faecal chromium concentrations of single grab samples and the faecal chromium concentrations of the various combinations of grab samples. Additionally, correlation coefficients were computed between the faecal chromium concentrations of a sample which consisted of two amalgamated faeces samples taken at 16.00 h on two consecutive days, with the various other combinations of grab samples.

Results

In Period 1 the barley, urea and chromic oxide pelleted compound was readily consumed by the cows and had usually been completely eaten within 5-10 minutes of being allocated to the animals. The hay component of the ration was also readily consumed by the cows and the allocation at each feed was usually completely eaten within 30 minutes.

The mean faecal chromium concentrations for each of the grab sampling methods in Period 1 are presented in Table 16. The mean faecal chromium concentration from 35 faecal grab samples (2.83 g/kg) was significantly lower than that from 7 grab samples (3.09 g/kg) and 1 grab sample (3.23 g/kg) ($P < 0.05$ and $P < 0.01$ respectively). Similarly the mean faecal chromium concentration from 21 faecal grab samples (2.96 g/kg) was significantly different to that from 1 grab sample (3.23 g/kg, $P < 0.05$). Less frequent grab sampling therefore apparently increased the mean faecal chromium concentration of the faeces, which was almost certainly caused by the periodicity of chromium excretion.

Table 16 Mean faecal chromium concentrations (g/kg DM) for each of the faecal grab sampling methods in Period 1

	Grab samples taken during collection period				
Faecal Cr (g/kg DM)	35	21	7	2	1
	a	b	c	d	e
Mean	2.83	2.96	3.09	2.96	3.23
S. dev.±	0.246	0.279	0.275	0.402	0.348
CV%	8.7	9.4	8.9	13.6	10.8

Means e > b , c > a , $P < 0.05$
e > a , $P < 0.01$

The coefficients of variation of the mean faecal chromium concentrations ranged from 8.7 - 13.6%, which suggests that, within the bounds of experimental error, chromium was fairly uniformly excreted by the animals within the group.

In Period 2 the cows readily consumed their respective allocations of hay and compound feed. There were no refusals of either feed.

The individual and mean faecal chromium concentrations for each frequency of grab sampling during the collection period, for Period 2, are presented in Table 17. The overall mean faecal chromium concentrations ranged from 2.52 - 3.43 g/kg DM. The periodicity of chromium excretion was reflected by the mean faecal chromium concentration from 21 grab samples (2.52 g/kg) (sampled at 07.00 h, 13.00 h and 19.00 h) which was significantly lower than for 7, 2 and 1 grab samples respectively.

The computed correlation coefficients are presented in Table 18. The faecal chromium concentration of the single grab samples of faeces showed a highly significant degree of relationship with the faecal chromium concentration of all the various multiple combinations of grab samples. Similarly the composite of two grab samples, taken at 16.00 h and on two consecutive days, and the faecal chromium concentration thereof was highly significantly correlated with the faecal chromium concentration of the combinations of 35, 21 and 7 grab samples taken over the seven day collection period (0.974, 0.928 and 0.994 respectively). Therefore, even although the mean faecal chromium concentration from 21 grab samples was significantly lower than that from one grab sample, a statistically significant correlation coefficient was apparent.

Table 17 Individual faecal chromium concentration (g/kg DM) for each grab sampling method in Period 2

Cow No.	Hay DM intake (kg)	Grab samples taken during collection period				
		35	21	7	2	1
1	2.54	4.29	3.44	4.75	4.64	5.09
2	2.54	4.47	3.75	4.56	4.32	4.64
3	2.54	4.66	3.98	4.79	4.52	5.02
4	2.54	4.38	3.75	4.98	5.14	5.06
5	3.38	3.20	2.74	3.58	3.81	3.74
6	3.38	3.24	2.73	3.72	3.38	3.89
7	3.38	3.26	2.28	3.64	3.59	3.27
8	3.38	3.40	2.69	3.60	3.79	3.80
9	5.07	2.20	2.14	2.76	2.41	2.59
10	5.07	2.40	2.10	2.97	2.79	2.46
11	5.07	2.14	2.09	2.62	2.53	2.68
12	5.07	2.48	2.14	2.99	2.80	2.82
13	5.92	2.15	2.00	2.60	2.08	2.21
14	5.92	2.35	1.19	2.42	2.27	1.98
15	5.92	2.09	1.95	2.25	2.54	2.66
16	5.92	2.19	1.40	2.69	2.34	2.62
		a	b	c	d	e
Mean		3.06	2.52	3.43	3.31	3.39
S. dev.±		0.945	0.835	0.917	0.974	1.067
CV%		30.9	33.1	26.7	29.4	31.5

Means d > b, e > b $P < 0.05$

c > b $P < 0.01$

Table 18 Correlation of the chromium concentration of single faecal grab samples and a composited sample consisting of two faecal grab samples (taken at 16.00 h on two consecutive days) respectively compared with the chromium concentrations of various multiple combinations of grab samples

	Multiple combinations of grab samples			
	35	21	7	2
Single grab samples	0.966	0.955	0.972	0.968
Composite of two grab samples	0.974	0.928	0.994	(1)

All the coefficients were highly significant ($P < 0.001$)

Furthermore, an examination of the inter-day variation in the faecal chromium excretion was perhaps afforded in the present experiment by consideration of the faecal chromium concentration of a single grab sample with that of the composite of two grab samples (correlation coefficient 0.968, $P < 0.001$).

Discussion

The fairly uniform excretion of faecal chromium between animals given a constant diet in Period 1, as indicated by the coefficient of variation of faecal chromium concentration of 8.7 - 13.6% (depending on grab sampling method) suggests that variation in the faecal chromium concentration between animals each given the same input of chromic oxide, in a group feeding situation, should be representative of the corresponding variation in, for example, forage intakes in the group.

The periodicity of faecal chromium excretion was observed in both Period 1 and Period 2, whereby the mean faecal chromium concentration depended on the particular grab sampling method (e.g. 35 grab samples compared with 7 grab samples over the collection week). The periodicity of faecal chromic oxide excretion may distort any estimations made of faecal dry matter output from the chromic oxide concentration of grab samples of faeces, thereby producing imprecise estimates of the absolute dry matter intake of the feeds being measured. Nevertheless, the relative feed intakes of the animals within the group can be ascertained by indirect calculation of faecal dry matter output from the chromium concentration of faecal grab samples.

The statistical significance ($P < 0.001$) of the correlation coefficients computed between the faecal chromic oxide concentration of one grab sample and the corresponding concentrations of various multiple grab samples (35, 21, 7 and 2 grab samples) taken over the seven day collection period, suggests that use of faecal chromium concentrations from one grab sample (for indirect estimation of faecal dry matter output or to indicate the relative intake of a chromic oxide containing feed within a group) may be as effective as the faecal chromium concentrations from multiple grab samples taken over a predetermined collection period. Similarly, where it was possible to take two grab samples which were subsequently composited, the faecal chromium concentration thereof was closely related to the corresponding concentrations of the multiple grab samples (35, 21 and 7, $P < 0.001$), again indicating the potential of taking infrequent samples of faeces containing chromic oxide, where estimates of faecal dry matter output are required, for example.

The relative accuracy of single rectal grab samples of faeces compared with repeated grab sampling over a period has therefore been established, where it is not possible to collect faeces samples for a

predetermined period or to carry out complete faecal collections. Nevertheless, the periodicity of faecal chromic oxide excretions prohibits the calculation of absolute feed intake from the estimated faecal output. However, the calculated relative quantities of feed intake indicate the variation of feed intake within a group of animals.

Conclusion

The fairly uniform concentration of faecal chromium from grab samples within the group of animals (Period 1) suggests that the overall diet DM digestibility was constant in the group. Illustration of the variation in feed intake, or estimation of dry matter intake, in a group of animals, by chromium dilution in the faeces, involves the assumption that the diet DM digestibility is indeed uniform between the animals in the group.

Experiment 1.3.2 Comparison between the ability of single grab samples of faeces and repeated grab samples over a period to accurately determine the faecal concentration of chromium derived from a constant input of dietary chromic oxide, in suckler cows (Part 1 and Part 2)

Part 1

Introduction

Further to the comparative study in Experiment 1.3.1 between the faecal chromium concentration from single grab samples and repeated grab sampling when suckler cows in pregnancy were given a restricted diet (i.e. below full voluntary intake), the following two experiments were conducted to determine if single grab samples of faeces from animals receiving chromic oxide in the feed would produce faecal chromium concentrations in the faeces which were identical to or could be related to a sample formed by the amalgamation of 21 grab samples over an extended period. However, in the present study the animals in both experiments had full voluntary access to individually offered straw, which may be more applicable to group-feeding situations in that the possible range of straw intake, in a group-feeding situation, may be better simulated than where the animals had restricted access to feed.

The animal experiments from which these data were obtained were conducted for a quite different purpose by Mr. J.P. Alawa within the Animal Husbandry Department of Glasgow University Veterinary School. I am indebted to him for permission to use some of his unpublished data.

Materials and Methods

Twenty suckler cows (mainly Hereford cross) in mid-pregnancy were tied in individual standings in a byre, where each animal had separate access to individual feeding facilities. In five pre-arranged balanced (in terms of liveweight) groups, each of four cows, the animals were allocated the basal diets in one feed at 07.30 h each day, which consisted of 2.25 kg DM of brewers grains (in either the wet or the factory dried form), both with or without 70 g urea. The cows were additionally given 0.17 kg DM of a cubed barley compound which contained chromic oxide, in one feed per day at 07.30 h. Barley straw was individually allocated to the cows on an ad libitum basis and was replenished at 08.30 h, 12.00 h and 16.00 h.

After a 14-day introductory period, faecal grab samples were taken (by J.P. Alawa) on three occasions each day (10.00 h, 13.00 h and 16.00 h) for seven consecutive days. All 21 faeces samples from each cow were amalgamated to give one composite sample, which was analysed for chromium. At 16.00 h on the seventh day, for the purposes of this particular experiment, a further single grab sample of faeces was obtained from each cow, and this was analysed separately for chromium.

Regression relationships were established between the voluntary straw intake and the faecal chromium concentrations of the single grab sample and 21 grab samples respectively.

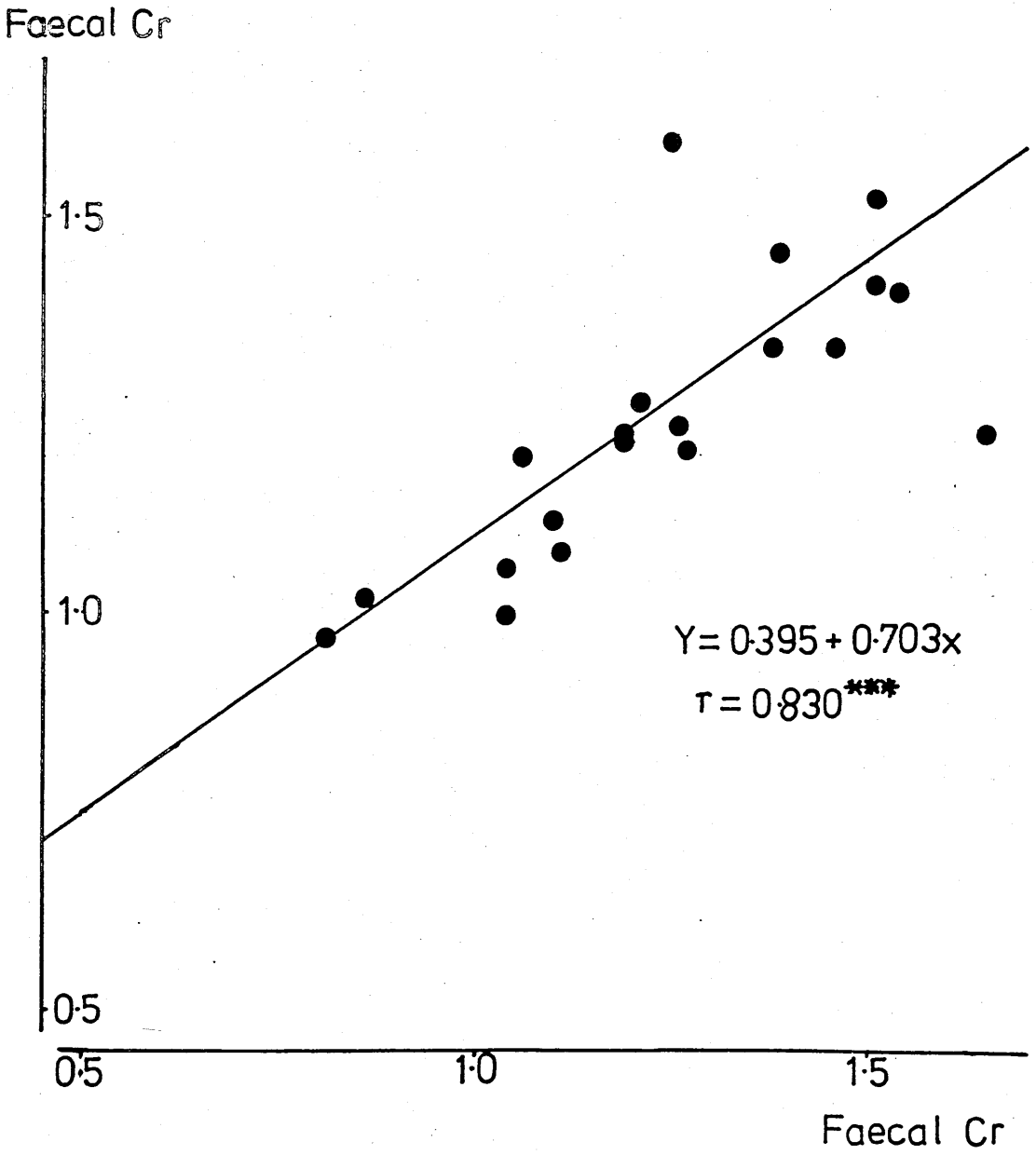
Results

The individual and mean faecal chromium concentrations from one grab sample and 21 grab samples, the voluntary straw intake and the liveweight of the cows are presented in Table 19. The mean faecal chromium concentration from one grab sample was lower (1.21 g/kg) than from 21 grab samples (1.24 g/kg). However, the difference was not statistically significant. Figure 1 shows the relationship between the chromium concentration in the single grab sample of faeces, taken at 16.00 h on day 7(x) and that of the amalgamated 21 samples of faeces (y) obtained over the seven day period. The correlation coefficient was 0.830 and was significant at $P < 0.001$. The regression equation was $y = 0.395 + 0.703x$ (S. dev. 0.1017, $r^2 = 68\%$), which suggests that, although the line of the equation does not cut the intercept at zero, the regression relationship was highly significant. Indeed, the 95% confidence interval would probably include zero. A single grab sample of faeces obtained at 16.00 h therefore underestimates the chromium concentration in the faeces.

Table 19 Individual and mean faecal chromium concentrations (g/kg DM) of single and 21 grab samples of faeces respectively, and the corresponding voluntary straw intake (kg DM) and liveweight data (kg)

Cow	Faecal chromium concn. (g/kg DM)		Voluntary straw intake (kg DM)	Liveweight (kg)
	1 sample 16.00h	21 samples over 7 days		
1	1.19	1.22	6.00	473
2	0.86	1.02	7.31	502
3	1.27	1.21	7.11	556
4	0.81	0.97	8.12	566
6	1.38	1.34	6.35	450
7	1.06	1.20	6.65	492
10	1.11	1.08	6.47	529
11	1.19	1.23	7.62	465
14	1.46	1.34	6.95	506
15	1.21	1.27	7.61	531
18	1.65	1.23	6.46	561
20	1.04	1.06	7.14	480
22	1.51	1.53	6.17	445
24	1.51	1.42	6.18	490
28	1.10	1.12	8.22	551
29	1.04	1.00	8.44	456
38	1.54	1.41	5.51	428
41	1.26	1.24	6.14	421
44	1.25	1.60	6.49	449
48	1.39	1.46	5.62	484
n	20	20	20	20
Mean	1.21	1.25	6.83	492
S.dev†	0.209	0.177	0.85	4.5
CV%	17.3	14.2	12.4	9.1

Figure 1 Regression relationship of the form $y = 0.395 + 0.703\,x$ (*** $P < 0.001$) where y = faecal chromium concentration (g/kg DM) of 21 grab samples and x = faecal chromium concentrations (g/kg DM) of single grab samples.


Faecal Cr
1·5
1·0
0·5
Y= 0·395 + 0·703x
r = 0·830***
0·5
1·0
1·5
Faecal Cr

At the time these results were obtained, the effects of the various dietary treatments on the intake and digestibility of the straw, conducted by J.P.Alawa, had not been evaluated. However, it was expected that any dietary treatment effects would be relatively small. With this qualification, correlation coefficients and regression equations have been derived between the voluntary straw intake (y) and the faecal chromium concentration (x) for both the single sample and the amalgamation of 21 samples. The regression equations were:-

21 samples $y = 10.9 - 3.23\ x$ (S.dev. = 0.645, r^2 = 45.3%)

1 sample $y = 9.99 - 2.61\ x$ (S.dev. = 0.669, r^2 = 41.3%)

Both regression relationships were statistically significant ($P<0.01$) and of comparable accuracy. If each were used to predict straw dry matter intake from faecal chromium concentrations, example results would be:-

(x) Faecal Cr	(y) Predicted straw intake (kg/DM)	
g/kg	21 samples	1 sample
1.0	7.67	7.38
1.5	6.05	6.07
2.0	4.44	6.07

Discussion

It could thus be proposed that in a group feeding situation (as opposed to individual feeding as in this present experiment), repeated faecal sampling can give an accurate estimate of straw intake. If, however, only a single sample of faeces is obtained, the assessment might be less accurate, as the mean faecal chromium concentration may be different to that of 21 grab samples, which is likely to reflect the periodicity of faecal chromium excretion. Allowances could, however, be made for this inaccuracy of prediction if the total amount of feed given (the individual intake of which is being assessed) to the group were known.

As a single sample of faeces produces a chromium concentration which is related to that obtained by repeated sampling, then the calculated individual feed intakes can be summated and then adjusted in proportion to the total feed allocated to the group.

It is interesting to record that for these cows, which were in mid-pregnancy, there was a significant ($P < 0.05$) relationship between cow liveweight kg (x) and voluntary straw intake kg (y), i.e. $y = 2.54 + 0.0087x$ (S.dev. 0.773, $r^2 = 21.4\%$). The range of values for straw intake were fairly widespread and may indeed have been influenced by the dietary treatments where, for example, urea was not allocated.

Experiment 1.3.2

Part 2

In view of the promising results obtained in Experiment 1.3.2 Part 1, the opportunity was taken to repeat and extend the observations in a second experiment, the main part of which was conducted by J.P. Alawa for a different purpose.

Materials and Methods

The twenty suckler cows used in Experiment 1.3.2 Part 1 , which were now at a much later stage of gestation (generally 6-2 weeks from parturition) were re-randomised and given the same dietary treatments as before. Chromic oxide, in a barley cube, was again given at 07.30 h each day. The individually fed cows were allowed full voluntary access to straw.

After a 14-day introductory period, faecal grab samples were again obtained, three times each day, at 10.00 h, 13.00 h and 16.00 h, for seven days by J.P. Alawa. The 21 faecal samples were amalgamated, and subsamples of the composited samples for each cow were dried, milled and analysed for chromium. Additionally, for the purpose of this particular experiment, further single grab samples were obtained from each cow at 10.00 h and 16.00 h on the seventh day of the collection period. The single grab samples were analysed separately for chromium.

Results

The individual and mean faecal chromium concentrations for each of the grab sampling methods, the voluntary straw intake and cow liveweight data are presented in Table 20 .

The overall mean concentration of chromium was highest (1.32 g/kg) in the amalgamated 21 grab samples. The lowest mean value (1.23 g/kg) was from the single grab samples taken at 16.00 h. As the mean of the samples obtained at 10.00 h was 1.31 g/kg, this implies that at some other time of the day (possibly 13.00 h) there would be a higher overall mean concentration.

Regression equations were computed between the chromium concentration of the single faecal samples obtained at 10.00 h and 16.00 h (x) respectively and the faecal chromium concentration of the composite of 21 samples (y). The following relationships were established:-

At 10.00 h $y = 0.142 + 0.902\ x$ (S.dev. = 0.128, r^2 = 57.2%)
At 16.00 h $y = 0.381 + 0.769\ x$ (S.dev. = 0.113, r^2 = 66.9%)

Both of the regression equations were highly significant ($P < 0.001$) and the distribution of the individual values was similar to that shown in Fig.1 .

There was also a highly significant relationship between the chromium contents of the single samples of faeces obtained at 10.00 h and 16.00 h ($r = 0.854$, $P < 0.001$), even although the respective mean faecal chromium concentrations were different. Nevertheless, the difference was not statistically significant ($P > 0.05$).

The overall mean voluntary intake of straw by the 20 cows (given the same combination of background feeds, brewers grains and urea as in Experiment 1.3.2 Part 1) was 5.48 kg DM (Table 20) compared with 6.83 kg DM obtained in mid-pregnancy in Experiment 1.3.2 Part 1 . There was now, at this present stage of gestation, no relationship between cow liveweight and voluntary straw intake. It is appreciated that intakes by individuals might be variably affected by advancing pregnancy and, at the time of writing, the overall digestibility of the diets has not been evaluated. Nevertheless, an attempt has been made to relate the chromium contents in the faeces of the cows with their straw intake (Table 21).

Table 20 Individual and mean faecal chromium concentrations (g/kg DM) of single and 21 grab samples of faeces respectively, and the corresponding voluntary straw intake (kg DM) and liveweight data (kg)

Cow	Faecal chromium concn. (g/kg DM)			Voluntary straw intake (kg DM)	Liveweight (kg)
	1 sample 10.00h	1 sample 16.00h	21 samples over 7 days		
1	1.09	0.96	1.16	5.57	476
2	1.24	1.24	1.40	5.59	499
3	1.29	1.24	1.45	4.59	543
4	1.17	0.86	1.00	6.14	551
6	1.50	1.48	1.36	4.98	451
7	1.18	1.13	1.11	6.17	504
10	1.34	1.22	1.30	4.78	446
11	1.18	1.04	1.01	7.08	474
14	1.37	1.27	1.35	5.33	510
15	1.54	1.49	1.40	4.64	540
18	1.17	1.15	1.20	5.80	555
20	1.40	1.44	1.47	6.44	491
22	1.42	1.48	1.50	5.16	445
24	1.52	1.31	1.40	5.20	512
28	1.17	0.93	1.15	6.28	545
29	1.18	1.01	1.27	6.00	445
38	1.31	1.41	1.59	5.32	436
41	1.12	1.12	1.23	5.92	430
44	1.52	1.49	1.48	4.78	446
48	1.61	1.41	1.75	3.92	474
n	20	20	20	20	20
Mean	1.32	1.23	1.33	5.48	489
S.dev±	0.161	0.204	0.192	0.761	42.3
CV%	12.2	16.5	14.4	13.9	8.6

Table 21 The relationship between faecal chromium content (x) and the voluntary straw intake of cows (y) in late pregnancy

Sample	Regression Equation	S.dev. ±	r^2%	Sig.P
One at 10.00h	y = 9.91 - 3.36x	0.551	50.4	0.001
One at 16.00h	y = 8.32 - 2.30x	0.617	37.8	0.01
21 over 7 days	y = 9.40 - 2.94x	0.525	54.9	0.001

The most significant regression relationship ($P < 0.001$, S.dev. ± 0.525), with the least standard deviation of the prediction of y, was produced from analysis of the amalgamation of 21 samples obtained over 7 days. However, the regression relationship produced from the single sample obtained on one day at 10.00 h ($P < 0.001$, S.dev. ± 0.551) was substantially as precise, with a slightly larger standard deviation of the prediction of y. There was also a fairly good regression relationship ($P < 0.01$, S.dev. ± 0.617) when the chromium values for the single samples, obtained on one day at 16.00 h, were employed.

If the latter regression equations (Table 21) were used to predict straw dry matter intake from faecal chromium concentrations, where the same basal diet would be offered, examples results are presented in Table 22 .

Table 22 Predicted values of voluntary straw intake using various values for the chromium content of faeces

Equation	Voluntary straw intake (y) kg DM		
Faecal chromium (g/kg)	1.0	1.5	2.0
y = 9.91 - 3.36x	6.55	4.87	3.19
y = 8.82 - 2.30x	6.02	4.87	3.72
y = 9.40 - 2.94x	6.46	4.99	3.52

The example results of predicted voluntary straw intake in Table 22 are somewhat variable. Nevertheless, there is little doubt that single grab samples of faeces can produce a useful indication of straw intake.

Conclusion

The results of both sections of Experiments 1.3.2 tend to suggest that single grab samples of faeces obtained from cows on straw based diets have chromium contents which are well correlated to values obtained by three times a day sampling of faeces over a seven day period. Furthermore, the relationship between dry matter output of faeces and individual feed intake (assuming that dry matter digestibility from one cow to another is reasonably constant) is as reliably indicated by single grab samples as from amalgamated samples taken over a predetermined collection period.

Experiment 1.3.3 Alternative faecal markers to chromium

Introduction

In the determination of individual feed intake, under a wide range of dietary inputs, by indirect estimation of faecal dry matter output, it is not always practicable to include chromic oxide as the indigestible marker, supplied either from gelatin capsules or incorporated into the feed dry matter. It may be possible to utilise a naturally occurring dietary constituent as the faecal marker if it is present in the component of the diet at appropriate concentrations.

Wilson and Ritchie (1981) have demonstrated that a calcined magnesite can be selected with a low (i.e. over 50%) dietary availability and that there was little animal-to-animal variability. Therefore, a constant proportion per unit weight of magnesium intake is likely to be excreted in the faeces, given that the magnesium source is constant between animals. Consequently, the concentration of magnesium in the faeces may reflect the difference in intake in group feeding situations.

It may also be possible to use copper as an alternative faecal marker to chromium. The A.R.C. (1980) have concluded that the coefficient of absorption for copper by cattle was 0.04, i.e. 96% of the dietary input of copper is recovered in the faeces. The comparable figure for sheep depends rather more on the dietary sulphur and molybdenum intakes. When the dietary sulphur and molybdenum intakes are fixed, the coefficient of absorption of copper by sheep was in the order of about 0.03 to 0.05. To all intents and purposes,

therefore, about 95% of dietary copper is recovered in the faeces. Consequently, it is also possible that the concentration of copper in the faeces may reflect the difference in intake in group feeding situations.

The present experiment investigates the uniformity of excretion of magnesium and copper in the faeces when a constant diet was individually allocated to suckler cows.

Materials and Methods

The faecal samples obtained in Period 1 of Experiment 1.3.1 were also analysed for magnesium and copper. Unfortunately, it was discovered that magnesium oxide had been erroneously omitted from the formulation of the barley/urea compound and, therefore, the uniformity of excretion of faecal magnesium could not, in effect, be investigated. Copper had been incorporated into the barley/urea compound at a rate of 0.5 g/kg fresh matter (i.e. 2.0 g $CuSo_4.5H_20$/kg).

Results

The mean faecal copper concentrations and the coefficients of variation are presented in Table 23.

The mean faecal copper concentrations from 35, 21 and 7 grab samples were not significantly different, one from the other. However, the mean faecal copper concentration from 35 grab samples (299.0 mg/kg) was statistically different from that of one grab sample (320.5 mg/kg) at $P < 0.05$. Similarly, the mean faecal copper concentration from 21 grab samples (295.4 mg/kg) was statistically different from that of both two grab samples (310.9 mg/kg, $P<0.05$) and single grab samples (320.5 mg/kg, $P<0.01$) and the mean concentration of 7 grab samples was statistically different (303.1 mg/kg) than that of single grab samples (320.5 mg/kg) at $P<0.05$.

Table 23 Mean faecal copper concentrations (mg/kg DM) of suckler cows given a constant diet (5 kg FM/head of hay and 1.5 kg FM/head of barley/urea compound

Faecal Cu (mg/kg DM)	Number of faecal grab samples				
	35	21	7	2	1
n	16	16	16	16	16
	A	B	C	D	E
Mean	299.0	295.4	303.1	310.9	320.5
S.dev.±	18.89	16.21	18.51	22.92	24.02
CV%	6.3	5.5	6.0	7.4	7.5
Means	E < A,	E < C,	D < B	P < 0.05	
			E > B	P < 0.01	

Table 24 Correlation coefficients (r) between the faecal chromium concentration (g/kg DM) and faecal copper concentration (mg/kg DM) for the various methods of grab sampling

	Number of faecal grab samples				
	35	21	7	2	1
r	0.765	0.869	0.703	0.865	0.851

All the correlation coefficients were statistically significant ($P < 0.001$)

The observed statistical differences in the mean copper concentrations, respective of the frequency of faecal grab sampling, may indicate a diurnal excretion pattern of copper, where a single grab sample produces a statistically larger copper concentration than 35 grab samples. Sampling error is also involved and will be reduced for 35 grab samples compared with less frequent grab samples.

Correlation coefficients were computed between the faecal chromium concentrations and the corresponding faecal copper concentrations of the grab samples and the results are presented in Table 24 . All the correlation coefficients were statistically significant ($P<0.001$) suggesting that copper was excreted in the faeces in direct proportion to chromium, which should have been completely excreted in the faeces (assuming 100% recovery rate) as it is indigestible.

Discussion

The relatively low coefficients of variation for the mean faecal copper concentrations (5.5-7.5%) suggest that copper is fairly uniformly excreted by the cows when they were allocated constant inputs of hay and compound feed respectively, even although the method of faecal sampling apparently influenced the absolute concentrations of copper in the faeces.

The low basal variation of faecal copper excretion and the statistical significance ($P<0.001$) of the correlation coefficients between the faecal chromium and respective faecal copper concentrations perhaps indicates the possible applicability of copper, as well as magnesium (as proposed by Wilson (1981) which could not, unfortunately, be pursued in the present study) as alternative faecal markers to chromium.

The potential efficacy of magnesium was pursued in Experiment 1.4 in view of its more likely inclusion at elevated levels in ruminant diets for cows at grass and the importance there of ensuring uniformity of intake .

Experiment 1.4 Establishment of calibration equations to predict individual hay intake by a group of suckler cows

Introduction

The prediction of individual straw intake from computed calibration equations, which were calculated between known intakes of straw and the corresponding faecal chromium concentrations from rectal grab samples, was observed in Experiment 1.3.2. This was pursued further in the present experiment where calibration equations were developed between known inputs of hay (y) and the corresponding faecal chromium and magnesium concentrations respectively as the x component, derived from a constant input of chromic oxide and magnesium oxide in a pelleted compound. The suckler cows which were used in Experiment 1.3.1 were again employed in the present experiment.

The use of calibration equations to estimate individual feed intake may provide a suitable alternative to the indirect estimation of faecal dry matter output from the concentration of chromium in rectal grab samples, where it is necessary to know the dry matter digestibility of the dietary components, before extrapolation to individual feed intake. The calibration method avoids the necessity to determine the dry matter digestibility of the dietary component.

The computation of calibration equations involves the assumption that the overall diet digestibility between the animals in the group is uniform. If this assumption is correct (and was indicated to be so in Experiment 1.1), the variation in faecal chromium or magnesium concentration between animals will truly reflect the corresponding differences in the imposed levels of hay allocation to each of the animals. The determination of overall diet digestibility was afforded by reference to Experiment 1.3.1, where the same group of suckler cows, to be used in the present experiment, were each allocated a constant intake of 5 kg fresh dry matter/head of hay and 1.5 kg fresh matter/head of a compound feed which contained chromic oxide. This is referred to in Period 1 of the present experiment.

In Period 1 calibration equations were established in the group of 16 suckler cows (previously mentioned) which were individually given various allocations of hay (according to liveweight) and equal allocations (1.5 kg FM/head) of a compound feed containing chromic oxide and magnesium oxide. Both faecal chromium and magnesium concentrations were respectively related to individual hay intake.

In Period 2 the calibration equations were used to predict the individual intake of hay which was offered to the same group of animals from two feedings. The same total allocation of hay was offered to the group as had been individually allocated in Period 1. The allocation of the chromic oxide containing compound feed remained the same as in Period 1.

Materials and Methods

Preliminary to Period 1, the overall diet digestibility for the group of 16 suckler cows, individually allocated a constant amount of hay and chromic oxide containing barley/urea compound (Experiment 1.3.1), was calculated from the equation using the faecal chromium concentrations from Table 16, Experiment 1.3.1.

Overall diet dry matter digestibility =

$$1 - \frac{\text{(concentration of chromium in diet dry matter)}}{\text{(concentration of chromium in faecal dry matter)}}$$

Unfortunately similar calculations could not be made using the equivalent concentration of magnesium, as magnesium oxide had been erroneously excluded from the formulation of the barley/urea compound in Experiment 1.3.1. Nevertheless, calibration equations were computed in the present experiment which used faecal magnesium concentration from grab samples for investigative purposes.

In Period 1 the same group of suckler cows were again allocated 1.5 kg FM/head/day of a barley/urea, chromic oxide pelleted compound at 07.30 h. The cows were divided into groups of four in order of liveweight and the cows in each group were individually allocated either 3 kg FM, 4 kg FM, 6 kg FM or 7 kg FM of hay/head/day in order of increasing liveweight. The respective allocations of hay were offered to the animals in two equal feeds at 08.00 h and 16.30 h. The proximate analysis of the feeds for both Period 1 and Period 2 are presented in Table 25.

Table 25 Proximate analyses of hay and barley/urea compound

	Hay	Barley/urea compound	
		Period 1	Period 2
Dry matter (g/kg)	845	880	891
Composition of dry matter (g/kg)			
Crude Protein	73	223	226
Crude Fibre	336	41	44
Ether Extract	10	4	12
Soluble Carbohydrates	525	641	620
Ash	56	91	98
Chromium	-	5.78	6.43
Magnesium	1.78	25.39	22.50

After a preliminary period of seven days, faecal grab samples were taken in the same manner as in Experiment 1.3.1 (Table 15) for a seven day collection period. The faeces from the multiple grab samples were amalgamated during the collection period. Prior to analysis for chromium and magnesium, the multiple faecal samples were subsampled, dried and milled. The single grab samples were dried, milled and analysed for chromium and magnesium.

Ten separate calibration equations were computed between the allocated hay dry matter intake (y) and the respective faecal chromium concentrations (x) and faecal magnesium concentrations (x) of the various grab samples.

During Period 2 the cows were offered the same total quantity of hay fresh matter (80 kg/day), as had been individually allocated to them in the byre, in two equal feeds from two feedrings (each with head spaces separated by vertical bars to prevent movement from side to side). At 08.00 h and 16.30 h the cows were released from the byre and allowed access to the feedrings until they had consumed the hay allocation. After a preliminary period of seven days, faecal grab samples were taken per rectum as shown in Table 15 (Experiment 1.3.1). However, it was decided to omit the 35 grab sample collection during Period 2, due to highly significant correlation coefficients

obtained between the respective faecal chromium and magnesium concentrations of the various methods of grab sampling and the respective faecal chromium and magnesium concentrations of the amalgamated 35 grab samples which was observed in Period 1.

The faecal chromium and magnesium concentrations (x) were respectively substituted into the corresponding regression equations (related to the number of grab samples) established in Period 1, and the individual intakes of hay dry matter (y) were thence estimated.

Results

The barley, urea and chromic oxide pelleted compound was readily consumed by the cows and had usually been completely eaten within five to ten minutes of being allocated to the animals in both Period 1 and Period 2. When different levels of hay were individually allocated to the group, in order of liveweight, in Period 1, the hay was usually consumed within 20, 25, 35 and 40 minutes at each feed for allocations of 3 kg FM, 4 kg FM, 6 kg FM and 7 kg FM respectively. There were no refusals of hay. In Period 2 when 80 kg FM hay was allocated to the entire group of 16 cows in two equal feeds, the animals were keen to go forward to the feedring and usually settled down after several minutes of moving within and between the feedrings. Cow 13, however, was not used to eating from a feedring, had difficulty in learning how to move her head into the right position, even although attempts were made to show her how to get her head through the bars during the preliminary run-in week of Period 2. Consequently cow 13 moved around the feedrings and was a disruptive influence throughout Period 2, nudging the other animals as they attempted to consume the hay. Cows 9 and 11, on the other hand, were persistent at the feedrings and usually pushed several cows (cows 1 and 2) out of the way as they attempted to consume more hay. The hay allocation was usually consumed by the group within 30-35 minutes. During the first 20 minutes of access to the hay from the feedrings, most of the cows persisted at the feedring (except cow 13) and several animals started to move away usually after 25 minutes when most of the hay had usually been consumed.

The mean faecal chromium concentrations obtained from Table 16, Experiment 1.3.1, when the 16 suckler cows were individually allocated 5 kg FM of hay and 1.5 kg FM of a barley/urea compound, and the corresponding mean overall diet dry matter digestibility coefficients are presented in Table 26. The mean faecal chromium concentrations and

their respective coefficients of variations have been previously discussed in Experiment 1.3.1 with reference to basal coefficients of variation in a group, where each animal consumed constant quantities of both hay and compound feed. The mean overall diet digestibility coefficients were similar (between 0.59 and 0.64) between the various sampling techniques (e.g. either 35, 21, 7, 2 or 1 grab samples) and the variation of the digestibility coefficients within the group was fairly compact around each of the means, thereby producing fairly small coefficients of variation (5.8 - 9.0%).

Table 26 Mean faecal chromium concentrations (g/kg DM) obtained in Experiment 1.3.1, and the corresponding overall mean diet dry matter digestibility coefficients for each of the grab sampling methods.

	Grab samples taken during the collection period				
Cr (g/kg DM)	35	21	7	2	1
Mean	2.83	2.97	3.09	2.96	3.23
S.dev. ±	0.246	0.279	0.275	0.402	0.348
CV%	8.7	9.4	8.9	13.6	10.8
DM digestibility coefficient of diet					
Mean	0.59	0.61	0.62	0.60	0.64
S.dev. ±	0.039	0.041	0.036	0.054	0.041
CV%	6.6	6.7	5.8	9.0	6.4

The calibration equations computed in Period 1 are presented in Table 27. All the equations were statistically significant and each had fairly low errors associated with the prediction of the mean hay intake (y) related to a mean dry matter intake of 4.23 kg (± 0.469 to ± 0.538 and ± 0.391 to ± 0.633 for the calibration equations computed from faecal chromium and magnesium concentrations respectively).

Table 27 Calibration equations computed between hay dry matter intake (y) and faecal chromium concentration (x) and faecal magnesium concentration (x) respectively.

Number of grab samples taken during collection period	Calibration equation	Error associated with prediction of y	r^2%	Signif. P<
Faecal chromium concentration				
35	y = 8.28 - 1.34x	0.496	87.1	0.001
21	y = 7.91 - 1.48x	0.588	81.9	0.001
7	y = 8.97 - 1.40x	0.469	88.6	0.001
2	y = 8.75 - 1.33x	0.524	85.6	0.001
1	y = 8.15 - 1.17x	0.531	85.2	0.001
Faecal magnesium concentration				
35	y = 9.30 - 0.42x	0.508	86.4	0.001
21	y = 9.29 - 0.41x	0.499	86.9	0.001
7	y = 9.91 - 0.43x	0.399	91.6	0.001
2	y = 9.47 - 0.34x	0.391	92.0	0.001
1	y = 7.70 - 0.29x	0.633	79.0	0.001

For Period 2, the individual faecal chromium and magnesium concentrations from the various sampling methods (either 1, 2, 7 or 21 grab samples taken over the collection period) were substituted for x in the respective calibration equations, thereby predicting individual hay intake. Unfortunately, two different batches of barley/urea and chromic oxide pelleted compound feed were used in Period 1 and Period 2 respectively. Consequently there was a discrepancy in the concentration of chromium (5.78 g/kg DM and 6.43 g/kg DM for Period 1 and Period 2 respectively) and the concentration of magnesium (25.39 g/kg DM and 22.50 g/kg DM for Period 1 and Period 2 respectively) in the compound feed for each period. It was therefore necessary to reduce the faecal chromium concentrations (x) in Period 2 by a factor of 0.89 (5.78 / 6.43) and to increase the faecal magnesium

concentrations (x) in Period 2 by a factor of 1.13 (25.39 / 22.50) to facilitate their substitution into the respective calibration equations determined in Period 1 for the prediction of hay intake (y) in Period 2. The corrected mean faecal chromium and magnesium concentrations are presented in Table 28.

Table 28 Corrected mean faecal chromium and magnesium concentrations for Period 2 (n = 16).

	Number of faecal grab samples			
	21	7	2	1
Corrected faecal chromium concentrations (g/kg DM)				
Mean	2.63[a]	2.93	3.18	3.28[b]
S.dev ±	0.647	0.731	1.004	1.062
Range	1.98-4.39	2.31-5.38	2.24-6.45	2.48-6.73
CV%	24.6	26.7	31.6	32.4
Corrected faecal magnesium concentration (g/kg DM)				
Mean	12.86	13.80	12.71	13.92
S.dev ±	2.533	3.764	3.117	3.178
Range	10.57-19.89	10.90-26.32	9.93-22.5	10.13-23.01
CV%	19.7	27.3	24.5	22.8

Mean values with different superscripts are significantly different

a and b = $P < 0.05$

The mean faecal chromium concentrations (and the respective coefficients of variation) appeared to increase as the number of faecal grab samples, taken over the collection period, decreased. Indeed, the mean faecal chromium concentration from 21 grab samples (2.63 g/kg DM) was significantly lower than that from one grab sample (3.28 g/kg DM, $P < 0.05$), again reflecting the periodicity of faecal chromium excretion. The mean faecal chromium concentration of the 21 grab samples taken over the collection period may be the most representative of the overall mean faecal chromium concentration over the 24 hour period, even although the faecal grab samples were taken between 07.00 and 19.00 h only. Therefore, the periodicity of faecal chromium excretion is demonstrated by the mean faecal chromium concentrations of one, two and seven grab samples, taken over the collection period, whereby it appears that faecal chromium excretion is greater at 16.00 h (when one and two grab samples were taken) than at 13.00 h (when the seven grab samples, one per day, were taken). However, there is a reduced sampling error associated with the latter faecal chromium concentration which may confound the diurnal effect of the chromium excretion.

The mean faecal magnesium concentration ranged from 12.71 g/kg DM, from two grab samples, to 13.92 g/kg DM from one grab sample. None of the differences in the mean faecal magnesium concentrations, between the various sampling methods, was statistically significant.

Hay had been allocated at a rate of 4.2 kg DM/head/day in Period 2. Table 29 presents data for the individual hay intakes of the cows as calculated from the various prediction equations. The predicted sum of the individual and mean intakes of hay dry matter, using the faecal chromium concentration of grab samples, were fairly close to the allocated mean, particularly where the prediction equation $y = 8.15 - 1.17x$ was used (computed from one faecal grab sample). The mean hay dry matter intake in this case was 4.3 ± 1.24 kg, although the error associated with the prediction of y (hay intake) was fairly large (0.531 kg). When the prediction equations $y = 8.97 - 1.40x$ and $y = 8.75 - 1.33x$ (computed from seven and two faecal grab samples respectively) were used, the predicted mean hay intakes were 4.9 ± 1.03 kg and 4.5 ± 1.33 kg respectively. The latter two overestimated mean hay intakes (by factors of 1.17 and 1.07 respectively) may have been expected in view of the periodicity of faecal chromium excretion. However, when one faecal grab sample had been used in the computation of the prediction equation, the predicted mean hay intake was very

similar to the allocated mean, even although there is likely to be a similar periodic effect of faecal chromium excretion. When the faecal chromium concentrations of 21 grab samples were used to predict hay intake, the mean predicted hay intake (4.0 ± 0.97 kg DM) was also similar to the allocated mean (4.2 kg DM). The faecal chromium concentrations of 21 grab samples may be more representative of the true mean faecal chromium concentration for a 24 hour period, thereby the predicted hay intake may be more representative of the true intake. The relatively lower coefficient of variation (24.3%) for the predicted mean hay intake from 21 faecal grab samples may also emphasise this point (coefficient of variation for the prediction of hay intake from one grab sample was 28.8%).

In Period 2, cow 13 had been observed to be unsure of the correct way to use the feedrings, in order to consume the hay on offer. This was reflected in the predicted small quantities of hay consumed by this animal (0.2 kg DM to 1.4 kg DM with respect to method of grab sampling), when faecal chromium concentration was used as the prediction component of the calibration equations. Cows 9 and 11 had both been observed to persevere at the feedring and this was reflected in relatively high hay dry matter intakes which were usually greater than the predicted mean intake for the group (e.g. 5.6 and 5.5 kg DM/head respectively where the calibration equation was $y = 8.97 - 1.40x$, and the predicted mean intake was 4.9 kg DM).

Table 29 Predicted individual and mean intakes of hay dry matter (y), allocated at a rate of 4.2 kg DM/head/day in Period 2, using previously established calibration equations computed with the faecal chromium concentrations (x) of grab samples

	Number of faecal grab samples			
	21	7	2	1
y	7.91-1.48x	8.97-1.40x	8.75-1.33x	8.15-1.17x
Predicted hay DM intake (kg)				
Cow Number				
1	2.3	5.1	4.8	4.7
2	3.9	5.2	4.8	4.5
3	4.5	3.9	2.7	2.9
4	3.6	4.3	4.5	4.0
5	4.5	5.2	5.2	5.1
6	4.4	5.7	4.8	4.9
7	3.6	5.0	4.4	3.9
8	4.5	5.3	5.0	4.3
9	4.7	5.6	5.2	5.3
10	3.9	5.2	4.9	4.7
11	4.9	5.5	5.2	5.0
12	5.0	5.5	5.3	5.1
13	1.4	1.4	0.2	0.3
14	4.9	5.0	5.8	4.9
15	4.3	5.1	5.2	5.2
16	3.9	5.1	4.6	4.3
n	16	16	16	16
Mean	4.0	4.9	4.5	4.3
S.dev ±	0.97	1.03	1.33	1.24
CV%	24.3	21.0	29.6	28.8

The predicted individual and mean hay intakes for each of the sampling methods using the faecal magnesium concentrations of the grab samples are presented in Table 30. The calibration equations computed using both 21 grab samples ($y = 9.29 - 0.41x$) and 7 grab samples ($y = 9.91 - 0.43x$) resulted in the most accurate predictions of hay dry matter intakes, with mean calculated intakes of 4.0 ± 1.03 kg and 4.4 ± 0.78 kg, compared with the allocated quantity of 4.2 kg DM/head, although the errors associated with the prediction of the hay intake (y) were ± 0.499 and ± 0.399 kg respectively. However, where the calibration equation from 7 grab samples was used ($y = 9.91 - 0.41x$), the predicted hay intake by cow 13 was -1.4 kg DM. This value was omitted from the calculation of the mean predicted hay intake as it was probably caused by an analytical or sampling error. The mean intake of hay dry matter calculated using the calibration equations computed from 2 and 1 faecal grab samples, and the magnesium concentrations thereof, over and under estimated the mean allocated quantity by factors of 1.23 (5.2 kg DM) and 0.88 (3.7 kg DM) respectively. The coefficients of variation of predicted hay intake were in the range of 17.7% to 25.8% and, even although this was not in the same sequence as for prediction of hay intake, using faecal chromium concentrations, nevertheless they were in approximately the same range (20.8% to 29.8% using prediction equations computed from faecal chromium concentrations).

The eating behaviour of the cows was again reflected in the computed individual hay intakes which had been predicted from the faecal magnesium concentrations. Cow 13 consumed between 1.1 and 1.8 kg DM hay, which reflected her reluctance to effectively use the feedring. However, even although the predicted hay intakes by cow 11 were consistently greater than the mean intake for the group, irrespective of the frequency of grab sampling, two of the corresponding predicted hay intakes by cow 9 were below the mean intake for the group, which was not consistent with the results obtained using faecal chromium as the predictor variable.

Table 30 Predicted individual and mean intakes of hay dry matter (y), allocated at a rate of 4.2 kg DM/head/day in Period 2, using previously established calibration equations computed with the faecal magnesium concentrations (x) of grab samples

	Number of faecal grab samples			
	21	7	2	1
y	9.29-0.41x	9.91-0.43x	9.47-0.34x	7.70-0.29x
Predicted hay DM intake (kg)				
Cow Number				
1	4.4	4.3	5.8	4.1
2	4.1	4.6	5.1	3.8
3	2.0	2.6	4.3	2.7
4	3.4	2.9	4.3	3.1
5	4.8	5.1	6.0	4.8
6	4.4	4.6	5.4	4.5
7	3.9	3.9	4.9	3.2
8	4.9	5.3	6.1	4.2
9	3.9	4.0	5.3	3.7
10	4.2	4.7	5.4	3.8
11	4.4	5.0	5.4	4.3
12	4.7	5.2	6.1	4.2
13	1.1	(-1.4)	1.8	1.1
14	4.7	4.4	5.8	4.2
15	4.5	4.7	6.0	4.6
16	4.0	4.1	5.0	3.3
n	16	15	16	16
Mean	4.0	4.4	5.2	3.7
S.dev. ±	1.03	0.78	1.07	0.91
CV%	25.8	17.7	20.6	24.6

Discussion

The overall diet dry matter digestibility coefficients (0.59 - 0.64 depending on frequency of faecal sampling) were observed to be relatively uniform between the cows (when they were individually allocated a constant amount of both hay and barley/urea compound, Experiment 1.3.1) which was indicated by coefficients of variation of between 5.8% and 9.0%, depending on the frequency of faecal sampling. In the subsequent development of calibration equations variation in faecal chromium concentration, derived from a constant intake of chromic oxide individually allocated to the cows, should therefore effectively reflect the corresponding differences in the imposed levels of hay allocation to each of the animals.

The high degree of statistical significance ($P < 0.001$) of the calibration equations for each sampling regimen, using both faecal chromium and magnesium concentrations respectively as the predictor variables, indicated their potential applicability in predicting hay intake from faecal chromium and magnesium concentrations respectively. The calibration equations are specific to the group of animals and experimental conditions used in their computation, where the diet had been allocated on a restricted basis, i.e. less than voluntary intake. Accordingly, it is unlikely that accurate predictions of hay dry matter intake would be estimated, using the established equations, where full voluntary access to hay was available to the cows on a group basis.

The predicted dry matter intakes of hay in Period 2, using faecal chromium concentrations as the predictor variable (x), were apparently influenced by the sampling technique, whereby one faecal grab sample predicted the hay intake to be nearest (4.3 kg DM/head) the allocated mean intake of 4.2 kg DM/head, which may have been unexpected in view of the likely effect of the diurnal excretion of chromium on the concentration of chromium in the faeces and the likely error associated with taking only one grab sample to represent the true mean faecal chromium concentrations. Nevertheless, the predicted mean intake of hay calculated from 21 grab samples (4.0 kg DM/head) was also fairly close to the allocated mean of 4.2 kg DM/head, even although the error associated with its prediction was $\pm$ 0.588 kg, compared with a marginally smaller error of $\pm$ 0.531 kg associated with the prediction of hay intake (y) using the faecal chromium concentration from single grab samples. However, the corresponding coefficient of variation of 24.0% for the predicted mean intake of hay from 21 grab samples may

suggest that the errors associated with the periodicity of faecal chromium excretion and the sampling method have been reduced, compared with the coefficient of variation of 28.8% where single faecal grab samples were taken.

When the faecal magnesium concentrations of the various sampling methods were used as the predictor variables (x) in the prediction of hay dry matter intake in Period 2, the predicted quantities were again influenced by the faecal sampling technique. The mean predicted hay dry matter intakes were fairly similar to the allocated quantity of 4.2 kg DM from both the prediction equations of 21 grab samples and 7 grab samples (4.0 kg DM and 4.4 kg DM respectively), even although the error associated with the predicted mean was larger for 21 grab samples ($\pm$ 0.499 kg) compared with 7 grab samples ($\pm$ 0.399 kg). Nevertheless, the existence of a negative hay intake value for cow 13 from the calibration equation computed from 7 grab samples, may refute the applicability of this particular calibration equation.

Indeed, the applicability of faecal magnesium concentrations as suitable markers to reflect differences in feed intake, relies on similarity in the digestibility of the dietary magnesium between the animals, irrespective of possible level of feeding effects. Unfortunately, this could not be pursued in the present experiment. However, the predicted hay intake of cow 13, which was observed to consume very little hay, was consistently well below the mean intake for the group (1.1 - 1.8 kg DM) when faecal magnesium concentration was used as the predictor variable, which perhaps indicates the potential application of faecal magnesium concentration to illustrate variation in feed intake.

The computed calibration equations were useful in the prediction of group fed hay in Period 2, and may well be an effective alternative to estimate feed intake, under fairly controlled experimental conditions, compared with extrapolation to feed intake from indirect estimations of faecal output where it is necessary to estimate the dry matter digestibility coefficients of the individual dietary components.

SECTION 2 AN ASSESSMENT OF THE INDIVIDUAL FEED INTAKE OF HOUSED EWES IN EARLY LACTATION GIVEN A COMPLETE DIET.

The present series of experiments describes the use of calibration equations, established in Experiments 2.1 and 2.2 between feed dry matter intake and the faecal chromium concentrations of grab samples, to predict the individual feed intake of a complete diet by housed ewes in early lactation with twin lambs at foot (Experiment 2.3). The complete diet consisted of a mixture of molassed shredded sugar beet pulp, soya bean meal and barley husk siftings and was offered on a restricted basis to the ewes (i.e. less than full metabolisable energy allowances as defined by MAFF 1984 Technical Booklet 433). The bulky physical nature of the complete diet may influence the extent of the variation in individual feed intake through effects on the rate of consumption as indicated by Foot and Russel (1973).

In Experiment 2.4 the possible influence of the physical method of feed presentation (i.e. from troughs or a feedring or from behind a feed barrier) on the variation in individual feed intake of the same complete diet was investigated using ewes in early lactation with single lambs at foot.

Experiment 2.1 Determination of a calibration equation, of the form $y = c + mx$, between measured quantities of a complete diet (y) individually allocated to ewes in early lactation and the corresponding faecal chromium concentration of grab samples (x).

Introduction

The objective of the present experiment was to compute a calibration equation between measured inputs of a complete diet individually allocated to ewes in early lactation, with single lambs at foot, and the corresponding faecal chromium concentration of grab samples. The calibration equation could then be used to predict the individual intake of the complete diet by ewes with twin lambs at foot (Experiment 2.3) where approximately the same experimental conditions were imposed.

Materials and Methods

Fourteen Greyface ewes (Scottish Blackface females x Border Leicester males) of mixed age and mean liveweight 68 kg, with single lambs (mean age 7 days) were selected from an inwintered ewe flock and individually penned with straw bedding. The ewes were paired according to liveweight (range of 54-80 kg). Each pair was given one of seven allocations (either 1.25, 1.46, 1.66, 1.87, 2.08, 2.29 or 2.50 kg DM/day increasing according to liveweight) of a complete diet (of energy density 11.2 MJ ME/kg DM) which consisted of a loose mix of shredded molassed sugar beet pulp, soya bean meal and barley husk siftings (Table 31 (A) and (B)). These allocations were designed to include the reasonably possible range of individual dry matter intake within a group of similar ewes (Experiment 2.3) where the group allocation of 1.8 kg DM/head/day supplied 20 MJ ME. The ewes were given equal portions of their allocation twice daily at 07.30 h and 16.00 h. The ewes were each given one gelatin capsule, containing 1.0 g chromic oxide, once per day at 09.00 h. After a ten-day preliminary period, grab samples of faeces were obtained over the next three days. Faecal samples were taken (per rectum, whenever possible) three times per day at 09.00, 13.00 and 16.00 h. The nine fresh faecal samples were amalgamated for each ewe after the three days and then dried and milled and subsampled prior to chromium analysis.

A regression equation was thence established using faecal chromium concentration (x) and feed dry matter (y).

Table 31 (A) Composition of complete diet and (B) the proximate analyses of the feeds

(A) Composition of complete diet (% FM)

	66.5	Molassed sugar beet pulp (shredded)
	16.0	Soya bean meal
	16.0	Barley husk siftings
	1.0	Dicalcium phosphate
	0.5	Salt
plus	0.006	Trace element supplement

(B) Proximate analyses of feeds

	Molassed sugar beet pulp	Soya bean meal	Barley husk siftings
Dry matter (g/kg)	850	859	833
Composition of dry matter (g/kg)			
Crude protein	109	494	49
Crude fibre	138	53	294
Ether extract	4	20	12
Soluble carbohydrates	669	363	552
Ash	80	70	93

Results

The ewes and lambs remained healthy throughout the experiment, and the lambs had a mean liveweight gain of 380 (±92.5) g/day. The ewes which had been allocated 1.25 and 1.46 kg DM/day were notably hungry and were keen to eat the bedding straw. The ewes given the highest amounts of feed (2.6 kg DM/day) consumed the diet readily. All the ewes had completely consumed their respective allocations within 30-45 minutes.

Whenever possible the faecal samples were obtained per rectum. On occasion some of the ewes were empty; however, a sample was generally obtained by selecting the freshest faeces from the bedded floor, but this was only done when it was obviously uncontaminated with bedding. There were differences in the consistency of the faeces with (generally) increasingly hard pellets with decreasing feed allocation.

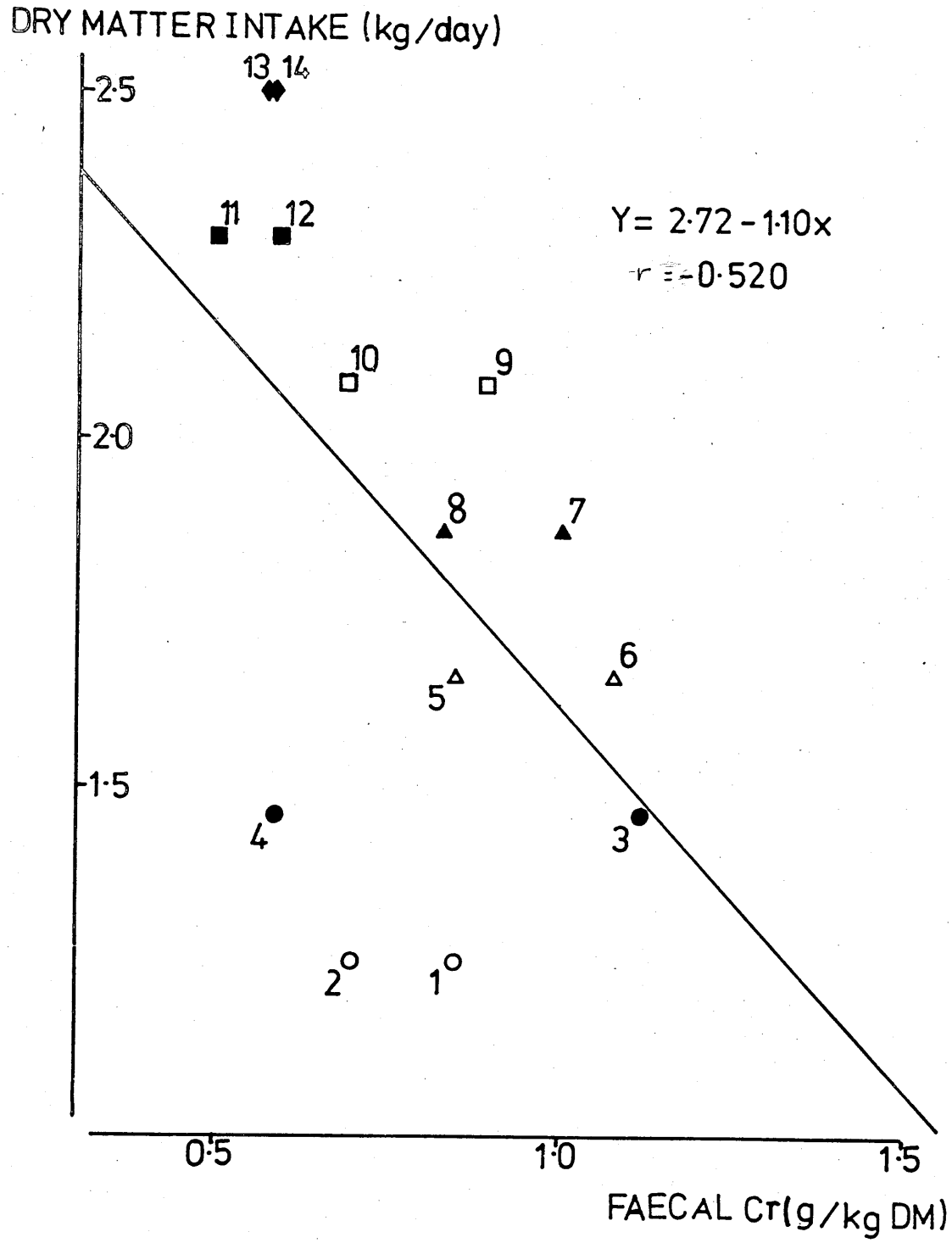
The individual faecal chromium concentrations and the corresponding dry matter allocations of the complete diet are presented in Table 32 and Figure 2. The mean faecal chromium concentration was 0.77 ± 0.201 g/kg DM. The individual data were used to compute the regression equation $y = 2.72 - 1.10\ x$, where y = feed dry matter intake and x = faecal chromium concentration in the dry matter. However the regression was not statistically significant ($P > 0.05$). The error associated with the regression line was 0.386 and R^2 was 26.5%.

By exclusion of the data of ewe 2 and ewe 4, which both had relatively low faecal chromium concentrations (as shown on Figure 2) in relation to their respective feed intakes (and indeed were those ewes which were observed to be particularly keen to consume bedding straw), the resulting regression equation ($y = 3.16 - 1.51\ x$) was much improved ($r^2 = 61.5\%$, $P < 0.01$). The error associated with the prediction of y (feed intake, mean allocation rate for the group was 1.87 kg DM) was ± 0.262 kg.

Table 32 Individual and mean faecal chromium concentrations (g/kg DM) from grab samples and the corresponding dry matter intakes of the complete diet

Ewe Number	Faecal chromium concentration (g/kg DM)	Intake of complete diet (kg DM)
1	0.85	1.25
2	0.70	1.25
3	1.12	1.46
4	0.59	1.46
5	0.85	1.66
6	1.08	1.66
7	1.00	1.87
8	0.83	1.87
9	0.89	2.08
10	0.69	2.08
11	0.50	2.29
12	0.59	2.29
13	0.57	2.50
14	0.58	2.50
Mean	0.77	1.87
S. dev ±	0.201	(0.432)
CV%	26.1	(23.1)

Figure 2 Calibration equation of the form $y = 2.72 - 1.10 x$ ($P > 0.05$) where y = dry matter intake and x = faecal chromium concentration of grab samples (paired symbols e.g., ○ ○ , ▲ ▲ indicate paired ewes).


DRY MATTER INTAKE (kg/day)
2·5
2·0
1·5
13 14
11 12
10
9
8
7
6
5
4
3
2
1
Y= 2·72 - 1·10x
r = -0·520
0·5
1·0
1·5
FAECAL Cr(g/kg DM)

Discussion

The faecal chromium concentrations were much more varied than was anticipated and were not at all well correlated with the corresponding feed intake values ($r = -0.514$, $P > 0.05$). One of each of the pairs of sheep (ewe 2 and ewe 4), given the two lowest feed allocations of 1.25 and 1.46 kg DM/day, were particularly out of sequence. This was emphasised in the resulting non-significant regression equation and the associated error (0.386) around the regression line. There was nothing unusual in the behaviour of the latter ewes, apart from appearing hungry and being particularly keen to consume bedding straw. Indeed their particular irregularities were further emphasised by the statistical significances of the regression equation ($y = 3.16-1.51\ x$, $P<0.01$) computed with the exclusion of the data from ewe 2 and ewe 4. However the other two ewes given the allocation of 1.25 and 1.46 kg DM/head, also consumed bedding straw. Sampling errors and differences in digestibility, suggested by variation in the consistency of the voided faeces between individuals, may help to explain these irregularities.

The method of administration of the chromic oxide marker, by a capsule to be swallowed, may also have contributed to the irregularities in the mean faecal chromium concentrations, particularly of ewe 2 and ewe 4, in that regurgitation or chewing and hence loss or partial loss of the capsule may have occurred. This may have contributed to the relatively low concentration of faecal chromium in these two ewes, with respect to their corresponding pairs given similar levels of feed allocation.

In view of the irregularities in the faecal chromium concentrations, with the subsequent non-statistical significance of the regression equation between mean faecal chromium concentration (x) and feed dry matter allocation (y), when all the ewe data were included, it was considered necessary to repeat the calibration experiment to produce a more accurate and statistically significant regression equation (Experiment 2.2). Simultaneously, the reliability of using chromic oxide capsules was investigated, compared with the inclusion of chromic oxide powder (incorporated into a pelleted barley ration) in the complete diet. Chromic oxide presented in capsule form once a day, may not have become intimately mixed with the feed intake in the alimentary tract, and may have produced a more irregular diurnal excretion pattern of chromium compared with chromic oxide mixed in with

the allocated feed intake.

Experiment 2.2 A further attempt to compute calibration equations of the form $y = c + mx$ between measured inputs of the complete diet and the corresponding faecal chromium concentrations of grab samples, where the chromic oxide was supplied from gelatin capsules or incorporated into the feed.

Introduction

As a result of the poor, statistically non-significant regression relationship between individual intake of a complete diet and the corresponding faecal chromium concentrations from grab samples, in Experiment 2.1, the present experiment was conducted in an attempt to develop a statistically significant regression relationship between these two parameters under similar experimental conditions to those imposed in Experiment 2.1. One of the factors which may have contributed to the poor regression relationship, in Experiment 2.1, may have been the method of administration of chromic oxide in gelatin capsules and therefore in the present experiment calibration equations were computed when faecal chromium concentrations were derived from chromic oxide presented in gelatin capsules (Period 1) compared with faecal chromium concentrations derived from chromic oxide incorporated into the feed dry matter presented to the ewes (Period 2).

Materials and Methods

The same 14 ewes from Experiment 2.1 were re-randomised into pairs according to liveweight (mean ewe liveweight 70 ±4 kg) and each ewe was individually penned, with her respective single lamb, with straw bedding. During both Period 1 and Period 2 each pair was given one of seven allocations (1.25, 1.46, 1.66, 1.87, 2.08, 2.29 and 2.50 kg DM/head/day increasing according to liveweight) of the same complete diet as was allocated in Experiment 2.1 (Table 31). The ewes were given equal portions of their respective allocations twice daily at 07.30 h and 16.00 h, as before. The lambs were kept separately from the ewes during feeding time to prevent them from possibly consuming some of the feed allocated to the ewes.

The lambs (mean liveweight 26 ±3 kg) had ad libitum access to

both a pelleted creep feed and hay. The proximate analyses of the creep feed and hay are presented in Table 33.

Table 33 Proximate analyses of pelleted lamb creep, hay and barley/chromic oxide

	Pelleted lamb creep	Hay	Barley/chromic oxide cube
Dry matter (g/kg)	858	850	861
Composition of dry matter (g/kg)			
Crude protein	149	93	104
Crude fibre	51	366	50
Ether extract	12	16	10
Soluble carbohydrate	744	456	802
Ash	44	69	34
Chromium	-	-	4.87

During Period 1, the ewes were each given one gelatin capsule, containing 1.0 g of chromic oxide, once per day at 09.00 h. On days 8, 9 and 10 of Period 1, faecal grab samples were taken per rectum at three collection times, which were 09.00 h, 13.00 h and 16.00 h. On day 8 the faecal samples from each ewe for each of the collection times were kept separately, and the three faecal samples per ewe were subsequently amalgamated with the separate faeces samples from the three respective collection times on days 9 and 10. Hence there were three combined 3-day samples per ewe for each sampling time at the end of the three day collection period. The faeces samples were dried, milled and analysed for chromium.

Allocation of bedding straw to each of the individual pens was restricted throughout Period 1 and the pens were not bedded at all on days 7 to 10 (inclusive) of the experimental period.

The mean faecal chromium concentration for each ewe was calculated from the three individual faecal chromium concentrations of the three combined 3-day samples for each collection time (3 observations per

ewe). The mean faecal chromium concentration for each ewe, thence became the x component of the regression equation which was subsequently computed with the corresponding allocated feed dry matter intake values (y).

In Period 2, which followed immediately after Period 1, the same experimental procedure was adopted as in Period 1, apart from allocation of chromic oxide. The ewes were each given 0.143 kg DM/day of a barley/chromic oxide pelleted cube, in place of an equivalent quantity of complete diet dry matter, with the morning feed allocation only (07.30 h) to imitate the once per day (at 9.00 h) allocation of the gelatin capsule (which contained chromic oxide) in Period 1. The allocation of 0.143 kg DM/head/day of the barley/chromic oxide cube was formulated to supply 1.0 g of chromic oxide to the ewes, which was equivalent to the allocation of chromic oxide from the gelatin capsules. In effect the concentration of chromic oxide in the barley/chromic oxide cube was 7.09 g/kg DM; therefore 0.143 kg DM of the cube supplied 1.01 g of chromic oxide. A similar faecal grab sampling pattern to that of Period 1 was adopted in Period 2, such that there were three combined 3-day samples per ewe for each sampling time (09.00 h, 13.00 h and 16.00 h) at the end of the three day collection period.

Again the allocation of straw bedding was restricted in Period 2 and the pens were not bedded at all on days 7 to 10 (inclusive).

The faeces samples were dried, milled and analysed for chromium. The mean faecal chromium concentration, for each ewe, was calculated from the three individual faecal chromium concentrations of the three combined 3-day samples (for each collection time), and was subsequently used as the x component in the regression equation computed against the respective allocations of feed dry matter as the y component.

Results

The ewes and lambs remained healthy throughout the experiment, and the lambs had a mean liveweight gain of 430 ± 114 g/day. All the ewes were notably hungry in both Period 1 and Period 2, particularly those given 1.25 and 1.46 kg DM/day. The allocations of the complete diet were usually completely consumed in 30-45 minutes.

When fresh bedding straw was supplied (sparingly) to each pen, it was readily consumed by the ewes. Several ewes spilled part of their feed allocation onto the floor outside their pens, since the feed buckets had been placed outside the pens. Any unsoiled material was retrieved at the end of feeding time and replaced in the buckets. Accordingly very little feed was wasted in this manner and the ewes ate substantially all of their allocated feed.

Faecal samples were obtained per rectum. If the ewe was empty, the freshest sample was obtained from the bedded floor. There were notable differences in the consistency of the faeces, as in Experiment 2.1, with increasingly hard pellets with decreasing feed allocation.

The individual faecal chromium concentrations for each of the sampling times (09.00 h, 13.00 h and 16.00 h) and the corresponding means concentrations for each ewe (x component of the regression equations) and the mean faecal chromium concentrations for the group for both Period 1 and Period 2 are presented in Table 34. There appears to be a different pattern of faecal chromium excretion between the two forms of presentation of chromic oxide, in that the excretion of chromium in the faeces between the ewes in Period 1 (gelatin capsules) followed an apparantly more consistent pattern than between the same ewes in Period 2 (chromic oxide incorporated into feed matter). In effect the faecal chromium concentration was generally greatest at 09.00 h than at 13.00 h and 16.00 respectively, for most of the ewes, (mean faecal chromium concentration 1.39, 0.94 and 0.91 g/kg respectively), when chromium was presented in gelatin capsules, even although none of the differences between the respective mean faecal chromium concentrations was statistically significant ($P>0.05$).

Table 34 Individual faecal chromium concentrations (g/kg) from each faecal sampling time (09.00 h, 13.00 h and 16.00 h) and the corresponding means for each ewe and group means for Period 1 and Period 2

		Period 1				Period 2			
Method of chromic oxide administration		Gelatin Capsules				Incorporated into feed dry matter allocation.			
Feed allocation (kg DM/head)	Ewe	09.00h	13.00h	16.00h	Mean	09.00h	13.00h	16.00	Mean
1.25	11	1.45	1.10	1.14	1.23	1.34	1.74	1.75	1.61
	12	1.97	1.40	1.39	1.59	2.54	2.01	2.38	2.31
1.46	2	1.09	0.97	0.98	1.01	1.57	1.65	1.65	1.62
	3	3.38	2.15	1.87	2.47	2.95	2.32	2.30	2.53
1.66	5	1.22	0.83	0.73	0.93	1.27	1.10	1.14	1.17
	10	1.21	0.81	0.81	0.94	1.70	1.46	1.34	1.50
1.87	14	1.10	0.95	0.92	0.99	1.45	1.50	1.23	1.39
	1	1.09	0.88	0.75	0.91	0.44	1.54	1.37	1.11
2.08	13	0.87	0.45	0.50	0.61	1.10	0.93	1.20	1.08
	7	1.10	0.90	0.88	0.96	0.85	1.10	1.08	1.01
2.29	9	1.10	0.74	0.65	0.83	1.37	0.99	1.09	1.15
	6	1.07	0.89	0.88	0.95	1.41	1.28	1.07	1.25
2.50	4	0.82	0.64	0.76	0.74	0.99	0.85	0.90	0.91
	8	0.61	0.45	0.47	0.51	1.10	0.94	0.82	0.95
Mean		1.29	0.94	0.91	1.05	1.43	1.39	1.38	1.40
S.dev. ±		0.677	0.424	0.365	0.484	0.645	0.441	0.479	0.490

When the chromic oxide was presented with the feed dry matter (Period 2), there was no definite pattern between the ewes in the excretion of faecal chromium, and indeed, the mean faecal chromium concentrations were fairly constant (1.43, 1.39 and 1.38 g/kg) for faecal samples taken at 09.00h, 13.00h and 16.00h respectively.

The individual dry matter feed intake and the corresponding mean faecal chromium concentrations, for Period 1 and Period 2, are presented in Figure 3.

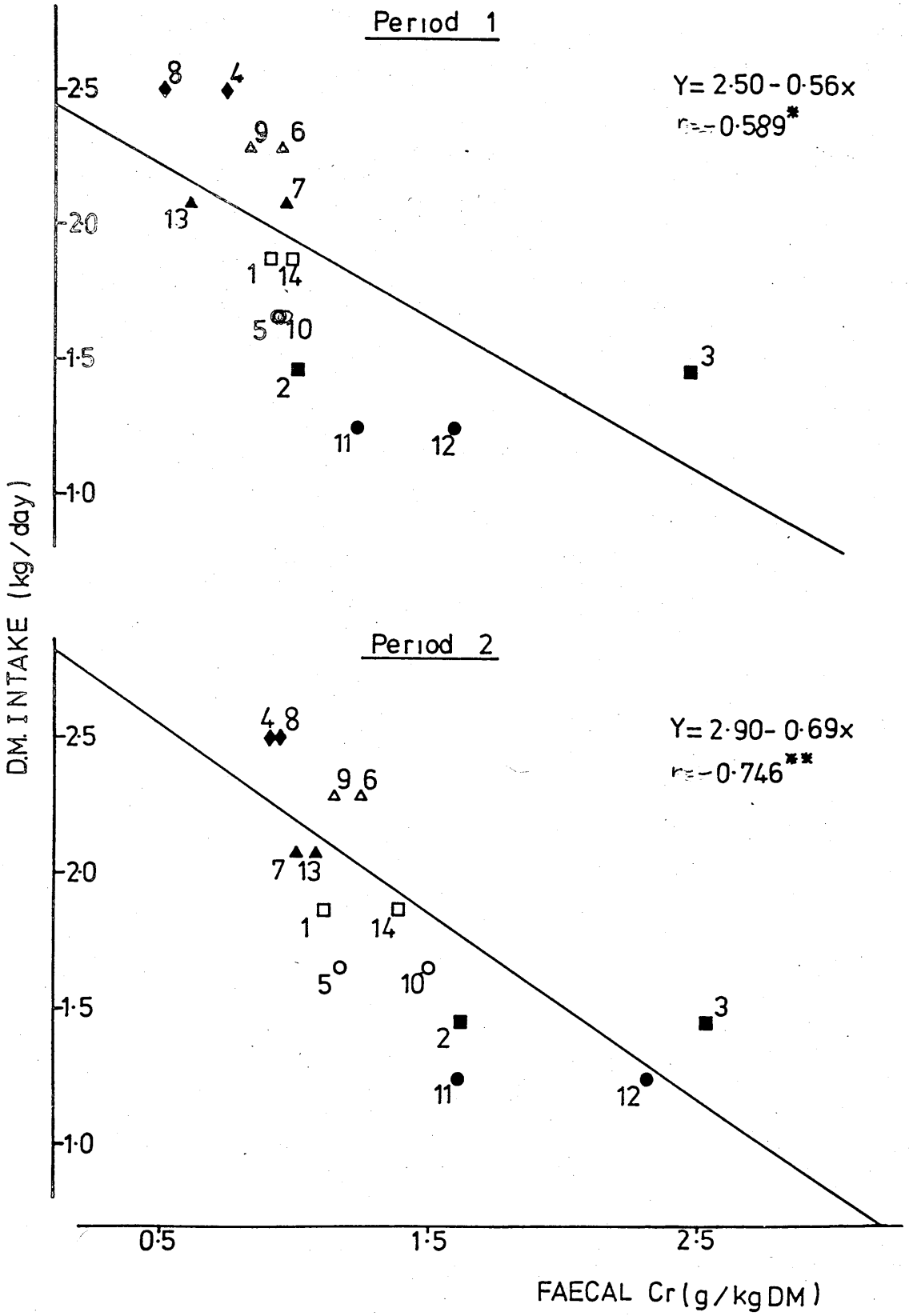
The regression equations computed between individual feed intake and the corresponding mean faecal chromium concentrations for both Period 1 and Period 2 are presented in Table 35.

Table 35 Regression equations computed between individual intakes of a complete diet and the corresponding mean faecal chromium concentrations of three combined 3-day samples taken at 09.00h, 13.00h and 16.00h respectively

Period	Regression equation y = feed DM intake kg x = faecal chromium concentration g/kg DM	Error associated with prediction of y ±	r^2%	Stat. Signif. P
1	y = 2.50 - 0.56 x (Equation 1)	0.35	34.8	0.05
2	y = 2.90 - 0.69 x (Equation 2)	0.29	55.6	0.01

The computed regression relationships for Period 1 (chromic oxide presented in gelatin capsules) and Period 2 (chromic oxide presented with the feed dry matter) were both statistically significant ($y = 2.50 - 0.56 x$, $P<0.05$ and $y = 2.90 - 0.69 x$, $P<0.01$ respectively). The error associated with the prediction of the mean feed intake (mean intake of 1.87 kg DM) was marginally larger (±0.35) for equation 1 (y=2.50-0.56x) than for equation 2 (y=2.90-0.69x) where the error was ±0.29.

Figure 3 Calibration equation for Period 1 and Period 2 where y = dry matter intake and x = faecal chromium concentration of grab samples (* $P < 0.05$, ** $P < 0.01$). Paired symbols e.g. ● ● , ▲ ▲ , indicate paired ewes.


Period 1
Y= 2·50 - 0·56x
r= -0·589*
Period 2
Y= 2·90 - 0·69x
r= -0·746**
D.M. INTAKE (kg/day)
2·5
2·0
1·5
1·0
0·5
1·5
2·5
FAECAL Cr (g/kg DM)

Discussion

The successful development of a statistically significant regression relationship, in the present experiment, between individual intakes of the complete diet and the corresponding mean faecal chromium concentrations of grab samples ($y = 2.50 - 0.56x$, $P<0.05$), where the chromium concentration was derived from chromic oxide in gelatin capsules, may have been effected by the more restricted allocation of bedding straw and the method of faecal sampling compared with Experiment 2.1, where the regression relationship between similar parameters was not statistically significant. It is likely that less bedding straw was consumed in the present experiment and consequently the influence of one of the factors which may have altered the faecal chromium concentration of grab samples was reduced. The method of grab sampling employed in the present experiment may have been less susceptible to sampling errors compared to Experiment 2.1, where all the nine faeces grab samples from each ewe, obtained during the three day collection period, were bulked together and subsampled prior to oven drying and analysis for chromium. It is possible that inadequate mixing, before subsampling, of these bulked faeces samples may have contributed to any unrepresentative faecal chromium concentrations.

When chromic oxide was presented with the feed dry matter (Period 2) the resulting regression relationship ($y = 2.90 - 0.69\ x$, $P<0.01$) had a reduced error associated with the prediction of y (± 0.29) compared with an error of ± 0.35 from the regression relationship established in Period 1, which may be as expected since error associated with possible regurgitation and/or loss of capsules were not present in Period 2.

The method of administration of chromic oxide, either in gelatin capsules (Period 1) or mixed with the feed dry matter (Period 2), apparently influenced the excretion patterns of chromium in the faeces. The mean faecal chromium concentrations from the grab samples taken at 09.00h, 13.00h and 16.00h during Period 1 (1.29, 0.94 and 0.91 g/kg DM respectively) were more disparate (particularly between 09.00h and 13.00h), although not statistically so, than the corresponding faecal chromium concentrations of Period 2 (1.43, 1.39 and 1.38 g/kg DM respectively) which were fairly constant. This may indicate that chromium is more easily equilibrated within the gastrointestinal tract when chromium is presented with the feed than from gelatin capsules.

Consequently there may be implications in the choice of chromic

oxide administration (either from capsules or mixed in the feed) where the chromium concentration of single grab samples of faeces are taken to be representative of individual feed intake. The administration of chromic oxide from capsules (given once per day) may be more likely to result in unrepresentative faecal chromium concentrations of single grab samples compared to when chromic oxide is well mixed with the feed allocations, with subsequent effects on the extrapolated feed intake data.

In the present experiment the apparent difference in the faecal chromium excretion patterns between Period 1 and Period 2, may not have been observed had one gelatin capsule per head, containing chromic oxide, been given to the ewes at each feeding time (i.e. two gelatin capsules/head/day). The chromium may have been better equilabrated in the gastrointestinal tract by this method.

Nevertheless, the regression equation ($y = 2.50 - 0.56\ x$) computed in Period 1, where chromic oxide was presented in gelatin capsules, was subsequently used in Experiment 2.3 to estimate the individual intake of the same complete diet, as in the present experiment, when it was allocated on a group basis to lactating ewes with twin lambs at foot.

Experiment 2.3 Application of the calibration equation $y = 2.50 - 0.56x$ to determine the individual feed intakes (y) of group fed ewes using the faecal chromium concentrations (x) of grab samples.

Introduction

The previously established regression equation (Experiment 2.2), $y = 2.50 - 0.56\ x$, was used in the present experiment to predict individual ewe dry matter intake (y), within two groups of lactating ewes with twin lambs, using the faecal chromium concentration (x) of grab samples. The variation in individual feed intake could therefore be assessed. The two groups (Group 1 and Group 2) acted as replicates (Group 1 n = 18, Group 2 n = 15). The experiment lasted six weeks and consisted of two periods each of three weeks duration. Faecal sampling was carried out towards the end of each three week period. After the first three weeks the lambs had access to ad libitum creep feed.

The ewes were allocated sufficient feed to provide a mean amount of about 20 MJ ME per head per day from a complete diet (11.2 MJ ME per kg DM) which consisted of a loose mix of shredded molassed sugar beet pulp, soya bean meal and barley husk siftings (Table 31 (A) and (B) in Experiment 2.1). The ration was insufficient to fully satisfy the ME allowance of 27.6-28.6 MJ ME for 60-70 kg lactating ewes with twin lambs (MAFF 1984). It was, however, expected to encourage a competitive eating situation. To fully meet this specified allowance, with the given complete diet, an allocation of 2.5 kg DM per ewe (instead of 1.8 kg DM per ewe) would be necessary. However, to meet this deficit in their energy requirements the ewes were expected to mobilise their energy reserves and consequently a liveweight loss of 0.25 kg/day for each ewe was anticipated (MAFF 1984). However, the ewes were very restless during the first period and it was assumed that the supplied ration was inadequate. Hence their daily feed allocation was increased from 1.8 to 2.1 kg DM/head/day, at the beginning of the second period. The variation in individual feed intake was therefore established under two levels of feed allocation, which varied in their degree of restriction.

The probable relationship between ewe dry matter intake and lamb liveweight gain was examined.

Materials and Methods

Two groups (Group 1, n = 18, Group 2, n = 15) of lactating, mainly Greyface ewes (Border Leicester x Scottish Blackface) of mixed ages and with mean liveweights 66 ±8 kg and 64 ± 10 kg respectively, were assembled with their respective twin lambs (mean liveweight of Group 1 lambs was 5.7 ± 0.98 kg and Group 2 lambs was 5.7 ± 1.30 kg) into two loose housing areas allowing about 4.5 m^2/head and bedded with barley straw.

During the first three weeks, 2.1 kg FM/head/day (equal to 1.8 kg DM/head/day) of the complete diet (Table 31, Experiment 2.1) was offered to both groups, behind a feed barrier with no vertical divisions, which allowed 0.45 m headspace per ewe, in two equal feeds at 07.30 h and 16.00 h. The ewes were observed at feeding times.

After a preliminary seven day period, during which time the ewes became adjusted to the diet, chromic oxide capsules (containing 1.0 g chromic oxide each) were administered once per day (one capsule per ewe) at 09.00 h for the following ten days. On days 8-10 (inclusive) of this period faecal grab samples were obtained per rectum once per day at 09.00 h. The samples were combined over the three day collection period and subsequently dried, milled and subsampled prior to chromium analysis.

Bedding straw was sparingly allocated in the housed area during days 1 to 6 of the ten day experimental period. On days 7 to 10 (inclusive) the housed areas were not bedded at all, in order to comply with the conditions of Experiment 2.2, where the calibration equation was computed.

At the beginning of week 4 all the ewes and lambs were weighed. Pelleted creep feed was offered to the lambs (mean age 28 days) for the first time at the beginning of week 4. The proximate analysis of the creep feed is presented in Table 33, Experiment 2.2. Simultaneously the feed allocated to the ewes was increased from 2.1 to 2.5 kg FM/head/day. The procedure outlined above for weeks one to three was repeated during weeks four to six. Faecal grab samples were obtained as before over a 3-day period at the end of week 6 and subsequently analysed for chromium. At the end of the six week period, all ewes and lambs were re-weighed. When the faecal chromium concentrations had been determined, individual dry matter intakes were predicted using the equation $y = 2.50 - 0.56 x$ (Experiment 2.2).

Results

One of the ewes in Group 1 was removed from the experiment at the end of the first period as one of her lambs died. Hence Group 1 consisted of 17 ewes and 34 lambs in the second period. All the other ewes and lambs in both groups remained healthy. The mean daily liveweight changes of the ewes and lambs are shown in Table 36. During weeks 1 to 3, the mean daily liveweight loss of the ewes in Group 2 (-0.12 kg/day) was significantly greater ($P<0.001$) than that of the ewes in Group 1 (-0.05 kg/day). However, during weeks 4 to 6 the mean daily liveweight loss of the ewes in Group 2 (-0.02 kg/day) was significantly less ($P<0.001$) than that of the ewes in Group 1 (-0.24 kg/day). There was no difference in mean daily lamb liveweight gain in weeks 1 to 3 (0.26 kg for the lambs in Groups 1 and 2). During weeks 4 to 6 the lambs from Group 2 had a significantly larger liveweight gain (0.32 kg/day $P<0.01$) than the lambs from Group 1 (0.27 kg/day).

The ewes readily came forward to consume the feed allocation as soon as it was placed into the troughs. All the ewes quickly settled down and persevered at the troughs until the allocation was cleared. There were no obvious cases of bullying between the ewes. The mean time taken to completely consume the allocation of the complete diet, at each feeding time, was 20 minutes for each group during weeks 1 to 3. During weeks 4 to 6 the mean time to clear the feed slightly increased to 25 minutes. In this latter period the lambs participated in the consumption of the feed offered to the ewes, even although the lambs were allocated pelleted creep feed and hay on an ad libitum basis. However, the proportion of the feed allocated to the ewes which was consumed by the lambs was assumed to be fairly small. During weeks 4 to 6, the lambs from Group 1 and Group 2 consumed 0.78 kg DM/head/day and 0.68 kg DM/head/day of the pelleted creep feed respectively.

When bedding straw was allocated in the loose housing area, albeit at a restricted level, it was usually readily consumed by the ewes from both groups, during both periods of the experiment.

The individual faecal chromium concentrations from Group 1 and Group 2 were substituted for x in the prediction equation $y = 2.50 - 0.56x$ (calculated in Experiment 2.2). The mean faecal chromium concentrations for each group are presented in Table 37. The mean faecal chromium concentrations were similar for Group 1 and Group 2 during weeks 1 to 3 (1.22 and 1.30 g/kg DM respectively) and decreased marginally to 1.18 and 1.10 g/kg respectively, in weeks 4 to 6 when 2.1

kg DM/head/day of the complete diet was allocated to the ewes instead of 1.8 kg DM/head/day during weeks 1 to 3. The coefficients of variation of the faecal chromium concentrations ranged from 29.3% (weeks 1 to 3, Group 1) to 71.9% (weeks 1 to 3, Group 2). However, the latter coefficient of variation was reduced to 19.7% by exclusion of three particularly high faecal chromium concentrations. Nevertheless the relatively high coefficient of variation of 71.9% is perhaps illustrating the greater range of feed intake in the group when a more restricted quantity of the complete diet was allocated (1.8 kg DM/head/day) during weeks 1 to 3, compared with 2.1 DM/head/day during weeks 4 to 6. However a similar effect was not observed by comparison of the corresponding coefficients of variation for Group 1.

The calculated individual dry matter intakes, and the mean group intakes ($\pm$S.dev) for weeks 1 to 3 and weeks 4 to 6 are presented in Table 38. During weeks 1 to 3, the ranges of dry matter intake for the ewes in Group 1 and Group 2 were 1.4 to 2.1 kg DM and 0.6 to 2.2 kg DM respectively. The mean dry matter intake for each group was comparable to the allocated quantity of 1.8 kg DM which confirms the efficacy of the prediction equation. Three of the ewes in Group 2 consumed less than or equal to 1.0 kg DM/head which probably accounts for the larger coefficient of variation of dry matter intake of 30.3% for Group 2, compared with 11.3% for Group 1. Nevertheless, exclusion of the three low intake values from Group 2 (i.e. less than or equal to 1.0 kg DM) reduced the coefficient of variation from 30.3% to 6.0%.

In Group 1, 11 of the 18 ewes (61%) consumed between 1.8 and 2.1 kg DM (i.e. at or above their allocation of 1.8 kg DM/head). In Group 2, 12 of the 15 ewes (80%) consumed between 1.8 and 2.2 kg DM (i.e at or above their allocation). Indeed, most of the ewes in the latter group, had individual dry matter intakes of greater than 2.0 kg.

Table 36 Mean daily liveweight changes of ewes and lambs (±S.dev) (kg/day)

	Weeks 1-3		Weeks 4-6	
Liveweight change	Ewe	Lamb	Ewe	Lamb
Group 1	-0.05(±0.16)	+0.26(±0.07)	-0.24(±0.15)	+0.27(±0.07)
Group 2	-0.12(±0.23)	+0.26(±0.07)	-0.02(±0.18)	+0.32(±0.07)
Difference in liveweight change between groups	0.07***	0	0.22***	0.05**

** P<0.01 *** P<0.001

Table 37 Mean faecal chromium concentrations (±S.dev) for Group 1 and Group 2 during weeks 1-3 and 4-6

	Group 1		Group 2		
Faecal chromium concentration (g/kg DM)	Weeks 1-3	Weeks 4-6	Weeks 1-3		Weeks 4-6
n	18	17	15	12+	15
Mean	1.22	1.18	1.30	0.86	1.10
S.dev ±	0.358	0.548	0.934	0.169	0.483
CV%	29.3	46.4	71.9	19.7	43.9

+ Excluding three particularly high faecal chromium concentrations (2.57, 3.27 and 3.33 g/kg DM).

Table 38 Predicted ewe dry matter intake kg DM/day (from y=2.50-0.56x) during weeks 1-3 and weeks 4-6 for Group 1 and Group 2

Group 1			Group 2		
Ewe No.	Weeks 1-3	Weeks 4-6	Ewe No.	Weeks 1-3	Weeks 4-6
DM allocated kg/head	1.8	2.1		1.8	2.1
01	2.1	2.0	19	2.1	1.9
02	2.1	2.1	20	0.7	1.2
03	1.7	1.4	21	1.9	2.0
04	1.8	2.1	22	2.1	2.0
05	1.9	1.9	23	0.6	2.1
06*	1.7	-	24	2.0	2.0
07	1.9	1.9	25	1.9	2.0
08	1.9	1.8	26	1.9	1.9
09	2.0	2.1	27	2.1	2.0
10	2.0	2.2	28	1.8	1.9
11	1.6	1.8	29	2.1	1.8
12	1.4	1.6	30	2.2	2.1
13	1.5	1.1	31	2.0	1.9
14	2.0	1.8	32	1.9	2.0
15	1.9	1.9	33	1.0	1.3
16	1.6	2.0			
17	1.8	2.1			
18	1.7	1.4			
n	18	17		15	15 (12+)
Mean (kg)	1.8	1.8		1.8	1.9 (2.0)
S.dev ±	0.20	0.29		0.53	0.27 (0.12)
CV%	11.3	16.4		30.3	14.2 (6.0)

* Ewe 6 removed from experiment during weeks 4-6 after one of her lambs died.

+ Exclusion of intakes less than or equal to 1.0 kg DM in Group 2 (weeks 4-6).

During the weeks 4-6 the range of calculated dry matter intakes for the ewes in Group 1 and Group 2 were 1.1-2.2 kg DM and 1.2-2.1 kg DM respectively. The coefficients of variation for feed dry matter intake were similar (16.4 and 14.2% for Group 1 and Group 2 respectively). In Group 1, 5 of the 17 ewes (29%) consumed 2.1-2.2 kg DM (i.e. at or above the feed allocation of 2.1 kg DM/head). In Group 2, 2 of the 15 ewes (13% consumed 2.1 kg DM (equal to the quantity of feed allocated). In effect the predicted mean intakes for Group 1 and Group 2 were 1.8 kg DM and 1.9 kg DM respectively.

The prediction equation had produced estimations of individual dry matter intake which were in effect 15% less and 10% less, for Groups 1 and 2 respectively, than the mean allocated quantity of 2.1 kg DM/head. The interference by the lambs at feeding time may partly account for the underestimations of dry matter intake during week 4-6. In effect the lambs from Group 1 and Group 2 are likely to have consumed 0.15 kg DM/head/day and 0.10 kg DM/head/day respectively (underestimations of total group allocation of 5.1 kg DM and 3.0 kg DM respectively).

Absolute and rank order correlation coefficients were computed between the combined feed dry matter intakes of the ewes from Group 1 and Group 2 during weeks 1 to 3 and the corresponding combined feed intake data from weeks 4 to 6. The absolute and rank order correlation coefficients were 0.526 ($P<0.01$) and 0.439 ($P<0.05$) respectively.

Ewe liveweight changes were correlated with the corresponding ewe dry matter intakes. In Group 1, the correlation coefficients were 0.355 and 0.086 for weeks 1 to 3 and weeks 4 to 6 respectively. Neither was statistically significant ($P>0.05$). In Group 2, the correlation coefficients were 0.692 ($P<0.01$) and 0.143 ($P>0.05$) for weeks 1 to 3 and weeks 4 to 6 respectively.

Lamb weight gain (total weight gain for each set of twins), combining the data from Group 1 and Group 2, was correlated with ewe dry matter intake for weeks 1 to 3 and weeks 4 to 6. The correlation coefficients were 0.532 ($P<0.01$) and 0.390 ($P<0.05$) for weeks 1 to 3 and weeks 4 to 6 respectively.

Discussion

The regression equation ($y = 2.50 - 0.56 x$) successfully predicted the individual dry matter intakes for the ewes in Group 1 and Group 2 during weeks 1 - 3. The predicted mean intake of 1.8 kg DM was comparable to the allocated quantity. The apparent accuracy of the prediction equation therefore justifies the technique by which it was derived (Experiment 2.2). The coefficients of variation for dry matter intake for Groups 1 and 2 were somewhat different (11.3% and 30.3% respectively). However, the large coefficient of variation for Group 2 was accounted for by the three ewes which only consumed 0.6 - 1.0 kg DM/head. Indeed the exclusion of the dry matter intakes of these three ewes in Group 2, reduced the coefficient of variation to 6.0%. The resulting metabolisable energy intakes of the ewes were of the same range and variation as the dry matter intakes. In effect the range of daily metabolisable energy intakes (20 MJ ME allocated/head) for Group 1 and Group 2, during weeks 1 to 3, were 15.7 - 23.5 MJ ME and 6.7 - 24.6 MJ ME respectively. Most of the ewes from Group 1 and Group 2 did, indeed, consume their allocation of ME (61% and 80% respectively). However, three of the ewes from Group 2 only consumed between 34% and 56% of their allocation of ME, which is further emphasised by considering the extent to which these ME intakes fall short of the ME allowance of 27.6 MJ ME/head (25%-42% respectively). Consequently, two of the ewes (20 and 23) had an average daily liveweight loss of -0.36 kg and -0.31 kg respectively, compared with the group mean of -0.12 kg. However, Ewe 33, which consumed 1.0 kg DM during week 1-3 (equivalent to 56% of the ME allocation and 42% of the ME allowance) showed a mean liveweight gain of 0.1 kg/day over the corresponding period.

The predicted dry matter intakes for weeks 4-6 did not correspond to the allocated quantity of feed. The previously established efficacy of the prediction equation to estimate individual dry matter intake from faecal chromium concentration, suggests that the predicted intakes during weeks 4-6 are indeed accurate. The participation of the lambs, when the ewes were offered the complete diet, is likely to have caused the underestimation of individual ewe intake. In effect the small quantities (mean intakes of 0.15 kg DM/head and 0.10 kg DM/head for Group 1 and Group 2 respectively) consumed by the lambs are an acceptably low proportion. Access to creep feed by the lambs was likely to reduce the nutritional requirements of the ewes, and was perhaps partly responsible for the fairly low coefficients of variation

of mean dry matter intake for Group 1 and Group 2 (16.4% and 14.2%) observed during weeks 4-6. Consequently the ranges of ME intakes for the ewes in each group (12.3-24.6 MJ ME and 13.4-23.5 MJ ME for Groups 1 and 2 respectively) were not as exaggerated as in the previous period, particularly for Group 2. However, only 29% and 13% of Group 1 and Group 2 respectively, consumed their ME allocation, due to the interference by the lambs.

The statistical significance of both the absolute correlation coefficient and the rank order correlation coefficient, computed between the combined feed intake data for Group 1 and 2 from weeks 1-3 and weeks 4-6 ($0.526, P<0.01$ and $0.439, P<0.05$), indicate that the pattern of intake between the ewes during weeks 1-3 was repeated during weeks 4-6 and perhaps further substantiates the efficacy of the calibration equation in the prediction of individual feed intake.

There were two degrees of feed restriction in the present experiment in that approximately 70% and 85% of the required quantity (MAFF, 1984) of feed was allocated during weeks 1-3 and 4-6 respectively. The coefficients of variation throughout this experiment were faily low and similar (range of 11.3-16.4% except for Group 2 during weeks 1-3 (30.3%) which was accounted for by three ewes with low intakes), which suggests uniformity of dry matter intake within the groups, irrespective of the degree of feed restriction. In effect, the coefficients of variation may have been expected to be smaller where the allocation of feed was more liberal (weeks 4-6) (see General Introduction and Literature Review). However, interference by the lambs in the consumption of the allocated feed may have prevented this effect from being observed. Indeed, the degree of restriction may still not have been sufficiently liberal to influence the pattern of feed intake.

The absence of statistically significant correlation coefficients between ewe liveweight changes and the corresponding feed dry matter intakes of the ewes, apart from in Group 2 during weeks 1 to 3 ($r = 0.692$, $P<0.01$), was perhaps unexpected but may indicate that the response to current nutritional inputs, in terms of liveweight change, may not be readily observed within a three week period. Indeed carry-over effects from the nutritional status of the ewes prior to parturition may be confounding the response in terms of liveweight change. Furthermore, within the groups the ewes are likely to have different abilities to mobilise energy reserves as well as different

milk yield potentials which will also confound any response to nutritional status (i.e. quantity of feed dry matter consumed) in terms of liveweight change.

Nevertheless, in Group 2 during weeks 1 to 3, 47.8% (r^2= 0.478) of variation in ewe liveweight change was accounted for by ewe feed dry matter intake and it may well be the case that this group of ewes was fairly uniform in terms of mobility of energy reserves, milk yield potential and carry-over effects from nutritional status prior to parturition. However, the influence of creep feed allocation to the lambs, during weeks 4 to 6, may have subsequently prohibited the establishment of a statistically significant correlation coefficient (r=0.143) between ewe liveweight change and feed dry matter intakes of the ewes during this period. Indeed the mobilisation of energy reserves was much reduced in the ewes in Group 2 during weeks 4 to 6 where the mean liveweight change was -0.02 ($\pm$0.18) kg/day, which may indicate less stress on the ewes possibly caused by the increased allocation of feed to the ewes during weeks 4 to 6, or the availability of ad libitum creep feed to the lambs.

The correlation coefficients for ewe dry matter intake (results from Group 1 and 2 combined) and lamb liveweight gain, for both periods, were statistically significant (0.53, $P<0.01$ and 0.39, $P<0.05$ for weeks 1 to 3 and 4 to 6 respectively). However, only 27.6% and 15.6% (Group 1 and Group 2 respectively) of the variation in lamb liveweight gain was accounted for by the ewe dry matter intake. This is perhaps what would be expected in view of the multitude of other factors which govern lamb liveweight gain (e.g. hybrid vigour, (lambs were Greyface x Suffolk), potential of the ewe to mobilise energy for milk production). The correlation coefficient was less during weeks 4 to 6 (0.39) than weeks 1 to 3 (0.53), when creep feed was offered to the lambs on an ad libitum basis, and this is the normally expected result.

Experiment 2.4. Determination of the uniformity of feed intake as influenced by the method of feed presentation (from troughs or a feedring or behind a barrier)

Introduction

Three alternative methods (troughs, feedring and feedbarrier) of presentation of the complete diet, previously offered in Experiments 2.1-2.3, on a group basis were investigated to quantify the range of individual dry matter intake in a group of 18 ewes with single lambs at foot.

Materials and Methods

Eighteen lactating mainly Greyface ewes (Border Leicester x Scottish Blackface) of mean liveweight 75 kg, were assembled in a loose housing area of about 40 m^2 (barley straw bedding) with their respective single lambs (mean age 21 days and mean liveweight 12 kg). A separate creep area was accessible to the lambs. In each of the three experimental periods the ewes were allocated 1.8 kg DM/head/day of the complete diet previously described in Experiment 2.1 (Table 31), in two equal feeds at 07.30 h and 16.00 h. The allocation of 1.8 kg DM/head provided approximately 20 MJ of metabolisable energy/head which was nearly sufficient to fully satisfy the metabolisable energy allowances, for ewes with single lambs, of 21.3-22.3 MJ ME/day (for ewes of 70 and 80 kg respectively) (MAFF 1984). This was consequently a more liberal allocation of feed than had been given to ewes with twin lambs in Experiment 2.3, where the allocation per head provided only approximately 70% of required ME allowance (compared with approximately 90% of the required ME allowance in the present experiment) during weeks 1 to 3.

There were three methods of feed presentation which were respectively used in Periods 1, 2 and 3 each of which were of 10 days duration (Table 39). In Period 1, the group of ewes was allocated the complete diet (1.8 kg DM/head/day) from three troughs, where the ewes had access to the allocated feed at both sides. In Period 2, which proceeded immediately after Period 1, the ewes were allocated the complete diet from an oval shaped feedring which had not previously been used by this group of ewes. The vertical bars around the feedring prohibited the ewes from pushing each other about, once their heads were in position. In Period 3, which proceeded immediately after

Period 2, the ewes had access to their allocation of the complete diet from behind a feed barrier at which they had access to the ration from one side only. Access to the other side of the barrier was restricted by a horizontal bar. There were no impeding vertical or diagonal bars along the feed barrier itself.

Table 39 Experimental design

Period (each of 10 days duration)	Method of feed presentation	Description
1	Troughs	3 troughs with access on both sides allowing 0.96 m/head (0.48 m on one side)
2	Feedring	Oval shaped feedring, 2.5 m in length. Vertically placed metal bars providing 28 head spaces each of 0.23 m, allowing 0.36 m per head for the group of 18 ewes.
3	Feed barrier	Troughs (0.25 m deep) with access to one side restricted by a horizontal bar 0.50 m from top of troughs, 0.45 m/head.

Following a five day preliminary period, during which time the ewes became used to the diet, a chromic oxide capsule (containing 1 g chromic oxide) was administered to each ewe, once per day 09.00 h, over a 30 day period. On days 8, 9 and 10 of each experimental period, the ewes were grab sampled (per rectum) at 09.00 h; the faecal samples were composited over the three days, dried, milled and subsampled prior to chromium analysis.

Bedding straw was sparingly allocated during day one to day six of each experimental period. During days seven to 10 of each experimental period no bedding straw was allocated in order to comply with the

experimental conditions under which the prediction equation had been computed (Experiment 2.2).

Individual ewe dry matter intake was predicted using the equation $y=2.50-0.56x$ (from Experiment 2.2), and the coefficient of variation for dry matter intake was established.

The ewes and lambs were weighed at the beginning and end of the experiment. The lambs had access to ad libitum creep feed (concentrate and hay) throughout the 35-day period. The proximate analyses of the lamb creep feed and hay are presented in Table 33, Experiment 2.2.

Results

The ewes and lambs remained healthy throughout the experiment and the mean liveweight gain of the lambs was 0.38 (±0.06) kg/day. As the experiment progressed (from Period 1 to Period 3) there was increasing competition between the ewes and lambs for the ewes' feed allocation, even although the lambs had access to ad libitum hay and creep feed. Interference from the lambs, in this respect, was particularly noticeable when the ewes were fed from behind the barrier (Period 3). All the ewes came forward to the feeding area (troughs, feedring or barrier) at feeding time and persevered until all the feed was cleared. The time taken for the ewes to complete the allocated rations of the complete diet was similar for all three methods of feed presentation, and was usually within 25-30 minutes. The behaviour of the ewes was particularly fractious when the complete diet was presented from the feedring (Period 2), with frequent changes of position by the ewes.

The mean faecal chromium concentrations (± S.dev) and the mean predicted feed dry matter intakes (± S.dev) of the ewes (predicted from equation $y=2.50-0.56x$, Experiment 2.2) for each method of feed presentation (Periods 1 to 3) are presented in Table 40.

Table 40 Mean faecal chromium concentrations and mean predicted dry matter intakes of the complete diet (1.8 kg DM given) for each method of feed presentation.

Period	1	2	3
	Troughs	Feedring	Feed barrier
Faecal chromium concentration g/kg DM			
Mean	1.05	1.33	1.30
S.dev.±	0.292	0.373	0.250
C.V.%	27.8	28.1	19.3
Predicted dry matter intake (kg)			
Mean	1.9	1.8	1.8
S.dev.±	0.17	0.21	0.14
C.V.%	8.7	11.6	7.8
Range (kg)	1.5-2.1	1.3-2.1	1.5-1.9

The mean faecal chromium concentration increased marginally from Periods 1 to 3 from 1.05 g/kg DM to 1.33 g/kg DM, which may reflect the possible increasing interference by the lambs in Period 2 and 3, whereby some of the ewes' feed allocation had been consumed. Thus the chromium supplied by the capsules has not been diluted by undigested feed material to the same degree in Periods 2 and 3, as in Period 1. Nevertheless, the predicted mean feed dry matter intake corresponded with the allocated quantity of 1.8 kg DM/head, although the predicted quantity in Period 1 was marginally greater (1.9 kg DM/head) than the allocated quantity, which may be due to sampling error.

During Period 1, when the allocation of the complete diet was presented from three troughs, 83% of the ewes in the group consumed at or above their feed dry matter allocation of 1.8 kg DM/head. For both Periods 2 and 3 (where the complete diet was presented from a feedring and from behind a feed barrier, respectively) 55% of the group consumed at or above their allocation of 1.8 kg DM/head of the complete diet.

Absolute correlation and rank order correlation coefficients were computed for ewe dry matter intake between the three different methods of feed presentation and the results are presented in Table 41. The absolute correlation coefficients between the individual feed intakes when the complete diet was presented from the feedring compared with from behind a barrier (0.595) and between the feedring and troughs (0.526) were both statistically significant ($P<0.05$). None of the rank order correlation coefficients was statistically significant ($P>0.05$).

Table 41 Absolute correlation and rank order correlation coefficients for individual ewe feed intake under three different methods of feed presentation.

	Troughs/ Feedring	Troughs/ Feed barrier	feedring/ Feed barrier
Correlation coefficient of ewe dry matter intake	0.526*	0.420	0.595*
Rank order correlation coefficient	0.450	0.299	0.371

The lambs consumed a total of 85.32 kg DM of the pelleted creep feed during the 30 day experimental period i.e. 0.16 kg DM/head/day.

Discussion

The coefficient of variation of dry matter intake within the group for the alternative methods of feed presentation (Periods 1 to 3) were very similar, being less than 12% for all three methods. It would appear, by comparing the coefficient of variation for the three periods, that a more uniform intake of the complete diet was promoted (albeit perhaps a marginal difference) by presenting the complete diet behind a feed barrier (CV of 7.8%). This is more clearly emphasised by looking at the coefficient of variation for faecal chromium concentration (19.3% for behind a barrier compared with 27.8% and 28.1% for troughs and feedring respectively). However, lamb interference was observed to be greatest when the ewes' feed was presented behind the barrier.

Lamb interference (hence observed competition) increased from

Periods 1 to 3 and may be confounding the effect of change in the method of presentation of the complete diet. When the diet was presented in troughs in the first period and the lambs were only 21+ days old, 83% of the ewes ate at or above their allocated ration of 1.8 kg DM. Lamb interference was observed to be minimal in this period. In Periods 2 and 3, when the lambs were 30-40 days old and seen to be actively competing to a greater extent, 55% of the ewes (in both periods) ate at or above their allocated ration of 1.8 kg DM. It is difficult to assess whether or not this is an effect of competition from the lambs and/or methods of presentation of the feed.

The behaviour of the ewes was most fractious when the diet was presented in the feedring; the CV for DM intake is marginally larger (12%) here than in the other periods (8.7% and 7.8% for troughs and feed barrier respectively).

The statistically significant correlation coefficients for troughs versus feedring (0.526) and feed barrier versus feedring (0.595) suggests that use of the feedring to present the feed allocation is effecting the same pattern of feed intake among the ewes as that achieved by troughs and the feed barrier respectively. The same pattern of intake between the ewes was not repeated however when the feed was presented in troughs and behind the feed barrier (non significant correlation coefficient). The ranking order (non significant rank order correlations) was, however, not maintained throughout Periods 1 to 3 which probably reflects the degree of restriction of the feed allocation and the consequently low coefficients of variation of feed dry matter intake.

In conclusion, it would seem that the alternative methods of presenting the complete diet available in this experiment ensured (given possible error in the prediction equation) that between 55-83% of the ewes ate at or above their DM allocation, given lamb interference. None of the ewes grossly over or under ate in all three situations, as observed by the low coefficients of variation for DM intake (<12%). The effect of the lambs would have to be removed in order to better assess the effect of alternative methods of feed presentation. Access to greater amounts of feed or even ad libitum allocation of the complete diet may also alter the pattern of intake between the ewes.

Indeed, it may have been expected that a feedring would promote more uniform intake of feed in a group, due to the greater inability of

the ewes to move once in place at the feedring (Konggaard, 1983). The behaviour of the ewes was however observed to be most fractious when the feed was allocated from a feedring in comparison to from behind a barrier or from troughs.

The low coefficients of variation for all three methods of feed presentation may also reflect the reduced incidence of distinct positions of social rank in groups of sheep (Syme and Syme, 1979) whereby competative behaviour for feed may be less marked than in cattle for example.

Indeed, a more restricted allocation of the complete diet from behind a feed barrier to ewes with twin lambs at foot (Experiment 2.3 during weeks 1 to 3), where the allocation of feed was devised to provide only 70% of the ME allowances (compared with provision of 90% of the ME allowances by allocation of 1.8 kg DM in the present experiment), resulted in coefficients of variation of between 11.3% to 15.6% (where three low intake values from weeks 1 to 3 in Group 2 have been excluded). This indicates a marginally greater disparity of feed intake within the group of ewes compared with the relatively lower coefficient of variation of 7.8% (from the present experiment) where there was a more liberal allocation of the complete diet from behind a feed barrier. Furthermore the relatively more uniform feed intake in the present experiment, when the complete diet was presented from behind a feed barrier, may also reflect the possibly lower degree of nutritional stress on the ewes as thay only had single lambs at foot, compared with twin lambs at foot in Experiment 2.3.

SECTION 3

Experiment 3.1 Influence of physical form of diet on the individual intakes of metabolisable energy and digestible crude protein by two groups of ewes in late pregnancy.

Introduction

The ability to supply ewes in late pregnancy with an acceptable allowance of energy and protein is a critical factor in the achievement of a successful lambing performance in the flock. The physical form of diet offered to the ewes and its method of presentation may affect the uniformity of individual feed intake within the flock and possibly give rise to widely different intakes of both energy and protein. Foot and Russel (1973) observed a somewhat greater variation in dry matter intake (mean intake of 621 ± 139 g/kg, coefficient of variation of 22.3%) between 11 dry, non-pregnant group fed ewes, on a mainly pelleted diet (dried grass pellets and dried grass in a chopped form) compared with that between similar group fed ewes on a predominantly roughage diet (hay and oats) where the coefficient of variation for dry matter intake (mean 756 ±101 g/kg) was 13.3%. It was suggested that the physical form of the diet had determined the extent of the variation in individual intake through its effects on rate of consumption.

The possible variation in individual intake in a group of ewes in late pregnancy may have a deleterious influence on lambing performance. This may be the case even when it is anticipated that all (or the majority) of the ewes may be bearing twin lambs in an intensive situation or single lambs under poorer circumstances. The provision of a diet which results in individual intakes which do not differ greater from the mean group intake may be very pertinent in late pregnancy as both over and under nutrition may be harmful.

The present experiment investigates this concept by comparing a conventional hay and concentrates diet with a complete diet in loose form, in their ability to provide a uniform intake of energy and protein to Greyface ewes in late pregnancy. A high proportion of the ewes in each group were expected to be carrying twins, and so the diets were formulated for twin bearing ewes.

The experiment involved complete faecal collections, measurement of individual liveweight changes in the ewes and an assessment of the

association between individual feed intake in relation to changes in various blood parameters (3-hydroxybutyrate, acetoacetate and non-esterified fatty acids) which have been used (e.g. Russel et al, 1967) as indicators of the energy status of pregnant ewes.

Materials and Methods

Animals and diet

Sixty-eight pregnant Greyface ewes, previously grazing sparse winter pasture, were ranked and paired, according to liveweight and body condition score, eight weeks before the predicted first lambing date (as determined from ram raddle markings). The ewes from each pair were then placed into either Group A or Group B such that each group had a mean liveweight of 80 ± 6 kg and body condition score 3. Each group was housed in an area of 140m^2 on straw bedding.

Group A and Group B were allocated diets A (complete diet) and B (hay and concentrates) respectively, both of which were devised so that approximately equal amounts of metabolisable energy (ME) and digestible crude protein (DCP) were supplied to each group, according to the allowances for twin bearing ewes MAFF (1984) and ADAS (1976).

There were two stages to the experiment. Period 1 lasted from eight to four weeks before the first ewe was due to lamb. Period II (when increased amounts of feed were offered to the ewes) lasted from four weeks before and until the start of parturition.

Diet A consisted of mixtures of shredded molassed sugar beet pulp, barley husk siftings and soya bean meal (together with added minerals and vitamins) as described in Table 42. Diet B consisted of allowances of hay and a cubed proprietary ewe nut (Table 42) in which 20 g of chromic oxide/kg fresh matter had been incorporated. Both rations provided similar quantities of dry matter to the ewes in each group in both periods. The proximate analyses of these feeds are given in Table 43. Digestibility trials were carried out using wether sheep (Appendix 2) to estimate (a) the digestible crude protein and (b) the digestible energy (bomb calorimetry) from which the ME values of the feeds were derived (DE x 0.81).

The ewes given the complete diet A were allocated their feed in two equal proportions at 07.30 h and 16.00 h. Presentation was in troughs allowing 0.43 m/ewe outside the pens and to which the ewes had access without the impedance of separating bars. The concentrate part

of diet B was given in the same way and at the same times. Hay was given to Group B ewes in hay racks with vertical bars allowing 0.28 m/head at about 08.00 h immediately after their concentrate allocation had been consumed. The ewes were observed at feeding time.

Table 42 Daily quantities of feeds offered to ewes (kg fresh matter/head)

		Period I	Period II
Diet A	Molassed sugar beet pulp	0.67	0.86
	Barley husk sifting	0.33	0.43
	Soya bean meal	0.13	0.21
	Total dry matter intake kg/head	0.96	1.28
	ME MJ/head	10.4	13.2
	Digestible crude protein g/head	92	125
Diet B	Hay	1.0	1.11
	Cubed concentrate	0.33	0.66
	Total dry matter intake kg/head	1.08	1.46
	ME MJ/head	9.4	13.1
	Digestible crude protein g/head	80	127

Recommended daily allowances (MAFF 1984 and ADAS 1976)

	ME MJ	9.8	13.6
	Digestible crude protein. g	74	130

Table 43 Proximate analyses and estimated ME and DCP contents of the feeds (mean of four samples of each taken in Period I and Period II)

	Diet A			Diet B	
	Molassed sugar beet pulp	Barley husk siftings	Soya bean meal	Hay	Cubed concentrate
Dry matter g/kg	843	869	864	797	867
Composition of dry matter (g/kg)					
Crude protein	110	34	477	83	203
Ether extract	1	19	11	12	32
Crude fibre	295	321	67	212	214
Ash	88	103	56	60	124
Sol. carbohydrates	506	523	389	633	427
Chromium	-	-	-	-	1.17

Estimated ME and DCP contents of diets per kg DM

	Diet A		Diet B	
	Period I	Period II	Period I	Period II
			Hay	Cubed concentrate
ME (MJ/kg DM)	10.8	10.3	8.2	10.2
DCP (g/kg DM)	95.7	97.6	42.0	160.8

The ewes were weighed and condition scored towards the end of Period I and Period II. The ewe were bedded with straw as required, however, this was avoided immediately before and during faecal collection periods.

Faecal collection

During weeks 5-6 (Period I) and weeks 2-3 (Period II) before the predicted first lambing date all the ewes were fitted with harnesses and nylon (1 mm) mesh faecal collection bags. Thereafter for five days the contents of the bags were emptied once per day into large polythene bags, and the total faeces were amalgamated for each ewe. At the end of the collection period the faeces samples were weighed and subsampled. The subsamples were dried and analysed for ash and chromium (Group B only). Chromic oxide had been included, in the formulation of the proprietary ewe nuts, to act as an indigestible marker. The total daily chromium content of the faeces allowed an estimate to be made of the total daily intake of concentrate. With a knowledge of the digestibilities of the dry matter of both the concentrate and the hay (Appendix 2), the amount of hay consumed could be calculated.

Plasma metabolites

On the last day of faecal collection of both Period I and Period II, blood samples were obtained from the jugular veins of the ewes into heparinised tubes, at 07.30 h before the morning feed. The blood samples were centrifuged and the plasma was analysed for acetoacetate, 3-hydroxybutyrate and non-esterified fatty acids (Appendix 1).

The ewes in Groups A and B were maintained on their respective dietary treatments until parturition, when they were removed with their progeny to separate groups. The lambs were weighed within 24 hours of birth and the ewes were weighed two to three days after parturition.

Results

During Period I, ewe 179 from Group B died from pulmonary adenomatosis (Jaagsiekte) having shown inappetance for several weeks. Ewe 746 from Group A aborted during Period I. On investigation of the foetus, it was diagnosed that the cause had been enzootic abortion. Thence both groups of ewes were each given 10 ml of long-acting Terramycin (Pfizer) as a preventative measure against enzootic

abortion.

During Period II, four ewes from Group A and one ewe from Group B suffered from pregnancy toxaemia. The ewes were treated with 60 ml propan-1, 2-diol once or twice a day (depending on the severity of the symptoms) plus 200 ml of 40% dextrose per day intravenously (Andrews, 1982) for three or four days. The treatment was successful in saving the ewes even although two of the ewes aborted (both from Group A).

Table 44 shows the data for lambing performance. The difference in lamb birthweight between Group A and Group B, for all the lambs born alive, was statistically significant ($P<0.001$) which was probably accounted for by the differences in the numbers of multiple births between the groups. The difference in twin birthweight between Group A and Group B was not statistically significant. Group A suffered a greater number of fatalities at birth due to pregnancy toxaemia and enzootic abortion, as previously mentioned. Ewe 112 from Group B was barren.

Table 44 Lambing performance (singles, twins etc. born alive)

Sets of:	Singles	Twins	Triplets	Quadruplets	Mean lamb birthweight (kg)	Mean lamb birthweight twins only (kg)
Group A	4	24	2	-	4.66 SE ± 0.112	4.66 SE ± 0.109
Group B	6	17	8	1	4.02 SE ± 0.123	4.53 SE ± 0.114
				Difference A-B	0.64***	0.13NS

*** $P < 0.001$; NS $P > 0.05$

At feeding time, the ewes from both groups came forward as soon as their respective diets were placed into the troughs and remained at the troughs, with intermittant changes of position, until the feeds were consumed. When hay was offered to Group B, after the concentrate ration was completely consumed, the ewes were keen to eat and persevered at the hay racks until the hay had been eaten. However, those ewes which became ill during the experiment (mentioned previously) did not usually come forward to eat when they were incapacitated. The amount of time taken to consume the diets is shown in Table 45.

The mean intakes ± S.dev of dry matter, metabolisable energy and digestible crude protein for Periods I and II are shown in Table 46. The discrepancies observed between the calculated intakes of dry matter, ME and DCP (from Table 46) and the respective allocated quantities (from Table 42), are likely to be caused by the use of incomplete data in the calculations of the mean dry matter intakes. Complete success in the faecal collection procedure was not achieved, resulting in faeces being collected from more than half of the ewes on only three or four days instead of five days. Consequently, the calculated mean dry matter intakes by these ewes may not be truly representative of their actual intakes. Nevertheless, the differences between the allocated and calculated values in Table 42 and Table 46 are fairly small (2-3%).

Table 45 Time taken to consume diets (minutes)

	Time taken to clear allocation per feed	
	Period I	Period II
Group A (Diet A)	12-15	20-25
Group B (Diet B) Hay	60-70	60-70
Concentrate	3-5	4-6

Table 46 Mean intakes and coefficients of variation of total dry matter (kg DM), metabolisable energy (MJ ME) and digestible crude protein (g DCP) per ewe/day (31 or 32 ewes/group)

	Period I			Period II		
	DM	ME	DCP	DM	ME	DCP
Group A. Complete diet						
n	32	32	32	32	32	32
Mean	0.97	10.4	92.3	1.25	13.1	124.4
S. dev ±	0.190	2.04	18.18	0.259	2.69	25.63
CV%	19.7	19.7	19.7	20.6	20.6	20.6
Group B. Hay and concentrate						
n	31	31	31	32	32	32
Mean	1.11	9.6	80.5	1.49	13.1	130.4
S.dev ±	0.301	2.60	19.08	0.345	3.11	27.51
CV%	27.2	27.1	23.7	23.2	23.7	21.1

For Group A the coefficients of variation (19.7 and 20.6%) for DM, ME and DCP were similar for Periods I and II. For Group B, the coefficients of variation for total DM intake were slightly greater (23 and 27%) than in Group A, for Periods I and II respectively. The ME and DCP intakes for Group B were calculated by summation of each ewe's individual ME and DCP intakes from the hay and concentrates components of the diet. During Period I, concentrates and hay were allocated to Group B to contribute 30% and 70% of individual ME intake respectively. In effect the concentrates contributed to a range of 20-49% of individual ME intake in Group B during Period I and conversely hay contributed to a range of 51-80% of individual ME intake. During Period II, concentrates and hay were allocated to Group B to contribute 44% and 56% of individual ME intake respectively. In effect concentrates supplied between 17-78% of individual ME intake during Period II and conversely hay contributed between 22-83% of individual ME intake.

The coefficients of variation for hay dry matter intake by Group B in Periods I and II were 31.8% (mean 0.82 ±0.262 kg) and 30.8% (mean

0.92 ±0.282 kg) respectively. The coefficients of variation for concentrate dry matter intake by Group B in Periods I and II were 24.6% (mean 0.29 ±0.704 kg) and 23.8% (mean 0.57 ±0.136 kg), which are very similar irrespective of a twofold increase in the allocation of concentrates in Period II.

Figure 4 illustrates the pattern of ME intake for diets A and B, during Periods I and II. For Group A 68.8% and 62.5% of the observations of ME intake for Periods I and II respectively lie within ± 2 MJ ME of the mean; for Group B 61.3% and 56.3% of the observations of ME intake for Periods I and II respectively lie within ± 2 MJ ME of the mean.

Similarly, for DCP intake in Group A, 81.3% and 62.5% of the observations for Period I and II respectively lie with ± 20g DCP of the mean. In Group B 64.5% and 56.3% of the observations for Periods I and II respectively lie within ± 20 g DCP of the mean.

Table 47 shows separate rank order correlations and absolute correlation coefficients for ME and DCP intake between Period I and II. Correlation coefficients were thence determined between the individual components of diet B between Periods I and II, in terms of dry matter intake. For diet A (loose mix) both ranking order correlation and correlation coefficients for ME and DCP intake were low and non-significant. For diet B (hay and concentrates) the rank order correlation and correlation coefficient were 0.405 and 0.426 and statistically significant ($P<0.05$) for ME intake only. On investigating the degree of relationship between periods for the individual components of diet B, hay DM intake gave significant rank order correlation and absolute correlation coefficients ($P<0.01$ and $P<0.001$ respectively). The dry matter intake from the concentrate supplied did not show a similar statistically significant relationship between Periods I and II.

Figure 4 Frequency histograms of ME intakes (MJ/day) for Group A (Diet A) and Group B (Diet B) in Period 1 and Period 2 (⊢——⊣ indicates ± S.dev. of the mean)

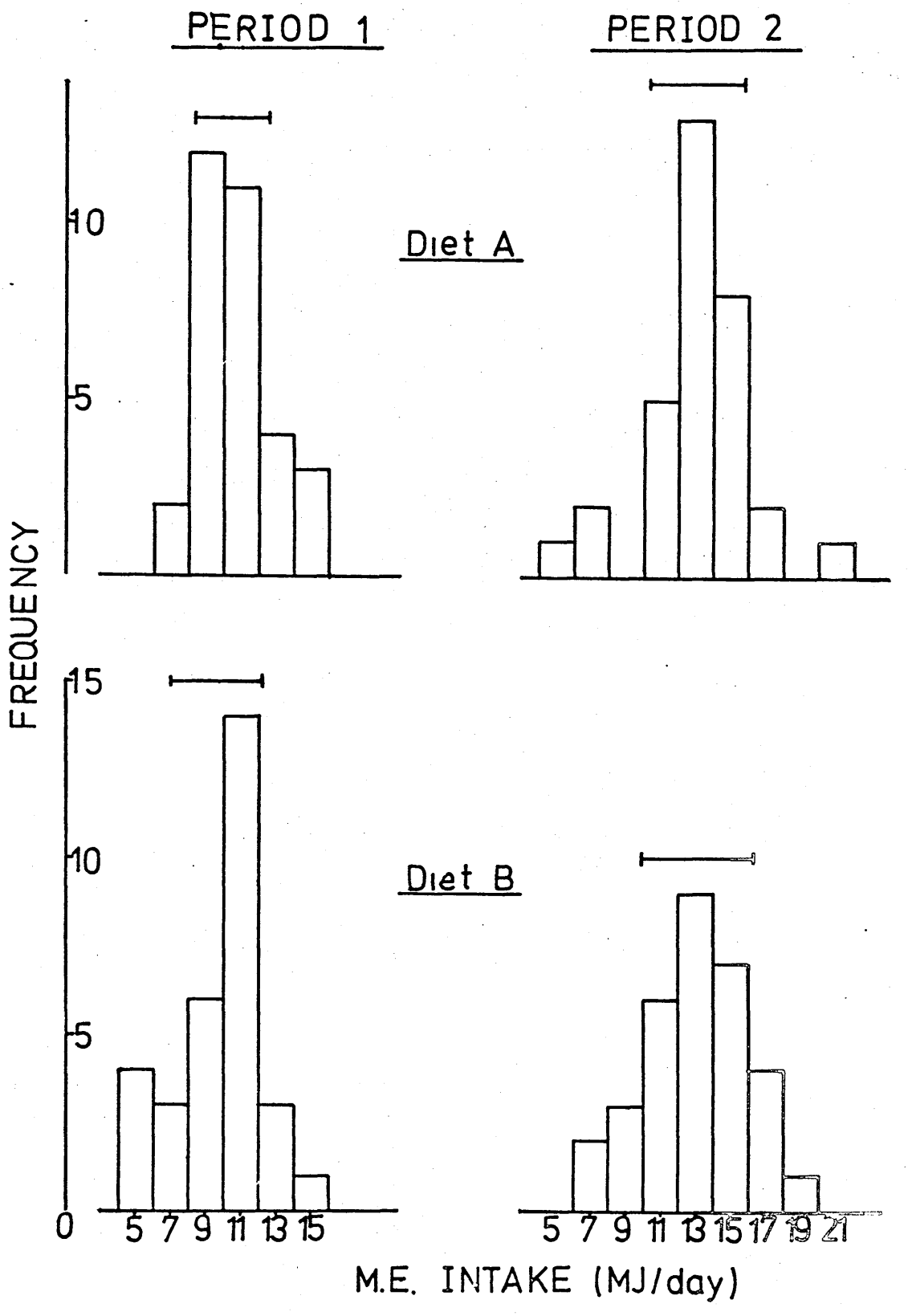

PERIOD 1
PERIOD 2
Diet A
Diet B
FREQUENCY
0
5
10
15
5 7 9 11 13 15
5 7 9 11 13 15 17 19 21
M.E. INTAKE (MJ/day)

Table 47 Correlation (r) and rank order (ro) correlation coefficients for ME (MJ) and DCP (g) intake between Periods I and II for diets A and B, and for hay and concentrate dry matter intake (kg) for diet B only.

Period I/II	Diet A		Diet B	
	ME	DCP	ME	DCP
r	0.081	0.158	0.426*	0.277
ro	0.198	0.260	0.405*	0.321
DM only, Diet B	Hay		Concentrates	
r	0.597***		0.223	
ro	0.425**		0.225	

* $P < 0.05$ ** $P < 0.01$ *** $P < 0.001$

The mean plasma metabolite data for Periods I and II are presented in Table 48. Thirty-four sets of plasma metabolite data from Group A and Group B, during Period II, were unfortunately mislaid, thus accounting for incomplete data in Table 48. Problems with the establishment of the analytical method in the laboratory also contributed to this. In Table 48, the plasma metabolite data of ewes which later gave birth to twin lambs, are considered separately for Period I only. The concentrations of all the plasma metabolites showed two and three-fold increases from Period I to Period II.

The relationships between the plasma parameters measured and ME intake and ME status are presented in Tables 49 and 50 for Period I and II respectively. ME status was calculated by determining the individual ME requirement of each ewe (MAFF 1984) at the time of blood and faecal sampling, with the benefit of knowledge of lambing performance and lambing date acquired later. The calculated ME requirement was subtracted from the determined ME intake, hence indicating a positive or negative energy status at the time of sampling. Regression relationships thence established between ME status and plasma metabolite concentrations were expected to be improved in terms of statistical significance and error since individual foetal burden at the time of sampling was being accounted for. Foetal burden was not considered in the computation of the corresponding regression equation between ME intake and plasma metabolite concentrations.

Table 48 Mean plasma metabolite concentrations - acetoacetate (AA) mg/1000ml, 3-hydroxybutyrate (3-OH) mg/1000ml, and non-esterified fatty acids (NEFA) ,uequivalents/1000ml

		Period I			Period II		
All ewes		AA	3-OH	NEFA	AA	3-OH	NEFA
Group A	n	27	25	21	12	15	11
	Mean	3.05	3.09	187.8	5.06	5.53	498.0
	S.dev±	1.29	1.07	81.2	1.36	1.53	181.8
Group B	n	29	29	24	15	15	10
	Mean	2.81	3.04	171.9	5.78	5.86	479.9
	S.dev±	1.16	1.16	70.4	1.35	1.26	158.9
Diff (A-B)*		0.25	0.05	15.9	-0.72	-0.33	18.1
Twin bearing ewes only							
Group A	n	20	19	15			
	Mean	3.17	3.18	192.9			
	S.dev±	1.35	1.09	87.2			
Group B	n	15	15	13			
	Mean	2.37	2.77	142.5			
	S.dev±	1.05	0.96	22.9			
Diff (A-B)*		0.80	0.41	50.4			

* Difference in metabolite concentrations between Group A and Group B within periods.

None of the differences was statistically significant P> 0.05

Table 49 Regression analyses between plasma metabolites (y) and ME intake (x) or ME status (x) for Group A and Group B (Diet A and Diet B respectively) in Period I (y = a + bx).

	Group A					Group B				
ME intake										
	n	a	b	s	r^2%	n	a	b	s	r^2%
AA	25	4.14	-0.105	1.347	2.3	27	2.26	+0.054	1.221	0.9
3-OHB	23	1.69	+0.15	0.993	7.9	26	3.37	-0.025	1.213	0.2
NEFA	20	402	-21.0	76.76	15.8	22	169	+0.709	73.76	0.1
ME status										
AA	24	3.02	-0.033	1.392	0.2	27	2.8	+0.001	1.226	0
3-OHB	22	3.36	+0.135	1.019	5.6	26	3.0	-0.106	1.193	3.6
NEFA	20	170	-19.9	76.76	15.8	22	175	-0.695	73.76	0

None of the regression relationships was significant ($P > 0.05$)

y = Plasma metabolite

x = ME intake or ME status

y = a + bx where a = intercept

b = regression coefficient

s = error of b

r^2 = % of the total variation in y accounted for by x

ME status = Calculated ME intake - ME requirement *

* ME requirement estimated from MAFF 1984

Table 50 Regression analysis between plasma metabolites (y) and ME intake (x) or ME status (x) for Group A and Group B (Diet A and Diet B respectively) in Period II (y = a + bx).

	Group A					Group B				
ME intake										
	n	a	b	s	r^2%	n	a	b	s	r^2%
AA	11	7.9	-0.216	1.148	42.0*	14	11.3	-0.417	0.896	56.8**
3-OHB	13	7.5	-0.158	1.568	14.9	14	10.2	-0.324	0.947	41.58*
NEFA	10	701	-14.9	194.5	7.5	9	614	-11.3	170.0	3.9
ME status										
AA	11	4.94	-0.145	1.299	25.7	14	6.07	-0.37	1.110	33.7*
3-OHB	13	5.32	-0.132	1.576	14.0	14	6.06	-0.143	1.200	6.1
NEFA	10	493	-1.82	202.1	0.1	9	468	-5.04	172.9	0.5

Statistical significance of regression equations

* $P < 0.05$ ** $P < 0.01$ Others were not significant $P > 0.05$

y = plasma metabolite

x = ME intake or ME status

y = a + bx where a = intercept

b = regression coefficient

s = error of b

r^2= % of the total variation in y accounted for by x

ME status = Calculated ME intake - ME requirement *

* ME requirement estimated from MAFF (1984)

For Period I (8-4 weeks before lambing) there were no statistically significant relationships between any of the plasma parameters and ME intake or status for either diet. During Period II (during the four weeks before lambing) acetoacetate produced statistically significant regression relationships with ME intake for Group A and Group B. The regression relationship between 3-hydroxybutyrate and ME intake for Group B was also statistically significant ($P<0.05$). For Period II, only acetoacetate produced a statistically significant regression relationship with ME status by using Group B only. The remaining regression relationships, although all tended towards a negative association between the determined parameters, were not statistically significant. The missing plasma metabolite data in Periods I and, more particularly, in Period II, may affect the interpretation of the regression equations.

The mean change in ewe liveweight from the beginning of Period I until just after parturition was -2.7 ($\pm$0.52) kg from Group A ewes, and -4.9 ($\pm$ 0.92) kg and Group B ewes respectively. The difference in liveweight loss (2.2 kg) between the groups was not statistically significant.

Discussion

Comparison of the coefficients of variation of ME intake for Group A and Group B, during Period I, suggests that the observations are spread out around the mean to a greater extent for diet B (hay and concentrates) compared to diet A (complete diet). Furthermore, during Period I the percentage of the observations of ME intake which came within $\pm$ 2 MJ ME of the mean ME intake were 68.8% and 61.3% for Diet A and Diet B respectively. This perhaps indicates that Diet A was, indeed, marginally more successful in promoting a more uniform individual intake of ME than Diet B. During Period I 81.3 % and 64.5 % of observations of DCP intake were within $\pm$ 20 g DCP for Diet A and Diet B respectively, which further suggests that Diet A promoted a more uniform intake of feed dry matter (and DCP) than Diet B.

When the dry matter offered to the ewes was increased in Period II, as demand for nutrients increased, the coefficient of variation for ME intake in diet A remained very similar (20.6%) to that achieved in Period I (19.7%). The bulky nature of this diet probably contributed to this similarity between periods and even although the dry matter offered was increased by 30% from Period I to Period II, the time taken

to clear the ration almost doubled. For diet B, the coefficient of variation of ME intake decreased marginally from 27% in Period I to 23% in Period II. The quantity of concentrates offered was increased by 10% from Period I to Period II and as the hay offered remained similar in both periods, it is likely that the more liberal allocation of concentrates contributed to this slightly lower coefficient of variation in Period II. For Groups A and B respectively, 62.5% and 56.3% of the observations of ME intake in Period II were within $\pm$ 2 MJ ME of the mean, again suggesting that diet A was marginally more successful than diet B in promoting a uniform ME intake within the group. In Period II, 62.5% and 56.3% of the observations of DCP intake, for diet A and diet B respectively, were within $\pm$ 20 g of the mean.

However, the issue is confounded by the fact that not all the ewes were carrying the same number of lambs. In Group B, 15 of the 32 ewes producing live lambs at birth were carrying either single, triplets or quads; in Group A only six of the 30 ewes were carrying either triplets or single lambs. The remaining ewes in each group were carrying twins. Feed intake may have therefore been affected where the ewes were able to express their ME requirements within the given restraints of the restricted feeding regimen. This would be exaggerated more in Period II than Period I, as nutrient demand increased, hence it is difficult to distinguish between an expression of ME requirements and the effect of diet type on influencing intake patterns in considering the shape of the histograms. The use of twin bearing ewes only would have perhaps counteracted this problem.

The non-significant correlation coefficients for diet A, during both periods, suggest that the ewes were eating at random within the group which is perhaps due to the fairly uniform intake and demand within Group A. The imposed restricted feeding regimen and the resulting low range of intake perhaps prevents the existence of statistically significant correlation coefficients. For diet B, the statistically significant ranking order correlation and correlation coefficient for ME intake in Period I and II was probably due to the similar ranking of hay dry matter intake (which only increased marginally from Period I to II) which produced statistically significant correlation coefficients for ME intake. The ewes from Group B did not maintain the same ranking order for concentrate intake in Periods I and II which may indicate that individual ewes became more

or less keen to consume concentrates as parturition approached.

The concentrations of the determined plasma metabolites increased from Period I to Period II,and although the differences were not statistically analysed due to missing data, the higher concentrations in Period II may indicate greater nutritional stress during the four weeks prior to parturition. None of the differences in mean plasma metabolite concentrations was significant between diets A and B in Period I and II. However the influence of foetal burden was not accounted for in this comparison. The differences in mean plasma metabolite concentrations for twin bearing ewes only, in Period I, were also not statistically significant. Missing data from Period II, prevented a similar comparison from being made. Indeed, it is perhaps more likely that differences in the mean plasma metabolite concentrations, between diets, would have been seen in Period II.

The measured plasma metabolites were related to ME intake data in terms of regression analysis. The absence of any significant regression relationships for Period I for both diets, even when ME status was used, may be due to the relatively low plasma concentrations which were determined. The ewes may have been supplied with sufficient adaquacy of nutrients during Period I which resulted in low concentrations of metabolic products of fat mobilization and hyperketonaemia. The relatively low range of ME intake data, in this restricted feeding regimen, may also have prevented the establishment of regression relationships. The ewes were fed approximately half their feed allocation twice a day which may not have been conducive to sufficiently exaggerating the pre-feeding concentrations of the circulating metabolites under investigation. Indeed fat mobilization and hyperketonaemia are likely to be occurring, even during Period I, which may have been substantiated by feeding the ewes once per day (Annison 1960) and hence exaggerating the pre-feeding concentration of the appropriate metabolite. Factors of stress and instability of the metabolites (Russel, 1978) may also have increased the difficulty of producing statistically significant relationships.

Acetoacetate concentration produced a statistically significant regression relationship with ME intake and status for diet B in Period II. However, the reliability of acetoacetate as an indicator of nutrient status, due to its instability in plasma, has been refuted by several workers (e.g. Lindsay, 1978).

3-hydroxybutyrate produced a statistically significant

relationship with ME intake only, the absence of a statistically significant regression relationship between ME intake/status and non-esterified fatty acids is perhaps surprising in view of the apparent success normally found (Russel et al, 1967), although the relationships found were negative associations between the parameters. Perhaps once-a-day feeding would have been more conducive to exaggerating the pre-feeding non-esterified fatty acid concentrations and hence produce significant regression relationships. The range of ME intakes obtained may have been too low in this respect. Ewes which were outwintered prior to parturition and given one feed per day may be more susceptible to elevation of plasma metabolite concentrations as lambing approaches. Indeed, changes in plasma metabolite concentrations are usually more clearly seen in ewes which are outdoors, and not housed, as in the present experiment. Presumably, the possible stress factor of exposure to inclement weather adds to the possible inadequacy of nutrient intake.

For the complete diet, statistically significant regression relationships for Period II are absent apart from acetoacetate concentration associated with ME intake, although the other associations are negative. The potential ability of the ewes in Group A to be highly selective in the prehension of ingredients may have precluded any associations. ME intake data was calculated on the assumption that the ingredients of diet A were eaten in the appropriate proportions to those offered in the diet. Hence the ability to be selective may result in over or under estimations of individual ewe ME intake, therefore reducing the possibility to produce regression relationships with blood parameters.

The existence of four of the five cases of pregnancy toxaemia in Group A (complete diet) may add credence to this latter supposition, in that selection of ingredients by some of the ewes may have prevented an adequate ME intake. These four ewes were fairly fit (body score about 2.5) which did not suggest a marked mobilisation of body fat. Of these four ewes, two were bearing twins and two triplets and all were old ewes and these factors may have ultimately contributed to their vulnerability to pregnancy toxaemia. The ewe from Group B which succumbed to pregnancy toxaemia had been fairly thin (body score 2) at the beginning of the experiment which perhaps contributed to her susceptibility.

Therefore, the attempt to develop regression relationships between

ME intake and ME status and the determined plasma parameters, although it did not particularly help in the comparison of uniformity of ME intake between the diets investigated, revealed inherent errors in the design of the experiment (e.g. feed selectivity problems for Group A), and indeed questions further the efficacy of the determined plasma metabolites to critically illustrate the degree of under nutrition in pregnant animals.

Ewe liveweight change from Period I until immediately after parturition, for Group A ewes and Group B ewes were fairly similar, even although the ewes from Group B showed a marginally greater liveweight loss. This is probably attributable to those eight ewes which gave birth to triplets and the one ewe which had quadruplets in Group B. Similarly, the significant difference in lamb birth weight between Group A (4.66 kg) and Group B (4.03 kg) is probably attributable to the greater number of triplet and quadruplet births in Group B than in Group A.

Conclusion

Allocation of a bulky complete diet (diet A) to pregnant ewes, was observed to promote a more uniform intake of metabolisable energy and digestible crude protein intake than allocation of a conventional hay and pelleted concentrate diet, even although the differences in the coefficients of variation were marginal. However, this marginal result supports work by Foot and Russel (1973) where a bulky diet promoted a more uniform dry matter intake (CV 13.3%) compared with a mainly pelleted diet (CV 22.8%) in dry, non-pregnant ewes.

Nevertheless, the diets allocated in the present experiment were perhaps not sufficiently dissimilar in physical form, i.e. in terms of bulk volume, to illustrate the possible influence of physical form of the diet on variation in feed intake in a group, unlike the diets allocated by Foot and Russel (1973). Indeed the hay component of diet B was allocated to contribute 70% of the metabolisable energy allowances to the group and therefore the possible influence of the pelleted component of the ration i.e. the compound feed, on the overall variation in dry matter or metabolisable energy intake was very much reduced. However, the coefficients of variation of metabolisable energy intake (and dry matter) from the hay component (31.8% and 30.8%) for Periods I and II respectively were greater than the coefficients of variation of metabolisable energy (and dry matter) from the pelleted

compound feed for Periods I and II (24.6% and 23.8% respectively). This is perhaps unexpected in view of the observed faster rate of consumption of the compound feed in comparison with the hay component of the diet. It perhaps reflects the differences in physiological demand, in terms of foetal burden, in Group B, whereby all the ewes were more likely to consume the fairly restricted allocation of concentrates in both periods, more readily than the bulky hay allocation.

Indeed the lower coefficients of variation of dry matter, metabolisable energy and digestible crude protein, in diet A (complete diet) compared with diet B (hay and concentrates), may be the result of the more uniform group of ewes in Group A compared with Group B, in terms of physiological demands i.e. foetal burden.

An increase in the quantities of feed allocated (i.e. diet A and the pelleted component of diet B) in Period II did not produce a marked influence of the variation in dry matter intakes (plus metabolisable energy intakes and digestible crude protein intakes) from diet A or the compound feed component of diet B in the groups of ewes. The allocation of diet A was only increased by 29% and consequently did not markedly influence the variation within the ewes in Group A. The effect is perhaps confounded by the increase in physiological demands from Period I to Period II, i.e. constant conditions do not exist for comparative purposes.

A twofold increase in the quantity of pelleted compound feed produced a slight decrease in the coefficient of variation for dry matter intake (from 24.6% in Period I to 23.8% in Period II). However the fairly restricted allocation of compound feeds in both periods has perhaps prevented a marked effect in terms of variation in intake in Group B. Again, the result is confounded by the variable increase in physiological demands in the group as parturition approached.

SECTION 4 EFFECTS OF THE INITIAL ACCEPTABILITY OF COMPOUND FEEDS, AS INFLUENCED BY DIFFERENCES IN PALATABILITY, ON THE INDIVIDUAL INTAKE OF GROUP FED COMPOUND FEED BY SHEEP.

Introduction

When compound feeds are offered to sheep for the first time the inital acceptability, as defined by the acceptability or rejection of compound feed over the first and subsequent three to four feeds, exhibited by the animals may influence the variation in individual intake of group fed compound feed. The possible initial unacceptability of the feed may have deleterious consequences, particularly where, for example, sheep in late pregnancy are offered a compound feed as a substantial part of the diet, which for reasons of least cost formulation, has been devised to contain relatively unpalatable ingredients incorporated at or just beyond their normally acceptable inclusion rates. These ingredients may be defined as unpalatable if they are rejected in preference to other feed ingredients offered simultaneously (Greenhalgh and Reid, 1971).

Experiments 4.1 and 4.2 examine the influence of the inclusion of marginally unpalatable ingredients, at or beyond their normally accepted inclusion levels in the compound feeds in dry, non-pregnant ewes which were individually fed a constant basal diet of dried grass. Complete faecal collections were undertaken in Experiment 4.2. In Experiment 4.3 the variation in individual intake of three compound feeds, which differed in their ingredient inclusion, was investigated in three groups of Greyface ewes in late pregnancy (by complete faecal collection).

Experiment 4.1 Feeding behaviour of ewes individually offered six compound feeds of similar proximate analysis and two molassed sugar beet products.

Introduction

Problems of acceptability of compound feeds by ewes may arise where least cost formulation produces a compound feed which contains several marginally unpalatable ingredients at their maximum inclusion levels. Five compound feeds, of similar proximate analysis (Table 51), were formulated with various inclusion rates of four marginally unpalatable ingredients, to investigate potential differences in acceptability of the feed by individually fed ewes. Two molassed sugar beet pulp products (molassed sugar beet pulp nuts and Triple nuts, a molassed sugar beet product which contains urea) and a proprietary compound feed B (BOCM Ewbol) were similarly investigated to act as internal standards (i.e. they were considered to be normally acceptable) (Table 51).

Materials and Methods

Thirty-two dry, non-pregnant Greyface ewes (mean liveweight 70.5 kg ± 7.3), whose lambs had been weaned at six weeks after lambing, were selected from the flock which was set-stocked on permanent pasture at Cochno Farm. The ewes were allocated to four experimental blocks according to liveweight, giving eight ewes per block. There were eight treatment diets (Table 51) with one ewe allocated at random to each treatment within a block.

For an introductory six day period all the ewes were given 0.66 kg fresh matter (FM) of a standard proprietary compound feed B (BOCM Ewbol) at 07.30 h and 0.66 kg FM of grass nuts at 1600 h. For Experimental Period 1 the ewes were introduced to their treatment diets (at 0.66 kg FM/head) given as the morning feed. Grass nuts were fed as usual in the afternoon. The ewes were on treatment for four days. Their behaviour at feeding time was observed daily.

After four days on treatment, all the ewes were offered the original standard compound B at 07.30 h for the following four days, during which time they were observed at feeding time. Following this, for Experimental Period 2, the ewes were re-randomised on to the eight treatments (ensuring each ewe was allocated to a different dietary treatment from previously). The ewes were observed at feeding time.

In this way each of the eight feeds was offered to eight different

ewes (by summation of Periods 1 and 2).

Table 51 Proximate analysis of feedstuffs (g/kg DM)

Feedstuff	Dry Matter	Crude Protein	Crude Fibre	Ether Extract	Nitrogen Free Extract	Ash
Molassed Sugar Beet Pulp Nuts	854	114	137	5	652	92
Triple Nuts	825	211	116	4	557	112
Ewbol B	874	171	138	30	544	117
Compound C	872	168	126	34	564	108
Compound D	867	156	155	26	553	110
Compound E	874	168	146	19	555	112
Compound F	879	174	159	25	548	94
Compound G	879	175	157	28	553	87
Dried Grass	923	134	268	32	507	73

Observations and Results

During the initial six day introductory period, when all the ewes were individually given 0.66 kg of the standard supplement (B) at 07.30 h and 0.66 kg of dried grass at 1600 h all the ewes commenced to eat both feeds immediately when placed before them and persevered until they had finished their ration. All ewes had finished their allocation within 10 minutes for compound B and between 10 and 15 minutes for the dried grass. Several ewes choked (temporarily) on the dried grass. This feature of behaviour did not disappear later on in the trial. The ewes did not exhibit choking behaviour when fed compound B.

On the first day of feeding the diets under investigation in Period 1, all the ewes completed their allocation of the eight separate feeds within 10 minutes except for two ewes given compound G. All the ewes started to eat as soon as the compound had been placed into the buckets. However, two of the four sheep given compound G were noticeably more reluctant to persevere. Nevertheless within 4 hours of feeding they had completed their ration, having eaten at intervals throughout the morning. Similar behaviour of these two sheep was

observed on days 2, 3 and 4 of the treatment. Ewes given compound G took noticeably more time to finish their ration. Ewes given Triple Nuts became reluctant to clear their ration on the second day of the treatment.

After four days on treatment, all the ewes received the original compound (B) in the morning for the following four days. Within ten minutes of being fed all the ewes had cleared their ration

On the first morning of treatment during Period 2, all the ewes finished within eight minutes except for two ewes allocated to compound G. Within 15 minutes these ewes had given up eating. However, within 3 hours after the compound had been placed into the buckets both ewes had finished. On the second day all the ewes had finished within 15 minutes, and those given compound G or Triple Nuts were more reluctant to do so. On days 3 and 4 of treatment all the ewes ate at a similar rate, and completed their allocation within 10 minutes.

After four days on treatment the ewes were fed the original compound (B) on the following morning. The ewes all completed their allocation within 10 minutes.

Conclusion

If the palatability of a compound feed is defined in terms of acceptability, it would appear that all the compounds investigated (sugar beet nuts, Triple Nuts, B, C, D, E, F and G) were acceptable to the ewes as they all cleared their allocation. However, there was a degree of unacceptability with compound G, in that four of the eight ewes allocated to compound G showed some reluctance to clear their ration, although initially they commenced eating. Eventually the ration was cleared by all the ewes. Triple Nuts were similarly observed to be unacceptable to some ewes on the second and subsequent days of treatment. This peculiarity has previously been observed when Triple Nuts have been given to sheep; however the Triple Nuts used in this experiment were one year old.

Therefore even although the five compound feeds under investigation had been formulated to include several marginally unpalatable ingredients at their maximum inclusion levels, there were no total rejections of any of these compounds. However differences in the rate of eating compound G were apparent although the ewes did not reject this compound completely. Problems may arise (if compound G was allocated) in a group feeding situation. In the first two or three days of introducing the compound, several ewes may eat sufficiently

slowly to allow the remaining ewes of the group to take more than their proper allocation. This aspect was pursued in Experiment 4.2.

Experiment 4.2 Feeding behaviour and estimates of individual intake when two compound feeds were offered to dry, non-pregnant ewes in group feeding situations.

Introduction

Examination of the acceptability of a diet under individual feeding conditions may give a false impression of palatability where the potential influence of competition between animals is absent. Hence it was considered necessary to investigate the behaviour of ewes in group feeding situations where they were offered two compound feeds (F and G) one of which had already been found to be less acceptable than the other as seen under individual feeding conditions (Experiment 4.1). The least cost formulations of compounds F and G were similar, apart from a novel ingredient inclusion in compound G. Proximate analyses of compounds F and G are shown in Experiment 4.1: Table 51.

Materials and Methods

Thirty-two Greyface ewes (from Experiment 4.1) were divided into two equal groups of 16 ewes (F and G), by selecting four ewes at random from each of the four blocks (Experiment 4.1). Groups F and G were housed in separate areas of about 20 square metres and each had access to two troughs, allowing 0.68 metres/head trough space (measured on both sides) for feeding of compound F or G (both allocated 0.63 kg fresh matter/head/day) at 07.30 h respectively. There were separate individual feeding pens for feeding dried grass at 1600 h.

After a six day introductory period, all the ewes were harnessed and faecal collection bags fitted to enable complete collection of faeces to be undertaken over the following six-day period. Chromic oxide had been included in the formulation of both F and G as an indigestible marker to enable individual intake of either F or G to be determined. Dried grass was given individually at a fixed rate (0.66 kg fresh matter/head/day) to allow a fixed output of undigested dried grass in the faeces, assuming similar digestibility between ewes. Hence determination of the individual intake of F and G was made possible by apportioning total faecal output to that due to F or G from faecal chromium output.

The faecal collection bags were emptied once per day during the collection period. The faeces were amalgamated for each ewe, weighed and subsampled at the end of the collection period. The subsamples were oven dried and analysed for chromium.

The ewes were observed at feeding time.

Results and Observations

On the first morning of treatment, as soon as compound F has been placed into the two troughs the ewes in Group F started to eat. After several changes of position the ewes settled down to clear up their ration within five minutes. All the ewes persevered at the troughs until the ration was finished. As soon as compound G had been placed into two troughs, the ewes in Group G started to eat. There appeared to be more activity around the trough area with these ewes compared to Group F, with the ewes changing positions more frequently within and between troughs. After five minutes, five ewes had finished eating and left the trough area, leaving 11 ewes persevering at the feed. After 12 minutes all the offered feed had been consumed.

This pattern of activity was similar over the following two mornings. The ewes in Group G took 10 minutes to clear their ration, with 5-8 ewes in the group moving from the trough before all the ration had been cleared. All the ewes in Group F stayed at the trough until the ration had been finished (5 minutes).

On the fourth morning both groups exhibited a similar pattern of behaviour and ate their allocation at a similar rate (within 5 minutes), with all the ewes persevering at the trough. This behaviour was repeated during the subsequent eight days on experiment.

Mean daily intakes of compounds F and G are shown in Table 52. These data relate to daily intake when both groups had settled down to a similar pattern of behaviour at feeding time, i.e. between days 6 and 12 of the experiment.

Figure 5 shows a frequency histogram of daily dry matter intake for individual ewes of compounds F and G. For compound F, the daily dry matter intakes for five of the 16 ewes were within $\pm$ 100 gms of the mean. For compound G the daily dry matter intakes for ten of the 16 ewes were within $\pm$ 100 g of the mean.

Figure 5 Frequency histograms of DM intakes (x 100 g) of Compound F and Compound G (⊢⊣ indicates ± S.dev of the mean).

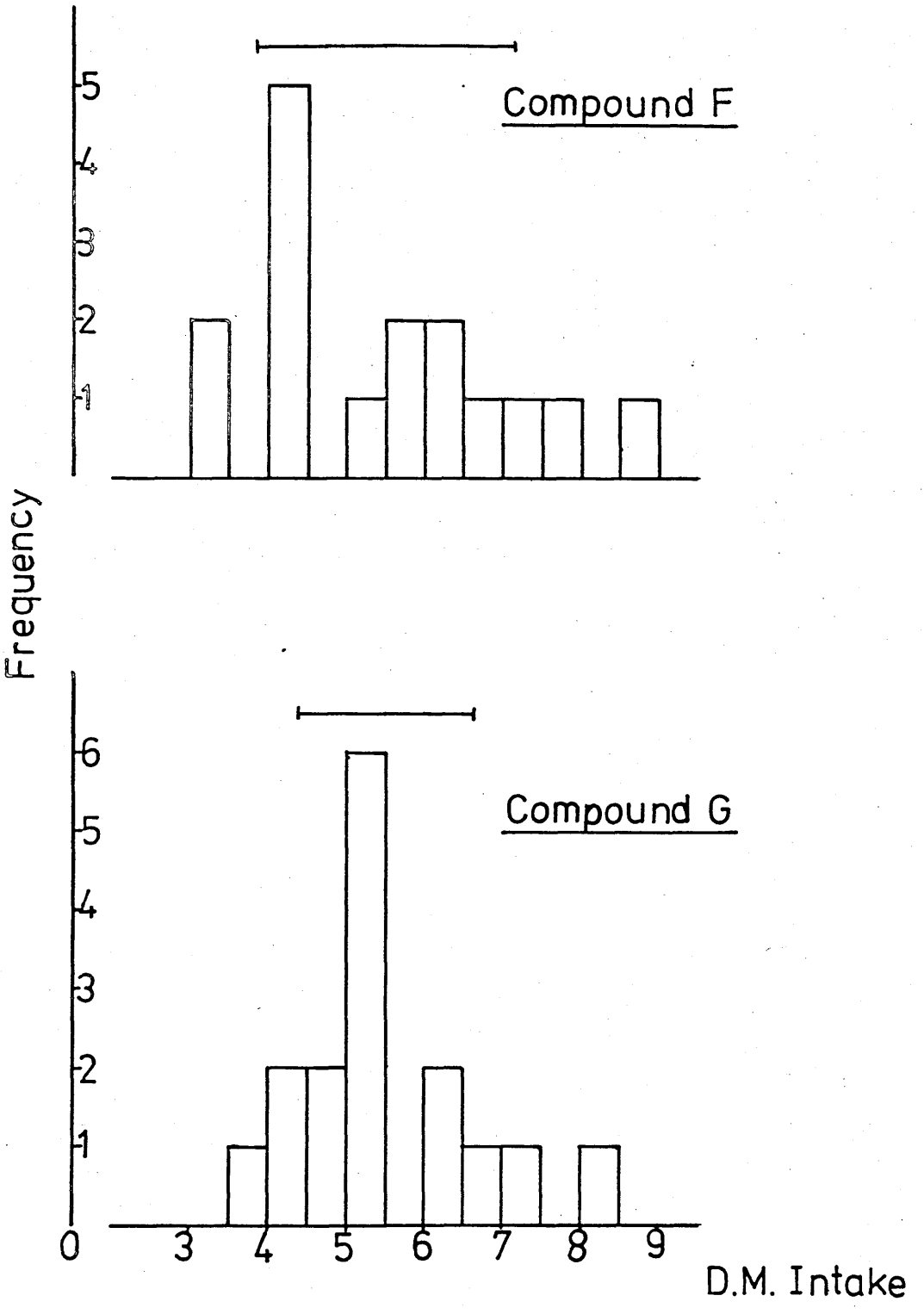

Compound F
Compound G
Frequency
D.M. Intake
0
1
2
3
4
5
6
7
8
9

Table 52 Mean dry matter intake (g) of ewes given compound F and G

	Compound F	Compound G
n	16	16
Mean	549	550
S.dev ±	166	113
Range	300-872	374-806
CV%	30.3	20.5

Discussion

On introduction of compounds F and G to the respective groups of ewes, both compounds appeared to be acceptable, in that both groups cleared their allocation with a relatively short period of time. However, for the first four days the rate of eating was slower for compound G (ten minutes to clear allocation) compared to compound F (five minutes to clear allocation), with some ewes in Group G retiring from the trough area before the allocated feed had been completely eaten. Thereafter both groups settled down to a similar pattern of behaviour, which would suggest that compounds F and G were equally acceptable to the ewes. Furthermore, compound G appeared to be more readily acceptable under the competitive situation of group presentation than when given individually in Experiment 4.1, where some of the ewes took up to four hours to clear their allocation.

Faeces were collected after the initial introduction of the compounds to the ewes, when both groups had settled down to a similar pattern of behaviour (i.e. both groups cleared their ration at a similar rate). The coefficient of variation of daily dry matter intake was 30.3% for compound F compared to 20.5% for compound G which may suggest that compound G was more uniformly consumed than compound F, in that daily intake figures congregated around the mean for compound G to a greater extent than for compound F (Figure 5). The larger standard deviation for compound F may have resulted from greater competition between the ewes for this feed, because they were keener to eat it, compared to ewes on compound G, where the standard deviation is smaller. Furthermore five out of sixteen ewes on compound F had a daily dry matter intake within ± 100 g of the mean compared to ten out of sixteen for compound G. This may perhaps suggest that the ewes were in fact less keen to eat compound G, giving a smaller spread of the

distribution around the mean.

Therefore, even although compounds F and G were observed to be equally acceptable in a group feeding situation, examination of individual intakes may refute this conjecture. Inclusion of the novel ingredient in compound G is likely to be responsible for this marginal degree of unacceptability. Indeed, it may be suggested that its inclusion is beneficial, in that a more uniform intake of compound cake within a group is ensured.

Nevertheless the problem of the initial unacceptability of compound G by a considerable proportion of the ewes in both Experiments 4.1 and 4.2 is important. If this feed had, for example, been introduced to ewes for the first time during late pregnancy it could be expected that some could experience a reduction for at least two and possibly four days in nutrient intake and this might have unfortunate consequences. This is further pursued in the following experiment (Experiment 4.3).

Experiment 4.3 Assessment of the acceptability and individual intake of three compound feeds offered to ewes in late pregnancy.

Introduction

The allocation of compound feeds which contain ingredients just beyond their normally acceptable inclusion rates (at which point a degree of unpalatability may be introduced), to ewes in late pregnancy (within 4-5 weeks of parturition), was investigated in the present experiment in view of the potentially deleterious effects on the ewes brought about by possible refusal of the concentrate. An abrupt decrease in the individual energy intakes of some or all of the ewes, perhaps with an associated stress factor (e.g. inclement weather), may have implications in the ketone body production of the ewes such that symptoms of pregnancy toxaemia may become apparent. This might apply particularly when a high proportion of twins were expected and where the concentrate feed provided a substantial part of the diet.

Three pelleted compounds (18% crude protein) were investigated in the present experiment, two of which (compounds G and H) were formulated with several ingredients beyond their normally accepted inclusion rates. The third compound (standard) was considered to be normally acceptable to ewes and was indeed a proprietary compound feed, formulated for ewes in late pregnancy. Indeed the standard compound (F) and compound G were the same compound feeds as those which had been allocated in Experiment 4.2 to dry, non-pregnant ewes.

The individual intakes of group allocated compound G and compound H by Greyface ewes, in late pregnancy, was measured (by complete faecal collection) after the ewes had been abruptly given the respective compounds for two days. The individual intake of the standard compound by the ewes was estimated in the same way, for comparative purposes. Measurement of individual compound feed intake (by complete faecal collection) was repeated after the ewes had been allocated either compound G or compound H for 13 days and had thus become accustomed to them and established a regular pattern of intake. Again the intake of standard compound was estimated in the same way for comparative purposes.

Materials and Methods

Three groups (Groups 1, 2 and 3) each of 19 pregnant Greyface ewes (70-80 kg liveweight), 85% of which were expected to have multiple

births (having been scanned) and were within four to five weeks of the predicted first lambing date (determined from raddle markings), were housed in three adjacent areas of approximately 120 m^2 on straw bedding. Groups 1, 2 and 3 were allocated to three different dietary treatments which were the standard compound, compound G and compound H respectively. The compound part of the diet was allocated at a rate of 0.80 kg FM/head/day to the groups in two equal feeds at 07.30 h and 16.00 h. Presentation of the compound feed was from troughs allowing 0.39 m/ewe outside the pens and to which the ewes had access without the impedance of separating bars. The compound feed allocation rate (0.80 kg FM/head/day) was maintained throughout the experiment.

Hay was given to each group at a rate of 1.5 kg FM/head/day in two approximately equal feeds, allocated immediately after the compound feed had been consumed at 07.45 h and 16.15 h. The hay was presented from hay racks with vertical bars allowing 0.28 m/head. The proximate analyses of the feeds are presented in Table 53.

The pattern of allocation of the compound feeds to the groups is presented in Table 54. For the first seven days of the experiment each of the groups was allocated 0.80 kg FM/head/day of the standard compound feed. On day seven all the ewes were fitted with harnesses and 1 mm mesh nylon faecal collecting bags. There was no collection of faeces on day seven when the bags were being adjusted. On days 8 and 9, 0.80 kg FM/head/day of either the standard compound feed or compound G or compound H, each of which contained chromic oxide at a rate of 2 g/kg FM, were allocated to Groups 1, 2 and 3 respectively. Faeces were collected from each ewe over the following five days starting on day 8 until day 13.

The faeces collection bags were emptied twice per day at 09.00 h and 15.45 h. The faeces from each day's collection were weighed and 10% subsamples were taken for each ewe. The subsamples from each day were amalgamated during the five day collection period. The subsamples from each ewe were subsequently dried, milled and analysed for chromium. On days 10 to 14 the ewes were again allocated the standard compound feed (no chromic oxide). Consequently the faeces collected, and therefore total chromium recovered, represented intake of two days allocation of either the standard compound or compound G or compound H (all of which contained chromic oxide), the latter two compounds having been abruptly introduced to the ewes of Group 2 and Group 3 respectively.

Table 53 Proximate analyses of feeds

	Standard Compound (F)		Compound G		Compound H		Hay
Collection period	1	2	1	2	1	2	
Dry matter g/kg	886	877	888	883	866	869	850
Composition of dry matter g/kg							
Crude protein	187	187	185	188	181	186	85
Crude fibre	153	164	160	163	172	170	328
Ether extract	41	35	39	33	27	27	16
Sol. carbohydrate	522	520	509	509	502	499	496
Ash	97	94	107	107	118	118	74
Chromium	0.962	0.973	1.047	1.124	0.833	0.990	-

Table 54 Allocation of compound feeds (standard (F), compound G and compound H) and faecal collection periods

Allocation of compound feeds (0.80 kg FM/head/day)

Days	Group 1	Group 2	Group 3	Faecal collection periods (incl.)
1-7	Standard	Standard	Standard	
8-9	Standard+Cr	Compound G+Cr	Compound H+Cr	
				Days 8-13
10-14	Standard	Standard	Standard	
15-27	Standard+Cr	Compound G+Cr	Compound H+Cr	
				Days 26-31
28-31	Standard	Standard	Standard	

+Cr denotes incorporation of 2 g/kg FM of chromic oxide to the compound feeds.

On day 13 single faecal grab samples were taken at 09.00 h from six randomly selected ewes from each group. The same ewes were again grab sampled on day 14 at 09.00 h. The two grab samples from each of the six ewes in each group were dried and analysed for chromium in order to observe whether or not the chromic oxide incorporated into the respective compound feeds, which had been allocated for two days only, had been substantially excreted after six or seven days following the allocation of the chromic oxide containing compound feed. If this was indeed the case, the faecal chromium concentrations of the six randomly selected faecal grab samples would be very small or neglible, irrespective of diurnal influences on the faecal chromium concentrations. Therefore the faecal chromium output over the five day complete faecal collection (days 8-13 inclusive) would be substantially representative of the intake of compound feed over the two day allocation period thereof.

For the thirteen days (days 15-22 inclusive) the chromic oxide containing compound feeds (standard, compound G and compound H,) were again allocated to Groups 1, 2 and 3 respectively. During days 26-31 faeces were completely collected from each ewe as per days 8-13. The faeces from each day's collection were weighed and 10% subsamples were taken which were amalgamated from each day during the five day collection period. The subsamples from each ewe were subsequently dried, milled and analysed for chromium.

On day 28 the standard feed was reintroduced to each group and hence the faeces collected (and therefore total chromium recovered) represented intake of the standard compound, compound G and compound H (to Groups 1, 2 and 3 respectively) over 2 to 3 days.

Absolute correlation coefficients and rank order correlation coefficients were computed between the compound dry matter intake calculated from the respective faecal collection periods for each compound feed.

Results

When each of the groups of ewes was allocated the standard compound feed (days 1 to 7) the ewes readily came forward and persisted at the troughs until the allocation of compound feed was completely consumed (usually within 4-5 minutes). The standard compound feed (+ chromic oxide) was also readily consumed by the ewes in Group 1 on days 8 and 9, and throughout the experiment. When compound G and compound H

(which both contained chromic oxide) were allocated to the ewes in Group 2 and Group 3 respectively, on days 8 and 9, the ewes readily come forward to the troughs. On day 8, however, four ewes from Group 2 and four ewes from Group 3 moved away from the troughs almost immediately (in less than 1-2 minutes) after the respective compound feeds had been placed therein, even although they had, indeed, consumed some of the allocation. The remaining ewes in each group settled down to completely consume the allocations of compound G and compound H (respectively), within 5-7 minutes.

On day 9, the same four ewes from each group were still reluctant to consume the respective compound feeds. However, they remained at the troughs until the respective allocations of compound feed had almost been completely consumed (>90% of the allocations). The time taken for each of the groups to completely consume compounds G and H, on day 9, was slightly less than on day 8 (4-6 minutes).

When the ewes from Group 2 and Group 3 were offered compound G and compound H (both containing chromic oxide) on the first day of the 13 day allocation period, the ewes were again reluctant to consume the respective compounds. Three or four ewes in each group were particularly unwilling to remain at the troughs. Nevertheless the allocations of compound G and compound H were consumed within 5-7 minutes. On subsequent days the ewes from Group 2 and Group 3 consumed compounds G and H (respectively) more readily and the allocations of 0.40 kg FM/head/feed were usually completely eaten within 4-6 minutes.

However, from day 25 and day 20 onwards ewes 433 and 451 from Group 1 and Group 2 respectively were observed to consume very little of the respective compound feeds (standard and compound G). They were usually the first to move away from the trough area 2-3 minutes after the respective compound feeds had been allocated.

Hay was readily consumed by all of the ewes throughout the experiment and the allocation of approximately 0.75 kg FM/head at each feed was usually completely consumed by each group within 25-30 minutes, and all the sheep usually persevered for this time.

During the faecal collection periods (days 8-13 and 26-31) the faecal collection bags were occasionally observed to be slightly out of position on the ewes , and therefore faeces were possibly not being completely collected. This was usually the case immediately before the faecal collection bags were emptied at 09.00 h, whereas the bags had been observed to be fitting properly at 07.30 h when the ewes were

given their morning allocation of compound feed, immediately followed by the allocation of hay. Therefore the extra weight of faeces collected in the intervening period (between 07.30 h and 09.00 h) probably accounted for the incorrect position of the faecal collecting bags. Nevertheless, the faeces were considered to be substantially collected for each ewe during the faecal collection periods, except when it was fairly obvious that substantial quantities of faeces were being lost (ie, it was particularly noticeable that the faecal collection bags were very improperly positioned. In the latter circumstances, the faeces collected from that day, from the particular ewe, were rejected (accounting in total for 5 collection days out of a possible 560 faecal collection days for the whole experiment).

The overall mean chromium concentrations of the two faecal grab samples, taken from six ewes in each group, on days 13 and 14 respectively (in effect 5 and 6 days respectively after the first allocation of the chromic oxide containing compounds) were 0.08 $\pm$ 0.027 g/kg DM. 0.06 $\pm$ 0.037 g/kg and 0.04 $\pm$ 0.019 g/kg DM for Group 1 (standard compound), Group 2 (compound G) and Group 3 (compound H) respectively. The relatively low concentration of chromium in the faecal grab samples suggests that the chromic oxide had been substantially excreted from the ewes within 5 or 6 days of the first allocation of the chromic oxide containing compounds. Therefore the chromium recovered by five day complete faecal collection was substantially representative of that which was indeed consumed over the two day allocation period.

Table 55 Mean dry matter intakes (± S.dev) (kg) of the standard compound feed(F), compound G and compound H.

Collection Period (days)		Group 1 Standard compound (F)	Group 2 Compound G	Group 3 Compound H
8-13	n	19	19	19
	Allocation rate/head	0.71	0.71	0.69
	Mean calculated intake	0.77	0.72	0.87
	S.dev ±	0.182	0.204	0.243
	Range	0.36-1.00	0.43-1.07	0.55-1.36
	CV%	23.6	28.3	27.9
	Recovery rate of allocated compound %	108.5	101.4	126.9 (105.2)+
26-31	n	19	19	17
	Allocation rate/head	0.70	0.71	0.70
	Mean calculated intake	0.69	0.65	0.68
	S.dev ±	0.166	0.248	0.145
	Range	0.31-0.95	0.36-1.24	0.47-1.03
	CV%	24.1	38.2	21.3
	Recovery rate of allocated compound %	98.6	91.6	97.1

+ Figure in parentheses refers to recovery rate obtained by substitution of the chromic oxide concentration in compound H, sampled during the first allocation period thereof (0.833 g/kg DM) by the chromic oxide concentration in compound H, sampled during the second allocation period thereof (0.990 g/kg DM).

The individual intakes of the compound feeds by the ewes were calculated from the determined total chromium recovered divided by the chromium concentration of the respective compound feeds. The mean daily dry matter intakes for each collection period are presented in Table 55. Two ewes were excluded from Group 3 during the second collection period (days 26-31). Ewe 73 aborted a set of twin lambs on day 25, the cause of which was suspected to be enzootic abortion. The vulval lips of ewe 436 had been stitched together as she had prolapsed badly and she was therefore considered unsuitable for faecal collection.

The calculated mean intakes of the respective compound feeds for Group 1 and Group 2 (0.77 and 0.72 kg DM respectively) from the first faecal collection period (days 8-13), were fairly similar to the allocated quantities (0.71 kg DM/head) and produced 108.5% and 101.4% recovery rates for the allocated quantities of compound feed respectively. However, the calculated mean intake of compound H (Group 3) from the first collection period (0.87 kg DM) was much greater than the allocated quantity of 0.69 kg DM/head, and signified a recovery rate of the allocated compound feed of 126.1%. This effect may have been caused by sampling error, in that the chromium concentration of the sample of compound H taken during the first faecal collection period may possibly not have been representative of the true chromium concentration of the compound. Uneven distribution of chromic oxide in compound H may have caused this.

Indeed the mean intake of compound H in the first collection period was 0.73 $\pm$ 0.204 kg DM, by substitution of the chromic oxide concentration of the first sample of compound H (0.833 g/kg DM) by the chromic oxide concentration of the second sample of compound H (0.990 g/kg DM). This indicates a recovery rate of the allocated compound of 105.2% instead of 126.1%.

The coefficients of variation for the mean compound dry matter intakes were 23.6%, 28.3% and 27.9% for the standard compound, compound G and compound H respectively. The distributions of values around the mean were therefore marginally more compact for the standard compound than for compounds G and H, indicating a slightly more uniform intake of the standard compound feed compared with the compounds G and H. Indeed the individual dry matter intake of the standard compound by 10 out of the 19 ewes (52.6%) was within $\pm$ 0.10 kg of the mean calculated intake compared with 3 out of 19 (15.8%) and 2 out of 19 (10.5%) for

compound G and compound H respectively.

The calculated mean dry matter intakes of the compound feeds (0.69, 0.65 and 0.70 kg DM for the standard compound, compound G and compound H respectively) from the second faecal collection period (days 26-31) were all very similar to the respective allocated quantities (0.70, 0.71 and 0.70 DM/head), and produced recovery rates of 98.6%, 91.6% and 97.1% respectively.

The coefficients of variation for the mean standard compound dry matter intakes in the second faecal collection period was of the same order (24.1%) to that achieved during the first faecal collection period (23.6%). The coefficients of variation for the mean dry matter intakes of compound G and compound H for the second faecal collection period were 38.2 and 21.3% respectively which are both somewhat different to that achieved from the first faecal collection period (28.3% and 27.9% respectively). It appears that the most uniform dry matter intake, during the second faecal collection period, was brought about by allocation of compound H (CV 21.3%) and the least uniform dry matter intake was brought about by the allocation of compound G (CV 38.2%). The fairly large coefficient of variation for Group 2 (compound G) was almost entirely caused by the relatively larger dry matter intake of only two ewes (148 and 160 consumed 1.10 and 1.24 kg DM of compound G respectively).

The recovery rate of the allocated quantity of compound H was 97.1% in the second faecal collection period, which suggests that a more representative sample of compound H has perhaps been procured in the second collection period (samples of the compound feeds, during the second collection period, were taken from day 15-27, compared with from day 8 and 9 during the first collection period).

During the second faecal collection period, the calculated individual dry matter intakes of the standard compound were within $\pm$ 0.10 kg of the calculated mean for 10 of the 19 ewes in Group 1 (52.6%). The calculated individual dry matter intakes of compound G and compound H were within $\pm$ 0.10 kg of the calculated mean for 6 out of 19 ewes (31.6%) and 8 out of 17 ewes (47.1%) respectively.

The absolute and rank order correlation coefficients, obtained from calculated compound dry matter intakes between the faecal collection periods for each respective compound are presented in Table 56. The correlation coefficient for compound G was statistically significant (0.671, $P<0.01$) whereas the respective correlation

coefficients for the standard compound and compound H were fairly low, although positive, and not statistically significant. The rank order correlation coefficients were statistically significant for compound G and compound H (0.603, $P<0.01$ and 0.485, $P<0.05$ respectively). The rank order correlation coefficient for the standard compound was fairly low (0.259) and not statistically significant.

Table 56 Absolute and rank order correlation coefficients computed between the compound dry matter intakes obtained from each faecal collection period for the respective compounds (standard, compound G and compound H)

Compound	Correlation coefficient	Rank order correlation coefficient
Standard	0.324	0.259
Compound G	0.671**	0.603**
Compound H	0.388	0.485*

* $P<0.05$ ** $P<0.01$

Discussion

When compound G and compound H were abruptly introduced to Group 2 and Group 3, during the first faecal collection period (and chromic oxide was introduced to Group 1, incorporated into the standard compound) the variation of compound dry matter intake was fairly similar for Groups 1, 2 and 3 (coefficients of variation 23.6%, 28.3% and 27.9% respectively), although the variation in intake of the standard compound feed was marginally smaller. Furthermore, the uniformity of intake of the standard compound was emphasised by observation of the number of ewes which comsumed $\pm$ 0.10 kg DM of the calculated mean intake (10 out of 19 ewes for the standard compound, compared with 3 out of 19 ewes and 2 out of 19 ewes for compound G and H respectively).

Nevertheless, the observed reluctance of several of the ewes from Group 2 and Group 3, on initial introduction to compound G and compound H respectively, and the marginally slower rate of consumption of the respective compounds serve to indicate that compound G and compound H were moderately more unacceptable to the ewes, from each respective

group, compared with the standard compound feed.

The corresponding coefficients of variation for intake of compound G and compound H calculated from the second faecal collection period (38.2% and 21.3% respectively), which involved a preliminary period of 13 days where the ewes from each group were again introduced to their respective compounds, were not consistent with those obtained from the first faecal collection period (28.3% and 27.9% respectively). However, the corresponding coefficient of variation for intake of the standard compound (24.1%) was very similar to that obtained during the first collection period (23.6%). Indeed the coefficient of variation for intake of compound G was considerably increased, whereas the coefficient of variation for intake of compound H was fairly reduced which suggested that after a preliminary introductory period, the ewes accepted compound H more readily than compound G. This was further emphasised by observation of the number of ewes which consumed within $\pm$0.10 kg of the calculated mean intake in each group (6 out of 19 ewes (31.6%) for compound G and 8 out of 17 ewes (47.1%) for compound H), the numbers and percentages of which had both increased from the first faecal collection period. The number of ewes which consumed within +0.10 kg DM of the calculated mean for the standard compound feed was the same as in the first collection period (10 out of 19 ewes).

The influence of proximity to parturition in the second faecal collection period (ewes were within approximately 10 days of parturition) may have had a further effect on the individual intake of compound feed by the ewes. Consequently ewes, within the respective groups, may have been differentially influenced by the degree of unacceptability of the compounds, particularly compound G and compound H. It appears then, that compound G may prove to be more unacceptable as parturition approaches.

Furthermore the statistical significance of the absolute correlation and rank order correlation coefficients (0.671, $P<0.01$ and 0.603, $P<0.01$ respectively) between calculated dry matter intakes from the first and second faecal collections by the ewes allocated compound G, suggests the same pattern and ranking order of dry matter intake of compound G calculated from the first and second faecal collection periods.

The relative unacceptability of compound G, by the ewes, seems to have persisted, therefore, from the first faecal collection period, where compound G was abruptly introduced, to the second faecal

collection period, where compound G was given to the ewes for 13 days prior to faecal collection.

The absence of statistically significant absolute and rank order correlation coefficients between the dry matter intake, calculated from the first and second faecal collection periods, by the ewes allocated the standard compound may indicate the relative acceptability of this compound, where intake has been differentially affected, between faecal collection periods, by other factors (eg. differences in proximity to parturition may have altered the pattern of compound intake between the ewes).

The absence of a statistically significant absolute correlation coefficient for dry matter intake of compound H, between faecal collection periods, suggested a different pattern of intake between the faecal collection periods even although the ranking order was fairly similar (0.485, $P<0.05$). This may indicate a degree of unacceptability of compound H by the ewes which persisted irrespective of the 13 day introductory period prior to the second faecal collection period, compared with the abrupt introduction to compound H prior to the first faecal collection period.

The results from the present experiment are quite different to those obtained from Experiment 4.2, where individual intakes of the standard compound (compound F) and compound G were measured by complete faecal collection using dry, non-pregnant ewes, which were allocated the compounds on a group basis. The faecal collection period of six days, in Experiment 4.2, was preceded by a six day introductory period. The coefficient of variation for individual intake of the standard compound (ie, compound F) and compound G were 30.5% and 20.3% respectively, which indicated that compound G promoted a more uniform compound dry matter intake than the standard compound. The rate of consumption of compound G, particularly over the first 2 to 3 days of allocation , was marginally slower than for the standard compound. However, Experiment 4.2 involved allocation of a constant quantity of dried grass to each of the ewes whereas in the present experiment the ewes had group access to hay and therefore the variable hay intake between the ewes may have influenced the pattern of intake of compound feed between the ewes moreso than where a constant allocation of dried grass was given to the ewes. Furthermore, the proximity of the ewes to

parturition in the present experiment (non-pregnant ewes were used in Experiment 4.2) may also prevent the production of similar results to those in Experiment 4.2.

Therefore, compound G was not as acceptable as compound H to ewes in late pregnancy, in that a less uniform compound intake was promoted by allocation of compound G compared with allocation of compound H to two respective groups of ewes. Nevertheless, both compound G and compound H were marginally unacceptable to four ewes in each group, on the first day of allocation of the compounds (the ewes were abruptly changed to the respective compounds) with possible deleterious consequences, in terms of exaggerating plasma ketone concentrations (and perhaps producing symptoms of pregnancy toxaemia) for example, particularly where an associated stress factor is present (eg inclement weather). It is perhaps likely that deleterious consequences caused by the initial allocation of marginally unacceptable compound feeds, may be observed therefore in ewes which are kept outdoors prior to parturition.

SECTION 5 VARIATION IN THE INDIVIDUAL INTAKE OF COMPOUND FEED IN GROUP FED CATTLE (SUCKLER COWS, DAIRY COWS AND GROWING STEERS)

The variation in individual feed intake in group fed animals may be influenced by many factors, e.g. the method of feed presentation (e.g. troughs or feedrings), frequency of feeding, physical form of diet and incidence of alimentary disease, which have been discussed more fully in the General Introduction and Literature Review section of the thesis.

In the present section the possible influences of the factors indicated above were investigated (separately) in various groups of cattle which were usually allocated compound feeds at a restricted level of intake. Experiments 5.1 to 5.4 (inclusive) examine the possible influence of method of presentation of the compound feed, frequency of feeding of the compound feed and physical form of the compound feed (Experiments 5.3 and 5.4) respectively on the individual compound feed intake in suckler cows. Experiment 5.5 attempts to assess the relative effectiveness of supplying a magnesium enriched compound feed to dairy cows under individual or group feeding conditions. Experiment 5.6 investigates the possible influence of ostertagiasis in Friesian steers on the variation in individual compound feed intake at grass and individual hay intake during housing.

Experiment 5.1 The influence of method of feed presentation on the variation in the individual intake of group fed pelleted compound feed by housed suckler cows, which were individually given constant amounts of roughage

Introduction

The influence of the method of feed presentation (i.e. troughs or feedring) on the uniformity of intake of group fed pelleted compound feed by a group of suckler cows was investigated in the present experiment. In Period 1 and Period 2 the group of cows was allocated the compound feed from three wooden cattle troughs or from two feedrings respectively. Hay was individually allocated to the group in the byre in both Period 1 and Period 2. The compound feed presented to the cows in Periods 1 and 2 proved to be relatively unacceptable and, indeed, there were refusals of compound feed in each period. Consequently, the cows were subsequently allocated a proprietary pelleted compound feed, which was expected to be relatively more acceptable to the animals, in three troughs (Period 3) to compare the uniformity of intake of a relatively more acceptable compound feed by the group. Hay was again individually allocated to the cows in the byre.

Materials and Methods

Sixteen dry, pregnant suckler cows (mainly Hereford cross) of mean liveweight 445 $\pm$ 49 kg were tied in a traditional byre where each cow had access to individual feeding facilities for the allocation of both roughage and concentrate feed. The cows also had access to a concreted area of $28m^2$ where cattle troughs and feedrings were alternatively made available for the allocation of compound feeds during the present experiment.

During Period 1 the cows were allocated 1.5 kg FM/head/day (in one feed) of a home-produced pelleted compound which consisted of barley, urea and chromic oxide, the proximate analysis of which is presented in Table 57. The allocation was evenly placed into the three wooden troughs (each of 3.5 m in length allowing 0.66 m, along one side, per cow) in the concrete yard at 07.30 h and the cows were untied from the byre to allow them access to the troughs in the yard. The cows remained in the yard until the compound feed allocation had been consumed after which they were again tied up in the byre and

individually allocated 2.5 kg FM/head of hay (usually at 08.00h). A further 2.5 kg FM/head of hay was given to the cows in the byre at 16.00 h.

Table 57 Proximate analyses of the compound feeds and hay

	Barley/urea compound		Proprietary compound	Barley/chromic oxide compound	Hay
Period	1	2	3	3	
DM (g/kg)	878	875	875	857	831
Composition of dry matter (g/kg)					
Crude protein	230	220	150	106	81
Crude fibre	47	46	126	55	321
Ether extract	5	8	27	16	57
Soluble carbohydrates	633	642	509	786	491
Ash	85	84	188	37	50
Chromium	4.25	3.93	-	5.84	-

Table 58 Method of faecal grab sampling

Samples taken and combined over 7 days	Time of sampling each day			
	0.700h	13.00h	16.00h	19.00h
21	+	+		+
7		+		
2 (on 2 consecutive days only)			+	
1 (on 1 day only)			+	

After a preliminary seven day period faecal grab samples were taken per rectum from the cows, as described in Table 58 for a further seven days. Where more than one grab sample was taken from the cows over the seven day collection period, the faeces samples were amalgamated for the respective sampling times from each day. At the end of the collection period the faeces samples were appropriately subsampled, dried, milled and analysed for chromium to facilitate calculation of the individual compound feed intake of the animals (Appendix 3).

During Period 2, which proceeded immediately after Period 1, the cows were again allocated 1.5 kg FM/head/day, in one feed, of the home produced barley/urea/chromic oxide compound (proximate analysis in Table 57) from two feedrings which had been placed in the concrete yard (each feedring had 16 head spaces of 0.3 m in width, effectively allowing 0.6 m per animal). Again the cows were untied from the byre at 07.30 h to facilitate access to the feedrings. The cows remained in the yard until the compound feed allocation had been consumed, after which they were tied up in the byre and individually allocated 2.5 kg FM/head of hay (usually at 08.00 h). A further 2.5 kg FM/head of hay was given to the cows in the byre at 16.00 h.

After a preliminary seven day period, faecal grab samples were taken, as described for Period 1, for a further seven days. The faeces samples were treated as in Period 1 and at the end of the collection period they were subsampled (if appropriate), dried, milled and analysed for chromium. The individual compound feed intake of the animals was thence calculated.

During Period 3, which followed immediately after Period 2, the cows were allocated 1.5 kg FM/head/day in one feed at 07.30 h of a proprietary pelleted compound feed (proximate analysis presented in Table 57) from three wooden troughs (0.66m/head/cow measured along one side) in the concrete yard. Additionally the cows were individually given 1.0 kg FM/head of a barley/chromic oxide pelleted ration in the byre at 16.00 h. Thus the cows received a constant allocation of chromium. Hay was also individually given to the cows at a rate of 5 kg FM/head/day, in two equal feeds at 08.00 h and 16.30 h immediately after the allocations of the respective compound feeds.

After a preliminary seven day period, faecal grab samples were taken , as described in Period 1 and Period 2, for a further seven days. The faeces samples were amalgamated appropriately as in Period 1

and Period 2 and at the end of the collection period the samples were dried, milled and analysed for chromium. The individual compound feed intake of the animals was then calculated.

Results

During Period 1 the cows usually came forward readily to the troughs and all of them began to consume the compound feed. However, after 15 to 20 minutes more than 8 to 10 of the cows had usually stopped eating, even although approximately one third of the daily compound feed allocation remained in the troughs. Cows 3, 27 and 10 were usually more keen to persevere at the troughs. Nevertheless, within 30 minutes of access to the compound feed all the cows had usually stopped eating having consumed approximately 90% of the allocation of compound feed. The cows were allowed an additional 20 to 30 minutes in the concrete yard with access to the troughs and, if they did not recommence to consume the compound feed within this time, they were put back in the byre. Indeed, on the first morning of Period 1, even when the cows were kept out in the concrete yard with access to the troughs until 11.15 h, they still did not completely consume their allocation. In effect, 18.6 kg DM of compound feed was refused during the faecal collection week, i.e. 2.7 kg DM/day which is equal to approximately 12.8% of the daily allocation of compound feed.

During Period 2 the cows also exhibited some reluctance to completely consume the compound feed allocation from the feedrings. All the cows usually came forward to consume the allocation. However, within 30-45 minutes most of the cows had moved away having consumed approximately 90% of the allocation. Cows 27, 3 and 4 usually remained at the feedrings for a longer time than the other cows, even although they did not usually finish off the allocation. After all the cows had stopped eating, they were allowed access to the feedrings for a further 20 to 30 minutes and, if they did not recommence consumption of the allocation of compound feed within this time, they were taken back to the byre. During the faecal collection week, 7.8 kg DM of compound feed was refused by the cows, i.e. 1.1 kg DM/day which is equal to 5.2% of the daily allocation of compound feed.

In contrast to Periods 1 and 2, the cows readily consumed their allocation of proprietary compound feed (from troughs) in Period 3. The allocation was usually completely consumed within 10 to 15 minutes of access to the troughs. All the cows came forward and remained at

the troughs until the compound feed had been completely consumed.

The individual compound feed intakes for each period were calculated from the faecal chromium concentrations and in proportion to the known quantity consumed per day by the group. In the calculations, the dry matter digestibility coefficients were assumed to be 0.70 for the hay component of the diets, 0.90 for the barley/urea/chromic oxide compound allocated in Periods 1 and 2, 0.75 for the proprietary compound feed allocated in Period 3 and 0.90 for the barley/chromic oxide compound also allocated in Period 3. The mean faecal chromium concentrations from each period are presented in Table 59. The coefficients of variation of the mean faecal chromium concentration were similar for each period and method of faecal sampling (15.1% - 28.9%) and indicate the relatively large constant contribution of faecal dry matter from the hay component of the diet (approximately 76% of feed dry matter allocation from hay) which was individually given to the cows. Any possible variation in the intake of the chromium containing feeds (Periods 1 and 2) or the proprietary compound feed (constant intake of chromium given to the cows in Period 3) was, therefore, masked by the larger contribution of hay to the faecal dry matter output. The mean dry matter intakes of the respective compound feeds allocated in Periods 1, 2 and 3, for each of the methods of faecal sampling, are presented in Table 60. During Period 1 the method of faecal sampling, where two grab samples were amalgamated, was erroneously omitted during the collection period.

Table 59 Mean faecal chromium concentration (n = 16) (± S. dev.) during Periods 1, 2 and 3 for each of the separate grab sampling methods

Faecal chromium concentration (g/kg DM)	Number of faecal grab samples taken during the collection period			
	21	7	2	1
Period 1 (troughs)				
Mean	2.29	2.35	-	2.35
S. dev. ±	0.550	0.555	-	0.559
CV%	24.0	23.6	-	19.6
Period 2 (feedrings)				
Mean	2.35	2.38	2.34	2.41
S. dev. ±	0.503	0.518	0.562	0.698
CV%	21.4	21.8	24.0	28.9
Period 3 (proprietary compound feed from troughs)				
Mean	2.10	2.29	2.17	2.34
S. dev. ±	0.358	0.642	0.328	0.371
CV%	17.1	27.9	15.1	15.8

During Period 1 and Period 2 the ranges of compound feed intake were similar for each of the methods of faecal sampling (as would be expected) and irrespective of the choice of feed presentation (i.e. from troughs or feedrings). The coefficients of variation for compound feed intake were between 20.0% and 30.0% and there was no apparent difference between troughs (Period 1) and feedrings (Period 2).

The numbers of cows which consumed within ± 20% of the mean quantity consumed by the group (i.e. between 0.9 and 1.4 kg DM for Period 1 and between 1.0 and 1.5 kg DM for Period 2) were similar for each method of feed presentation. This is presented in Table 61. Usually more than half of the group of cows (ie, >8) consumed within ± 20% of the mean intake, even although there were refusals of compound feed in both Periods 1 and 2.

Table 60 Mean dry matter intakes of compound feed (n = 16) (± S. dev.) during Period 1, Period 2 and Period 3 for each of the separate grab sampling methods

Compound feed intake (kg DM)	Number of faecal grab samples taken during the collection period			
	21	7	2	1
Period 1 (troughs)				
Mean	1.2	1.2	-	1.2
S. dev. ±	0.31	0.31	-	0.24
Range	0.7-1.8	0.8-1.7	-	0.8-1.6
CV%	25.8	25.8	-	20.0
Period 2 (feedrings)				
Mean	1.3	1.3	1.3	1.3
S. dev. ±	0.29	0.29	0.32	0.39
Range	0.9-1.7	0.9-1.7	0.9-2.1	0.7-2.1
CV%	22.3	22.3	24.6	30.0
Period 3 (proprietary compound cake troughs)				
Mean	1.3	1.3 (1.4*)	1.3	1.3
S. dev. ±	0.49	0.60 (0.50)	0.44	0.53
Range	0.7-2.2	0-2.4 (0.8-2.4)	0.6-2.3	0.6-2.2
CV%	37.7	46.2 (35.7)	33.9	40.8

* Exclusion of cow 22 with apparent nil consumption of compound feed (probable analytical error) (n = 15)

Table 61 The number of cows (total = 16) which consumed compound feed within ± 20% of the mean group intake for Periods 1, 2 and 3

		Faecal grab samples taken during the collection period			
Number of cows		21	7	2	1
Period	kg DM				
1	0.9-1.4	7	9	-	11
2	1.0-1.5	9	9	7	9
3	1.1-1.6	4	6	8	5

Rank order correlation coefficients were computed between the ranking order of the compound feed intake (for the respective methods of faecal sampling, except between 2 grab samples) from troughs and from feedrings. The rank order correlation coefficients were: -0.205, +0.201 and +0.200 for 1, 7 and 21 grab samples respectively and none was statistically significant, which would suggest that, assuming that the compound feeds allocated in Periods 1 and 2 were comparably unacceptable to the animals, the ranking order positions were not maintained when the compound feed was allocated from two feedrings instead of from three troughs (and vice versa).

During Period 3 when 7 faecal grab samples were taken, one of the calculated compound feed intakes was nil (cow 22) which may have been caused by an error in the analysis of the respective faecal chromium concentration. A less uniform intake of compound feed by the group of cows was observed in this period when a relatively more acceptable proprietary compound feed was offered to the cows from three troughs, where the coefficients of variation were between 33.9% and 40.8% (depending on the method of grab sampling) and between 20.0% and 25.8% in Period 1 when a relatively less acceptable compound feed was allocated to the cows in three troughs. Indeed, usually only less than half of the cows (4-8) (Table 61) consumed within ± 20% of the mean group intake (i.e. 1.1 - 1.6 kg DM) which was much reduced in comparison to the corresponding number of cows in Period 1 (7-11).

Rank order correlation coefficients were computed between the ranking

order of compound feed intake (for the respective methods of faecal sampling, except between 2 grab samples) of Period 1 and Period 3, where a relatively unacceptable and a relatively more acceptable compound feed was respectively allocated to the group from three troughs. The rank order correlation coefficients were 0.674, 0.328 and - 0.150 for 1, 7 and 21 grab samples respectively. Only the rank order correlation coefficient between the compound feed intake calculated from 1 grab sample in Period 1 and Period 3 was statistically significant ($P < 0.01$) which may have been fortuitous in view of the possibly more accurate determinations of feed intake from 7 and 21 grab samples of faeces, where chromium has been used as the faecal marker, as discussed in Section 1 of this thesis. It is more likely that the rank order correlation coefficients from 7 and 21 grab samples were more representative of the true ranking orders. It is apparent then that the ranking order of the cows was not maintained between Period 1, when a relatively unacceptable compound feed was allocated, and Period 3, when a relatively more acceptable proprietary compound feed was allocated to the cows. Therefore, a different pattern of intake between the cows was observed between Period 1 and Period 3.

Discussion

The uniformity of intake of the relatively unacceptable compound feed by the suckler cows was not greatly influenced by the method of presentation of the feed, i.e. from troughs or feedrings, as illustrated by the similarity in the respective coefficients of variation of between 20.0% and 30.0%. The coefficients of variation of compound feed intake in the present experiment (Period 1 and Period 2 only) were indeed fairly low in comparison with coefficients of variation of faecal chromium concentration of 40.0% and 61.1% for the allocation of 1 kg FM and 2 kg FM respectively of compound nuts from three troughs to suckler cows at grass (Experiment 5.4).

The pattern of compound feed intake between the animals in the group was apparently influenced by the method of feed presentation in that the ranking orders for compound feed intake were not maintained between Period 1 and Period 2 (i.e. between troughs and feedrings respectively).

The range of metabolisable energy intake by the cows from the compound feed intake (assuming 12.0 MJ ME/kg DM for the barley/urea compound feed) was between 8.4 and 20.4 MJ ME for Period 1 (troughs)

and between 8.4 and 25.2 MJ ME for Period 2 (feedrings) which would result in overall ME intakes (including hay intake) of between 48.4 and 60.4 MJ for Period 1 and between 48.4 and 65.2 MJ for Period 2, where the individual hay intake of 4.0 kg DM/head supplied 40.0 MJ ME (assumed 10 MJ ME/kg hay DM) in both periods. The cows were allocated 56 MJ ME/head/day (1.3 kg DM/head of compound feed and 4.0 kg DM/head of hay), 40 MJ ME of which was supplied from the hay component of the diet. Therefore the variation in intake of the compound feed allocation in Period 1 and Period 2 did not markedly influence the total ME intakes per animal.

In a situation where one of the objectives of giving the compound feed would be to provide a critical input of a supplementary material, such as magnesium or a growth stimulant, the variation in the intake of compound dry matter may have had a deleterious effect on the well-being of the cows, particularly where the intake of compound feed was very much less than the allocation rate (eg, 1.3 kg DM/head in this experiment).

During Period 3 when a relatively more acceptable proprietary compound feed was allocated to the cows, the variation in compound feed intake was less uniform than in Period 1 and Period 2, as illustrated by the larger coefficients of variation of compound feed intake (between 33.9% and 40.8%). The increased variation in individual intake within the group was further indicated by the fewer number of cows which consumed within $\pm$ 20% of the allocated mean (between 4 and 7 cows) in this period compared with usually more than 8 cows in Periods 1 and 2. The more liberal allocation of compound feed in this period, where the cows were additionally individually allocated 0.85 kg DM/head of the barley/chromic oxide compound (and, consequently, the cows may not have been as hungry as in Periods 1 and 2) may have promoted the increased variation in individual intake of the proprietary compound feed. Nevertheless the cows usually completely consumed the group fed proprietary compound cake, allocated in Period 3, within 10 to 15 minutes which may have promoted disparity in compound feed intake between the cows related to the increased rate of consumption of this more acceptable compound feed. In contrast, the compound feeds allocated in Periods 1 and 2 were not eaten with such keenness, even although the total allocation of compound feed was more restricted in these periods. It is, therefore, possible that the relatively unacceptable compound feed allocated in Period 1 and Period 2 promoted

a more uniform intake within the group than the more acceptable compound feed allocated in Period 3. This trend is likely to have been mediated through differences in the rate of consumption of the two compound feeds.

The possible influence of allocation of compound feed from troughs or feedrings on the variation in individual feed intake in the group of suckler cows may have been further demonstrated by the allocation of the proprietary compound feed from feedrings as well as from troughs (Period 3). The relative unacceptability of the compound feed allocated in Period 1 and Period 2 has confounded the possible influence of the method of feed presentation on individual feed intake in the group of cows.

A relatively unacceptable compound feed was also observed to promote a more uniform intake in a group in Experiment 4.2, where two pelleted compound feeds (compound F and compound G), which differed in acceptability, were allocated to two groups of ewes. The relatively more unacceptable compound (compound G) promoted a more uniform compound feed intake in the group than did compound F which was relatively more acceptable (coefficients of variation of 20.5% and 30.3% respectively).

The ranking orders of compound feed intake between Period 1 and Period 3, when the relatively unacceptable compound feed and the more acceptable proprietary compound feed were allocated respectively, were not maintained, even although the respective allocations were presented from three troughs with ample space in each period. The pattern of compound feed intake between the cows in the group was therefore apparently influenced by the degree of acceptability of the compound feeds.

The range of metabolisable energy intake, from the proprietary compound feed only, of the cows in Period 3 was between 6.6 MJ ME and 26.4 MJ ME (assuming 11.0 MJ ME/kg DM for the proprietary compound feed). Again the variation in intake of the compound feed allocation in Period 3 did not markedly influence the total ME intake per animal (56.8 to 76.6 MJ ME) due to the contribution made by the individual hay allocations (40.0 MJ ME/head) and by the individual alocations of 0.85 kg DM/head of the barley/chromic oxide compound (assumed 12.0 MJ ME/kg DM) to the total ME intake. Nevertheless the variation in the supply of essential minerals and trace elements and, indeed, growth promoting

compounds, had they been incorporated into the compound feed, to the group of animals may again have influenced the well-being of the cows, particularly where one of the objectives of giving the compound feed would be to provide a critical intput of a supplementary material.

Experiment 5.2 Influence of the method of compound feed allocation on the variation in individual compound feed intake in a group of housed suckler cows which were also group fed straw

Introduction

The present experiment examines the variation in individual intake of group fed pelleted compound feed to suckler cows under several methods of allocation. A constant rate of allocation of compound feed (i.e. 2 kg/head/day) was given to the group in one, two or three equal feeds during the day in three separate periods respectively. Pelleted compound feeds may be consumed relatively quickly, compared with a loose meal for example, (Foot and Russel, 1973) which should promote a fairly large variation in individual compound feed intake in the group. The variation may be further exaggerated by offering the allocation of 2 kg FM/head/day in two or three feeds respectively as the quantity allocated at each feed is reduced. The coefficient of variation of compound feed intake may therefore be expected to increase for three feeds/day compared with one feed/day of 2 kg FM/head/day.

The possible influence on the variation of compound feed intake in the group of cows of altering the rate of allocation of compound feed from 1 kg FM/head/day to 2 kg FM and 3 kg FM/head/day respectively given in one feed, was also assessed in the present experiment. As the compound feed allocation is increased, a commensurate decrease in the variation of individual intake in the group may be expected which may again be related to a possible decrease in the rate of compound feed consumption (Foot and Russel, 1973).

A comparison was also conducted between the variation in individual compound feed intake of those cows in the group which had a body condition score of less than or equal to 3 and the remaining cows in the group which had a body condition score of greater than 3 respectively. A constant allocation of compound feed was offered to each separate subgroup in one feed per day.

The cows were group fed straw throughout the experiment and the

individual intake thereof was determined in Period 1 and assumed to be maintained in that order during the subsequent experimental periods.

Materials and Methods

Twenty-one suckler cows (including seven first-calving heifers) in mid-pregnancy and of mixed age, mainly Hereford cross, and mean liveweight 460 ± 70 kg were abruptly separated from their respective calves in the late autumn, directly after being brought inside from grass. The animals were housed in an open-fronted building of 200 m^2 in area which was partitioned to provide a straw-bedded area (100 m^2) where the animals could be individually fed concentrates by means of lock-in feeders. The remainder of the building provided access to two feedrings (each with 16 spaces of 30 cm width separated by vertical bars) on the concrete floor, from which barley straw could be offered to the animals. Directly outside the building in a concreted yard there were four wooden cattle troughs (each of 3.5 m in length allowing 0.67 metres along one side per cow) which were used during the experiment for group feeding of concentrates (Periods 2 to 7).

Chromic oxide had been incorporated into the proprietary compound cake at a rate of 5 kg per tonne of fresh matter. The compound cake also contained monensin. Proximate analyses and digestibility data of the compound cake and straw are presented in Table 62.

There were seven systems of allocation of the compound feed (Table 63). Each period was of seven days. In Periods 1, 2, 3 and 4 a constant amount of 2.0 kg fresh matter per head was given on the following basis:-

Period 1: Individually in lock-in feeders in one feed at 07.30 h;

Period 2: In one group in troughs in one feed at 0730h;

Period 3: In one group in troughs in two feeds each of 1.0 kg per head at 07.30 h and 16.00h;

Period 4: In one group in troughs in three feeds each of 0.66 kg per head at 07.30h, 12.00h and 16.00h.

Table 62 Proximate analyses and digestibility data

	Proprietary pelleted compound cake	Barley straw
Dry matter g/kg	882	780
Composition of dry matter g/kg		
Crude protein	157	29
Crude fibre	124	446
Ether extract	17	14
Soluble carbohydrate	577	450
Ash	125	61
Chromium	1.927	-
Dry matter digestibility coefficient	0.63	0.43
ME MJ/kg DM	8.92	-

Table 63 Amounts and method of compound feed allocation (fresh matter)

Period	Allocation	Total feed per day kg/head	No. of feeds	Amount per meal kg/head
1	Individual	2.0	1	2.0
2	Group	2.0	1	2.0
3	Group	2.0	2	1.0
4	Group	2.0	3	0.66
5	Group	1.0	1	1.0
6	Group	3.0	1	3.0
7	Two subgroups	2.0	1	2.0

In Period 5 the allocation of feed given on a group basis was reduced to 1.0 kg per head and in Period 6 it was increased to 3.0 kg per head, both these amounts being given in troughs in one feed at 07.30h.

In Period 7 the cows were divided into two subgroups according to body condition score.

Group A (10 cows) were of body score ≤ 3; and

Group B (11 cows) were of body score >3.

Each group was given 2.0 kg compound cake in one feed at 07.30h.

Straw was allocated in the feedrings at a constant rate of 6.0 kg fresh matter per head per day throughout the experiment. It was given in two approximately equal feeds at 07.45h and 16.30h immediately following consumption of the concentrate. All the cows were seen to consume straw immediately.

The lying area for the cows (which was separate from the area of the feed rings) was bedded with 4 bales of poor quality straw (about 70 kg) at 07.30h each day. The cows were allowed back to it following their morning allocation of straw in the feedrings. As the area was restricted and thus bedding rapidly became contaminated with faeces and urine, little or none of the bedding straw was seen to be consumed by the cows. An identical daily procedure was followed throughout and the possibility cannot be excluded that a few of the cows might have consumed a small amount but, if so, it would have been consistent.

On days five and seven of each experimental period (1 to 7) faecal grab samples were taken from each animal immediately before the morning concentrate allocation. At the end of each period, the samples were amalgamated for each animal, dried, milled and analysed for chromium.

The individual faecal chromium concentrations for Period 1 were used to calculate the straw intake of each animal (Appendix 3), using dry matter digestibility coefficients of 0.43 (J. Alawa, personal communication) and 0.63 (from digestibility studies using wether sheep: Appendix 2) for the straw and proprietary concentrate respectively.

The faecal chromium concentrations from Periods 2 to 7 were used to calculate the individual concentrate intakes, assuming that the straw intake data from Period 1 was representative of the mean daily straw intake per animal throughout the whole experiment.

Correlation and rank order correlations were computed for individual compound cake dry matter intake and rankings thereof between

Periods 2 to 7.

Results

The time taken to consume the compound feed allocation per feed in each period is presented in Table 66. In effect, the rate of consumption per kg of cake allocated was fairly uniform between periods, i.e. 4-5 minutes per kg fresh matter. There was no obvious bullying between the animals during access to the compound feed throughout the experiment. Cow 6 was consistently the last of the group to come forward to the troughs when the compound cake had been presented. Throughout the experiment several animals (particularly cows 10 and 19) consistently persevered at the troughs until the compound cake allocation had been completely consumed, with more than half of the other animals having walked away after approximately 90% of the allocation had been consumed, i.e. at the stage when only isolated compound cubes were left in the corners and edges of the troughs.

The time taken to consume the straw allocation was approximately one hour per feed. All the animals persevered at the feedring with intermittent position changes until the straw was consumed. The calculation of individual straw intake from Period 1, when 2.0 kg per head of compound cake had been allocated individually, indicated a mean intake of 4.6 $\pm$ 0.59 kg of dry matter per head, resulting in a coefficient of variation of 12.8%. The calculated mean intake of 4.6 kg DM per head showed excellent agreement with the allocated quantity of 4.7 kg DM per head, using the determined dry matter digestibility coefficient of the straw of 0.43. The mean straw dry matter intakes for the cows (n = 14) and first-calving heifers (n = 7) considered separately, were 4.7 $\pm$ 0.63 kg and 4.3 $\pm$ 0.37 kg respectively. The difference of 0.4 kg DM was not statistically significant.

The means and standard deviations of faecal chromium concentrations for each period are presented in Table 64. The individual calculated dry matter intakes of straw (Period 1) and compound feed (Periods 2-7) are shown in Table 65 and the corresponding means and standard deviations are presented in Table 66. Cow 6 consistently consumed the smallest quantity of compound cake in the group per period, in the range of 40-70% of the mean for the period. This result reflects the observed reluctance of cow 6 to come forward to the troughs at feeding time. Cows 10 and 19 usually consumed the largest quantities of compound feed in the group per period, in the

range of 120-165% of the mean for the period. These results reflect the observed persistency of these two cows at the troughs at feeding time.

When the compound feed was allocated on a group basis, compared with individually, the coefficients of variation for the mean faecal chromium concentration for each period increased, e.g. 9.6% for Period 1 where 2 kg of compound feed was offered on an individual basis compared with 23.5% for Period 2, where 2 kg of compound feed was allocated to the group once a day (Table 64).

Table 64 Mean faecal chromium concentrations and standard deviations (g/kg dry matter) for Periods 1 to 7 (21 cows/group)

Period	Allocation	No. of feeds	Faecal chromium concentration Mean	± S. dev.	CV%
1	Individual	1	1.08	0.104	9.6
2	Group	1	1.03	0.243	23.5
3	Group	2	1.19	0.229	19.2
4	Group	3	1.13	0.238	21.1
5	Group	1	0.64	0.125	19.5
6	Group	1	1.37	0.185	13.5
7	Subgroup A*	1	0.94	0.215	22.9
	Subgroup B**	1	0.95	0.144	15.2

* 10 cows - Body condition score $\leq$ 3.0

** 11 cows - Body condition score > 3.0

Table 65 Individual dry matter intakes (kg) of straw (Period 1 only) and compound feed (periods 2-7) and the corresponding individual overall metabolisable energy (MJ ME) intakes (Period 1, ME from straw intake only)

Period	1		2		3		4		5		6		7		
Cow	DM	ME	DM	ME	DM	ME	DM	ME	DM	ME	DM	ME	DM	ME	
6	4.5	32.9	0.9	40.9	0.9	40.9	0.7	39.1	0.6	38.3	1.5	46.3	1.2	43.6	A
2	5.1	37.2	1.4	49.7	1.4	49.7	1.4	49.7	0.7	43.4	2.6	60.4	1.4	49.7	A
1	4.5	32.9	1.4	45.4	1.5	46.3	1.6	47.2	0.8	40.0	2.3	53.4	1.5	46.3	A
24	4.1	29.9	1.4	42.4	2.1	48.6	2.0	47.7	1.1	39.7	2.7	54.0	1.5	43.3	B
18	3.9	28.5	1.4	41.0	2.0	46.3	1.1	38.3	0.7	34.7	2.2	48.1	1.5	41.9	B
14	4.2	30.6	1.4	43.1	2.2	50.2	2.1	49.3	1.0	39.5	2.5	52.9	1.8	46.7	B
4	5.2	37.9	1.4	50.4	1.7	53.1	1.5	51.3	0.8	45.0	2.6	61.1	1.5	51.3	B
35	4.6	33.6	1.5	47.0	1.8	49.7	1.7	48.8	0.8	40.7	2.5	55.9	1.6	47.9	A
15	4.8	35.0	1.6	49.3	1.4	47.5	1.7	50.2	1.0	43.9	2.8	60.0	1.4	47.5	B
3	4.6	33.6	1.6	47.9	1.8	49.7	2.0	51.4	0.8	40.7	2.4	55.0	1.5	47.0	B
13	4.3	31.4	1.6	45.7	1.6	45.7	2.3	51.9	0.9	39.4	2.7	55.5	2.0	49.2	B
8	4.4	32.1	1.8	48.2	1.9	49.0	1.8	48.2	1.0	41.0	2.7	56.2	1.7	47.3	A
11	4.6	33.6	1.9	50.5	1.8	49.7	1.8	49.7	1.0	42.5	2.5	55.9	2.0	51.4	A
28	5.5	40.2	1.9	57.1	2.0	58.0	2.0	58.0	1.0	49.1	2.9	66.1	2.1	58.9	B
20	4.6	33.6	2.1	52.3	1.4	46.1	1.7	48.8	0.9	41.6	2.8	58.6	2.0	51.4	B
29	3.8	27.7	2.1	46.4	2.1	46.4	1.8	43.8	1.0	36.6	2.5	50.0	1.8	43.8	A
21	4.2	30.7	2.2	50.3	1.8	46.8	1.8	46.8	0.9	38.7	2.4	52.1	1.7	45.9	A
7	4.3	31.4	2.2	51.0	1.9	48.3	1.8	47.5	1.0	40.3	3.2	59.9	2.6	54.6	A
22	3.6	26.3	2.3	46.8	2.0	44.1	1.9	43.2	0.9	34.3	2.9	52.2	2.2	45.9	A
19	6.3	45.9	2.6	69.1	2.3	66.4	1.9	62.8	1.1	55.7	3.6	78.0	2.1	64.6	B
10	4.4	32.1	2.9	58.0	2.1	50.8	2.8	57.1	1.0	41.0	3.3	61.5	2.1	50.8	B

Mean ME intake from straw & compound feed (except Period 1)						A	B
	50.7	50.7	50.7	42.8	58.3	49.2	51.8
S. dev. ±	6.57	5.32	5.83	4.83	6.95	3.4	6.8
CV%	12.9	10.5	11.5	11.3	11.9	6.9	13.2

Calculated straw intake Mean (+ S.dev.) = 4.6 (+ 0.59) kg DM.

For period 7 letters A and B in column denote cows from subgroup A (body condition score $\leq$ 3) and subgroup B (body condition > 3)

The coefficients of variation for compound feed intake for Periods 2, 3 and 4 were 27.3%, 19.9% and 23.3% respectively which perhaps suggests a reduction in the variation, within the group, of compound feed intake when 2 kg fresh matter/head/day was allocated in two or three meals (Periods 3 and 4 respectively) compared with one meal (Period 2).

During Periods 5 and 6, where 1 kg and 3 kg fresh matter/head/day respectively of compound feed were allocated once per day to the animals, the coefficients of variation for compound feed intake were 17.9% and 16.1% respectively, which both suggest greater uniformity of intake within the group in comparison to allocation of 2 kg fresh matter/head/day in one feed, where the coefficient of variation was 27.3% (Period 2).

Table 66 Calculated mean dry matter intakes of compound feed (kg) for Periods 1 to 7 (21 cows/group)

Period	Method	No. of feeds	Time to consume mins.	Compound feed intake kg DM: Mean total given /h/d	S. dev. ±	Range	CV%
1	Individual	1	8-10	1.8	-	-	-
2	Group	1	8-10	1.8	0.481	0.9-2.9	27.3
3	Group	2	4-5	1.8	0.350	0.9-2.3	19.9
4	Group	3	2-3	1.8	0.410	0.7-2.8	23.3
5	Group	1	4-5	0.9	0.158	0.9-1.1	17.9
6	Group	1	10-12	2.6	0.426	1.5-3.6	16.1
7	Subgroup A *	1	6-8	1.8	0.404	1.2-2.6	22.9
	Subgroup B **	1	5-7	1.8	0.328	1.4-2.1	18.6

* 10 cows - Body condition score $\leq$ 3.0

** 11 cows - Body condition score > 3.0

When the group was divided into two subgroups (A and B) in Period 7, on the basis of body condition score ($\leq$ 3.0 and > 3 respectively), the coefficients of variation for compound feed intake were reduced to 22.9% and 18.6% for subgroups A and B respectively, in comparison to 27.3% when the same quantity of compound feed (2 kg fresh matter/head/day) was allocated to the whole group, in one feed, during Period 2. Cow 6 consumed the least quantity (1.2 kg DM) of compound cake within subgroup A, even although this respresented 70% of the mean intake which was an improvement on her previous intakes (e.g. 40-51% of the mean intake when 2 kg/head/day was allocated in Periods 2, 3 and 4). The improvement in uniformity of compound feed intake within subgroup B (CV of 18.6%) was reflected by the individual dry matter intakes of cow 10 and 19 (2.1 kg DM/head) which were not markedly larger than the mean intake (1.8 kg DM), even although this level of intake (2.1 kg DM) represented the maximum within the subgroup.

The overall mean compound feed dry matter intake for the cows (n = 14) and the first-calving heifers (n = 7), for Periods 2 to 6, were 1.7 $\pm$ 0.36 kg and 1.9 $\pm$ 0.12 kg. The difference of 0.2 kg DM was not statistically significant. When the mean dry matter intake for cow 6 was omitted, as this animal did not readily conform with the general group behaviour, the overall mean dry matter intake for the compound feed for the cows (n = 13) for Periods 2-6 was 1.8 $\pm$ 0.29 kg. The difference of 0.1 kg DM between the cows and first-calving heifers was not statistically significant.

The coefficients of variation of the overall mean intake of metabolisable energy (Table 65) from straw and compound feed for Periods 2-7 was of the same order as for straw dry matter and metabolisable energy intakes (12.8% and 13.1% respectively) from Period 1. The variation in the mean metabolisable energy supplied from compound feed (only) within Periods 2-7 corresponded with the variation in mean dry matter intake for the respective period. Therefore, for example, in Period 2 a range of 8.0 - 25.9 MJ ME from compound feed was observed, each animal having been allocated 16.1 MJ ME/head from compound feed. Consequently, the largest and the smallest ranges and coefficient of variation for mean ME intake from compound feed were 27.3% for Period 2 and 16.1% for Period 6 (range 13.4 - 32.1 MJ) respectively, where the mean dry matter intake was 2.6 kg/head, which corresponded to the coefficients of variation for the mean compound

feed dry matter intake.

Absolute correlations and rank order correlations were computed for compound feed intake between Periods 2, 3 and 4, and between Periods 2, 5 and 6. When the results from Periods 2 and 7 were correlated (absolute and rank order correlation) the data from subgroups A and B were amalgamated and treated as one group (n = 21) in the computations. The computed correlationships are presented in Table 67. Consideration of the absolute correlation coefficients and rank order correlation coefficients for Periods 2, 3 and 4 indicates that the pattern of intake was very similar between Periods 2/3 and 2/4 but not for 3/4 (correlation coefficients 0.563, $P < 0.01$; 0.614, $P < 0.01$ and 0.407 NS respectively). The ranking order was maintained between Periods 2 and 4 and 3 and 4 (0.481 $P < 0.05$ and 0.614 $P < 0.05$ respectively). Between Periods 2 and 3 the rank order correlation was not significant (0.416).

The correlation coefficients between Periods 2 and 5 (2 kg fresh matter/head/once a day and 1 kg fresh matter/head/once a day) and between Periods 2 and 6 (2 kg fresh matter/head/once a day and 3 kg fresh matter/head/once a day) were low and non-significant (0.115 and -0.169 respectively). However, the correlation coefficient between Periods 5 and 6 was 0.679 ($P < 0.001$). The ranking order correlation coefficients were significant (0.544, $P < 0.05$ for Periods 2 and 5 and 0.653, $P < 0.01$ for Periods 2 and 6), indicative that ranking order was maintained irrespective of the quantity allocated.

The correlation coefficient and ranking order correlation coefficients for Period 2 and Period 7, where the data from the subgroups A and B were amalgamated, were 0.073 ($P > 0.05$) and 0.81 ($P < 0.001$). This suggests consistency in the ranking order for compound feed intake, even although the animals were allocated their ration of compound feed in two subgroups in Period 7.

Table 67 Correlation (r) and rank order (ro) correlation coefficients for compound feed dry matter intake between periods

(1) Between Periods 2, 3 and 4 where 2 kg FM/head/day of compound feed was allocated in 1, 2 or 3 feeds respectively

	Between Periods		
	2/3	2/4	3/4
r	0.563**	0.614**	0.407
ro	0.416	0.481*	0.614*

(2) Between Periods 5, 2 and 6 where 1 kg, 2 kg and 3 kg FM/head/day respectively was allocated in 1 feed

	Between Periods		
	5/2	5/6	2/6
r	0.115	0.679***	-0.169
ro	0.544*	0.593**	0.653**

(3) Between Periods 2 and 7 where 2 kg FM/head was allocated in 1 feed to the group of 21 cows and two subgroups respectively

r	0.073
ro	0.81***

* $P < 0.05$ ** $P < 0.01$ *** $P < 0.001$

Discussion

The mean calculated straw dry matter intake of 4.6 kg showed good agreement with the allocated quantity of 4.7 kg, which perhaps augments the accuracy of the grab sampling technique. Straw dry matter intake was fairly uniform (CV 12.8%) within the group in Period 1 and was considered to be representative of individual straw dry matter in the subsequent experimental periods. Hence the straw intake data from Period 1 was used in the calculations of compound feed intake in Periods 2 to 7. However, for Period 6, where 3 kg fresh matter/head of compound feed was allocated, it is possible that the pattern of straw intake may have altered due to the elevated quantity of compound feed on offer. It is unlikely that a substitution effect occurred, as the straw was not offered ad libitum and it was a material of low quality. However, individual animals may have consumed a sufficiently greater quantity of compound cake to stimulate intake of the straw where ruminal cellulolysis has been promoted due to additional nitrogen, if this constituent was previously limiting, from the compound feed. In this instance the animal may have had an improved appetite for the roughage which may have been reflected in a small increase in straw intake, albeit under the restricted conditions. The alternative effect, on a similar vein, may have occurred where an animal whose previous straw intake was fairly low (e.g. animal number 22, straw intake of 3.8 kg DM) may have consumed a sufficient quantity of concentrate to inhibit cellulolysis and thus depression of straw intake results. In this instance the straw intake data calculated in Period 1 may not be truly representative of straw intake under elevated copncentrate allocation. Nevertheless, the allocated ratio for roughage to concentrates in Period 6 was 64:36, which is perhaps unlikely to be altered too drastically by the vagaries of individual intake behaviour.

The dry matter intake of straw by the cows (mean 4.7 $\pm$ 0.63 kg) and first-calving heifers (mean 4.3 $\pm$ 0.37 kg) was similar, although the cows consumed marginally more than the heifers. This result was consistent with the observed behaviour of the animals at the feedring where they persisted until most of the allocated straw had been consumed. However, the pattern of straw intake may have been different between the cows and first-calving heifers had the straw been chopped, for example, which may have affected the rate of consumption. This effect was observed when precision chopped silage was allocated to

a group of dairy cattle which consists of first-calving heifers and cows. The heifers were observed to consume significantly less silage than the cows (Experiment 6.1) although other factors contribute to this effect.

The rate of consumption per kg of compound feed was fairly uniform throughout the experiment, although for Period 7 the time taken to consume the compound cake by subgroup A was marginally greater than for subgroup B (6-8 minutes and 5-7 minutes respectively) which is probably accounted for by the inclusion of seven first-calving heifers in subgroup A. The rate of feed consumption of the younger animals, of lower liveweight, may have been less than that of the animals in subgroup B (there were no first-calving heifers in subgroup B).

The reduction in the coefficients of variation for compound feed intake, when 2 kg fresh matter/head/day was allocated in two or three meals compared with one meal (19.9%, 23.3% and 27.3% respectively) suggests that greater uniformity of compound feed intake was promoted by allocating the compound feed in two or three meals compared with one meal per day. This may be contrary to an expected increase in the variation in intake as the quantity of feed allocated was reduced (e.g. Foot and Russel, 1973). However, the effect is confounded due to the allocation of the reduced quantities in two or three meals per day, i.e. the influence of frequency of feeding has reduced the effect. The correlation coefficients between one meal compared with two or three meals per day were significant (one and two meals 0.563, $P < 0.01$, and one and three meals 0.614, $P < 0.01$) which suggests that the pattern of intake was similar irrespective of the frequency of allocation of the whole or parts of a total of 2 kg fresh matter of compound feed/head/day. The rank order correlation coefficient for one meal versus three meals per day was significant (0.481, $P < 0.05$) which indicates that the animals retained a similar rank order when one meal and three meals were allocated. The low coefficient of variation for Period 3, when the ration was allocated in two meals, and the absence of a statistically significant rank order correlation between Periods 2 and 3 may indicate a marked difference in the pattern of intake in Period 3 which promoted a more uniform intake of compound feed.

Allocation of 1 kg/head and 3 kg/head of compound feed in one meal per day (Periods 5 and 6 respectively) promoted greater uniformity in intake compared with allocation of 2 kg/head/day (Period 2) with coefficients of variation of 17.9%, 16.1% and 27.3% respectively. The

fairly restricted allocation of 1 kg/head may have been expected to produce a larger coefficient of variation for compound feed intake. However, similarity between the animals in the rate of consumption of the feed under restricted allocation is likely to account for the observed opposite effect. The pelleted nature of the ration is likely to have contributed to this similarity in consumption rate between the animals. The results may have been different if a bulky loose meal had been allocated, e.g. sugar beet pulp.

Allocation of 3 kg fresh matter/head/day promoted greater uniformity in intake than with 2 kg fresh matter/head/day which suggests that, under a more liberal concentrate regimen, the animals which are consuming the most slow down and the others are able to consume as much, i.e. the rate of feed consumption is reduced. Alteration of the trough space allowance, which was fairly generous, may have produced a different result.

The correlation coefficients between Periods 2 and 5 and Periods 2 and 6 were low and non-significant (0.115 and -0.169 respectively) suggesting that the pattern of intake between the rates of allocation were not similar, even although the coefficients of variation are low. The ranking order, irrespective of quantity allocated, was nevertheless maintained throughout Periods 2, 5 and 6.

When the animals were divided into two subgroups, on the basis of body condition score, which were allocated 2 kg fresh matter/head/day of compound feed separately, the coefficients of variation for compound feed intake were reduced to 22.9% and 18.6% for subgroups A and B respectively, from 27.3% when the animals were fed in one group. It is possible that animals with a similar rate of feed consumption (in terms of liveweight) were grouped together and consequently the variation in feed intake was reduced. Thus uniformity of compound feed intake was promoted in Period 7, which is illustrated particularly by the improvement in intake by cow 6 in subgroup A (1.2 kg DM, 70% of mean) whose intakes of compound feed in the previous periods were usually 40-50% of the group mean). Similarly, cows 10 and 19 whose previous intakes of compound feed were usually well above the mean group intake (e.g. 65% above the mean intake in Period 2) consumed only 20% more compound feed than the mean intake of subgroup B (i.e., 2.1 kg DM each).

Even although the animals were divided into subgroups A and B, when the feed intake data was amalgamated into one combined group, the

rank order correlation between Period 7 and Period 2 was significant (0.81 , $P < 0.001$) which suggests that the ranking order was maintained irrespective of the grouping arrangement. Therefore, even although changes in the method of compound feed presentation (e.g. once versus twice a day allocation) may alter the pattern of dry matter intake, in the shape of the distribution, the ranking orders between the animals appeared to be fairly rigid within the group studied in this experiment.

The observed coefficients of variation in the overall mean ME intake (from straw and compound feed), for each period, were of the same order as the low coefficient of variation for individual straw intake (12.8%) and were in the range of 6.9 - 13.2%. The compound feed was allocated to contribute between 18.7% (Period 5) and 40.0% (Period 6) of the ME supplied by the diet and, where the animal's individual ME allowance (50.1 MJME/head/day) was met (in Periods 2, 3, 4 and 7), the compound feed contributed to 32.0% of the ME allocation. In effect, the individual straw intake (assuming it was similar to the calculated quantity in Period 1) which was supplied to provide 60-81.3% of the ME allocation is likely to influence the range of individual total ME intakes more so than the compound feed, although perhaps to a lesser extent in Period 6. The small variation in the total ME intakes within each period therefore suggests uniformity in total ME intake, irrespective of the quantity or method of allocation of the compound feed. The animals have apparently adjusted their individual straw or compound feed intakes to consume an adequate intake of ME.

Nevertheless, the contribution of the compound feed to the nutrient status of the animals is critical in supplying protein, for example, which may be a limiting factor in the production of cellulolytic bacteria in the rumen, particularly where a low protein roughage is offered, e.g. straw, as well as essential minerals, e.g. magnesium, and any growth promoting additives, e.g. monensin, supplied in the compound feed used in this experiment. Hence, encouragement of uniformity of individual compound feed intake, e.g. by allocating compound feed in two feeds per day compared with one feed per day, may ensure a better response in terms of a sufficient intake of magnesium for example.

Experiment 5.3 The variation in individual compound feed intake in a group of lactating beef cattle offered pelleted concentrate feed in troughs or cattle cobs fed along the ground, both allocated at two levels (early grazing season)

Introduction

Magnesium supplementation of spring calving suckler cows when transferred to grass is usually thought advisable for the prophylaxis of hypomagnesaemia. The type of feed supplement (e.g. farm mixed, proprietary compound) and method of presentation (e.g. proprietary compound in troughs or proprietary cobs along the ground) may differ in their ability to ensure an adequate individual intake (of, for example, magnesium, metabolisable energy, an undegraded protein source etc.) when the supplement is group fed, assuming that competition exists within the group (Kendall, 1977). The variation in individual feed intake may be influenced by differences in the rate of feed consumption as determined by the physical form of the allocated compound feed (eg, Balch, 1971) and/or the quantity of compound feed offered (eg, Stoddard 1969). These aspects were pursued in the present experiment using a spring-calving suckler herd (plus followers and replacements) over a six week period during the early grazing season.

Two types of proprietary concentrate were purchased (BOCM Silcock) each of which contained magnesium as magnesium oxide. The variation in individual intake of the compound feeds under investigation was illustrated by reference to the faecal magnesium concentrations of grab samples.

In order to undertake this experiment several assumptions had to be made to allow the results to be interpreted. In order to compare the results of each experimental period it was assumed that the availability and digestibility of the magnesium source, from both proprietary compounds, were similar. It must also be assumed that the grass intake in each experimental period for each cow was the same and of similar digestibility.

Materials and Methods

Twenty-one spring calving Hereford x Friesian cows (of mixed ages and mean liveweight 500 kg) and their calves (aged from 10-60 days old) plus eight Hereford x Friesian bulling heifers grazed on eight hectares of a mixed sward previously dressed with nitrogen. A Hereford bull was

run with the group from the beginning of Period III.

The two proprietary magnesium compound feeds differed in physical form and each was allocated at two levels ie, 1 kg or 2 kg FM/head/day. In Period I and Period II 2 kg FM cobs and 1 kg FM cobs/head/day were allocated respectively. In Period III and Period IV 2 kg FM nuts and 1 kg FM nuts/head/day were allocated respectively. Each experimental period was of seven days duration. Descriptions and proximate analyses of the compound feeds are presented in Table 68. The experimental design is presented in Table 69.

Immediately before Period I there was a 10-day introductory period to allow the cows and heifers to adapt to being given cobs, as none of the animals had received this form of feed previously. The cattle were changed over onto nuts fed in four troughs at the beginning of Period III. A changeover training period was thought to be unnecessary as the cattle had been used to a cubed barley concentrate over the winter. The cattle had access to the troughs on both sides (trough space allowance = 0.59 metres per head).

The supplementary materials were fed at 07.30 h for all the experimental periods. The animals were observed at this time until they had cleared the feed.

On the seventh day of each experimental period rectal grab samples were obtained from the cows and heifers. Blood samples were obtained at the same time from the jugular vein. The faecal dry matter and the plasma fraction of the blood samples were analysed for magnesium (atomic absorption). Mean faecal magnesium and plasma magnesium concentrations were thence established for each period. The coefficient of variation for the group for each experimental period was also determined.

Table 68 Description and composition of the feeds.

	Nuts	Cobs
Description	Cylindrical pellets 1.5-2.0 cm long x 0.75 cm diameter	Biscuit shaped 3 cm x 3.5 cm x 2 cm Mean weight 25.9±4.7g
Proximate analysis		
Dry matter g/kg	857	861
Composition of dry matter		
Crude protein	120	150
Crude fibre	117	99
Ether extract	16	22
Soluble carbohydrates	598	602
Ash	149	127
Magnesium	16.52	10.78

Table 69 Experimental design

Period	Feed (kg Fresh matter allocated per cow)	Method of feeding
I	2 cobs	Spread on ground in a band 0.25 metre wide and 30 metres long, thus allowing 1 metre length per head.
II	1 cobs	
III	2 nuts	In four troughs each allowing 0.59 metres length per head from both sides.
IV	1 nuts	

Results

Grass availability declined during the experiment, although the supply was considered adequate throughout. The weather was variable during the six week period. The cattle were generally standing at the feeding area on cool, damp mornings. On warm, dry mornings it was usually necessary to drive the cattle to the feeding area. There did not appear to be a marked preference for cobs as opposed to nuts (and vice versa) in this respect, although weather and grass availability are confounding factors.

The time taken to completely consume the feed allocation was markedly more for cobs (30-45 minutes) compared with nuts (5-10 minutes) at both levels of allocation (Table 70).

Table 70 Plasma Mg concentration (mmol/litre), faecal Mg concentration (g/kg faecal dry matter) and mean time to clear feed for Periods I-IV

Period	Feed	Faecal Mg g/kg DM				Plasma Mg mmol/l				Time*
	kg FM	n	Mean	S.dev±	CV%	n	Mean	S.dev±	CV%	
I	2 cobs	22	6.73	1.04	15.5	28	0.88	0.08	8.7	45
II	1 cobs	23	6.40	0.89	13.8	26	0.89	0.09	11.0	25
III	2 nuts	23	7.74	2.13	27.5	29	0.84	0.13	15.9	10
IV	1 nuts	23	5.78	1.59	27.5	28	0.81	0.12	14.6	5

* Average time taken to completely consume feed (min).

When compound nuts were offered the behaviour of the group was more fractious compared to when the group was offered cobs. In all four experimental periods the bulling heifers (notably 29, 35, 36 and 71) were generally more reluctant to eat than the cows, particularly when the compound nuts were offered in Periods III and IV. Nevertheless, this behaviour was not reflected by relatively lower faecal magnesium concentrations (e.g. faecal Mg concentrations in Period III of 8.1, 6.3, 5.5 and 9.6 g/kg DM for heifers 29, 35, 36 and 71 respectively, which were observed to be reluctant to consume the compound nuts in Period III, overall mean faecal Mg concentration for Period III was 7.7±2.13 g/kg DM). Several cows were persistently keen to consume the allocated compound feed throughout the experiment,

particularly cows 27, 14 and 10 which had for example, faecal Mg concentrations of 15.0, 9.6 and 7.6 g/kg DM in Period III when 2 kg FM/head of compound nuts were allocated. The mean plasma and faecal magnesium concentrations for each period are presented in Table 70.

Rank order correlation coefficients were computed for individual ranking of faecal Mg concentration between the different allocations and types of compound feed in Periods I-IV. Only the rank order correlation coefficients for each level of allocation (either 1 or 2 kg FM/head) within the compound feed type were statistically significant (i.e. 0.463, $P<0.05$ between 1 kg and 2 kg cobs and 0.498, $P<0.05$ between 1 kg and 2 kg of nuts). The other rank order correlations, between cobs and nuts at both 1 kg and 2 kg FM/head, were low and not statistically significant which indicates that each individual's ranking order was not maintained when the group was allocated either 1 or 2 kg FM/head of cobs for example, instead of 1 or 2 kg FM/head of compound nuts.

The coefficient of variation of faecal magnesium concentration was 27.5% for compound nuts, at both levels of allocation, compared to 13.8-15.5% for cobs. The relatively high coefficient of variation for compound nuts (Periods III and IV) was caused almost entirely by the relatively larger faecal Mg concentrations of one cow only (cow 27, faecal Mg concentrations of 15.0 and 11.8 g/kg DM for Period III and IV respectively). Indeed, if the data for cow 27 is removed from Period III and Period IV the coefficient of variation is reduced to 19.0% and 16.7% respectively.

It was not possible to obtain a faecal sample from all the cows as some were empty at the collecting time. The mean plasma magnesium concentration was similar in each period (0.8 mmol/litre). The coefficients of variation in each period ranged from 8.7-15.9% with that for compound nuts (at both levels of allocation) being larger than for compound cobs.

Discussion

Comparison of the coefficients of variation for each experimental period suggests that a greater uniformity of supplement intake (and hence magnesium) is more likely to be achieved by offering compound cobs compared with compound nuts. However, omission of the relatively high faecal magnesium concentrations of cow 27 from both Period III and Period IV reduced the corresponding coefficients of variation from 27.5% to 19.0% and 16.7% respectively, which indicates that apart from one animal (cow 27) the intake of compound nuts was fairly uniform within the group. Nevertheless behavioural activity at feeding time suggested greater uniformity of intake when cobs were allocated. When the animals were offered nuts the time spent to clear the feed (at both levels of allocation) was very much reduced (10 and 15 minutes for 2 kg and 1 kg respectively) compared to when cobs were offered (45 minutes and 25 minutes for 2 kg and 1 kg cobs). The relatively slower rate of consumption when compound cobs were offered may have promoted a greater uniformity of feed intake compared with compound nuts, which were consumed more quickly. Behavioural activity was very much more fractious when nuts were offered as opposed to cobs in that 6-10 animals persistently kept in the background and did not persevere with the feed offered. However, when cobs were presented the majority of the animals persisted with the feed. This issue may be confused however, as the bull was introduced to the group at the beginning of Period III when nuts were presented. Behaviour may have been altered by his presence.

The apparent variation in compound feed intake was similar for each level of allocation (1 or 2 kg/head/day) within each type of compound feed (ie, compound cobs or nuts). The average rate of feed consumption was similar for each level of allocation (ie, approximately 25 minutes/kg FM for cobs and 5 minutes/kg FM for nuts) which may have promoted similar variation in intake at each level of allocation. The quantities allocated in this experiment were fairly small; the possible influence of the quantity of feed allocated on the variation in feed intake in the group may have been observed had there been a larger discrepancy in the quantities of feed offered. However, that would not conform with normal husbandry practice.

The animals demonstrated similar rank orders of faecal magnesium concentrations within each type of compound feed, i.e. either compound cobs or nuts, but not between type in that, for example, the animal

which had the highest ranking position for faecal magnesium concentration when 2 kg FM cobs/head was allocated, did not retain a similar position when 2 kg FM nuts/head was allocated and instead gained a lower ranking position. Therefore even although this may indicate a similar pattern of compound feed intake within each allocation of either cobs or nuts, the pattern was not repeated when compound cobs for example were allocated instead of compound nuts (and vice versa) at both levels of allocation i.e. 1 kg or 2 kg FM/head.

The supplement in this situation was used as a source of magnesium in the prophylaxis of hypomagnesaemia. Offering cobs to vulnerable stock may be more advisable than nuts to ensure an adequate and more uniform intake of magnesium within the group. This conclusion could also be applied to supplementation of stock with a protein source or an energy source. In this case plasma magnesium concentrations in all periods were well above (0.8 mmol/litre) the critical concentration of 0.4 mmol/litre where hypomagnesaemia may be a problem. From this it would appear that both nuts and cobs were equally effective in maintaining blood magnesium levels in this experiment. However this was not necessarily seen from behavioural aspects or indeed faecal magnesium concentrations.

The availability (and perhaps digestibility) of grass declined over the six weeks experimental period, which may invalidate comparison between experimental periods. However, the coefficient of variation of faecal magnesium concentration is being used as the basis of comparison between periods and not the mean faecal magnesium concentrations for each period. Hence although grass intake is likely to be different between periods (i.e. giving different mean faecal magnesium concentrations), it was assumed that grass intake within periods between cows was similar. Therefore use of coefficients of variation served to indicate the range of intake of supplement that occurred within experimental periods and served as a valid basis of comparison between periods.

A larger coefficient of variation may have been expected where 1 kg nuts or cobs was offered compared to 2 kg FM/head cobs or nuts. The coefficient of variation of individual concentrate intake by Greyface ewes (Kendall et al, 1980) has been demonstrated to increase from 34.3% when 504 g/head of a pelleted concentrate dry matter hed been consumed to 42.9% and 73.6% when 252 g/head and 84 g/head of concentrate dry matter had been consumed respectively, where the trough

space allowance had been maintained at 330 mm/head. It is perhaps surprising that a similar increase in the coefficient of variation had not been observed in the present experiment, when 1 kg FM/head had been allocated instead of 2 kg FM/head. However, the change in allocation from 2 kg FM/head to 1 kg FM/head represented only a decrease by a factor of two the present experiment. The increase in the coefficient of variation for dry matter intake from 34.3% to 73.6% (Kendall et al, 1980) was brought about by a corresponding decrease in dry matter intake by a factor of six (504 to 84 g DM/head/day).

The present investigation into the use of compound nuts and cobs by suckler cows suggested that uniformity of compound feed intake, by reference to faecal Mg concentrations, may be promoted by supplying compound cobs compared to compound nuts. Nevertheless, the relatively high faecal Mg concentration of one animal (cow 27) complicates this conclusion. In view of this, it was decided to repeat the experiment with the same group of animals in the autumn. The addition of chromic oxide to the formulation of the autumn compound feeds was thought to be necessary to further compare the efficacy of magnesium in this and similar contexts.

Experiment 5.4 The variation in individual compound feed intake in a group of lactating beef cattle offered pelleted concentrate feed in troughs or cattle cobs fed along the ground, both allocated at two levels (late grazing season).

Introduction

Reference to faecal magnesium concentrations in Experiment 5.3 indicated that allocations of 1 kg FM/head or 2 kg FM/head of compound cattle cobs promoted a more uniform individual compound feed intake than equivalent allocations of a pelleted compound feed in a group of suckler cows in early lactation.

The uniformity of individual intake of the same compound feeds by the same group of suckler cows was assessed in the present experiment which was conducted later on (September) in the same grazing season as Experiment 5.3. Chromic oxide was incorporated into the compound cattle cobs and the pelleted compound feed to facilitate the use of faecal chromium concentrations to illustrate the variation in intake of the compound feeds by the group of suckler cows.

Materials and Methods

Twenty-seven Hereford x Friesian cows (of mixed age and mean liveweight 500 kg) and their calves (4-5 months old) grazed together on 8 ha of permanent pasture in early autumn. The calves had separate access, via a calf creep gate, to an additional 2 ha of permanent pasture.

There were four experimental periods, each of seven days duration, beginning at the end of September when grass availability was still fairly high. The design of the experiment is presented in Table 71. The proprietary compound feed (either BOCM nuts or cobs, Table 68, Experiment 5.3) was allocated to the cows at 07.30 h each day. The calves were kept separately from the cows during feeding time. When the compound nuts were allocated (Period 1 and Period 4), the cows had access to the four troughs on both sides. Immediately before the beginning of Period 1 there was a three day preliminary period when compound nuts were offered to the group (2 kg FM/head) to accustom the cows to come forward to consume concentrates.

Table 71 Experimental design

Period	Feed (kg fresh matter allocation per cow)	Method of feeding
1	2 nuts	In four troughs each allowing 0.66 metres length/head from both sides.
2	2 cobs	Spread on ground in a band 0.25 metres wide and 27 metres long, thus allowing 1 metre length per head.
3	1 cobs	
4	1 nuts	In four troughs each allowing 0.66 metres length/head from both sides.

Table 72 Proximate analyses of the compound feeds

	Compound nuts	Compound cobs
Dry matter (g/kg)	893	868
Composition of dry matter (g/kg)		
Crude protein	146	147
Crude fibre	102	159
Ether extract	17	9
Soluble carbohydrate	626	517
Ash	109	168
Chromium	1.090	0.991
Magnesium	7.068	23.352

Magnesium oxide had been incorporated into each of the proprietary compounds. Additionally, each compound contained chromic oxide at a rate of 5 g per kg of fresh matter. The proximate analyses of the compound feeds on offer are shown in Table 72.

On the seventh day of each experimental period faecal grab samples were taken, at 11.00 h, per rectum, from each animal. Simultaneously, blood samples were taken from the jugular vein of each animal. The faeces grab samples were dried, milled and analysed for chromium and magnesium. The blood plasma samples were analysed for magnesium.

Results

Grass availability declined during the experiment. However, the supply was considered to be adequate throughout. There was rain almost every day of the experiment. The cows were usually waiting at the feeding area each morning at 07.30 h.

The mean faecal magnesium concentrations (g/kg DM) and the mean faecal chromium concentrations (g/kg DM) are presented in Table 73.

The rate of consumption of the allocated compound feed was fairly consistent at 5-10 minutes per kg feed fresh matter (Table 73) irrespective of the type or quantity of compound feed allocated, although the animals took rather more time to consume the cobs. This is a markedly different result to that obtained for cobs in Experiment 5.3, where the animals consumed the cobs at a rate of 20 minutes per kg of fresh matter allocated. However, the confounding factors of differences in grass quality and the physiological states of the animals may account for the apparently improved appetites of the animals in the present experiment.

All the cows were keen to consume their allocation of compound feed throughout the experiment, except for cow 5 and heifers 7 and 36 in Period 1 (mentioned later). Heifer 36 had shown a similar reluctance to consume compound feed in the spring (Experiment 5.3). Most of the animals persevered until the compound feed had been completely consumed. When 1 kg fresh matter as either cobs or nuts was offered to the group, the behaviour of the animals was much more fractious with increased activity in the feeding area (e.g. more frequent changes of position) compared to their behaviour in Periods 1 and 2, when 2 kg fresh matter of nuts and cobs were offered respectively.

Table 73 Faecal magnesium and chromium concentrations (g/kg faecal dry matter) and mean time to completely consume allocated feed for Periods 1-4

Period	Feed kg FM /head	Faecal Mg g/kg DM				Faecal Cr g/kg DM				Time*
		n	Mean	S.dev±	CV%	n	Mean	S.dev±	CV%	
1+	2 nuts	21	4.37	0.766	17.5	21	0.43	0.263	61.1	15
2	2 cobs	24	9.61	2.247	23.4	24	0.49	0.139	28.4	20
3	1 cobs	24	6.31	1.111	17.6	24	0.22	0.043	19.6	5-10
4	1 nuts	22	3.65	0.778	21.3	22	0.29	0.116	40.0	<5

+ Throughout Period 1 three cows were observed not to be consuming the allocated feed at all. Consequently the faecal Cr concentrations for these animals was 0 g/kg DM (omission of the same three animals n = 18; Mean = 0.51 ±0.209 g/kg; CV = 40.9%).

* Average time to completely consume feed (mins).

Table 74 Plasma magnesium concentrations (mmol/l)

Period	Feed kg fresh matter/head	Plasma Mg mmol/l n	Mean	S.dev±	CV%
1	2 nuts	27	0.91	0.095	10.5
2	2 cobs	27	0.92	0.075	8.2
3	1 cobs	26	0.75	0.066	8.8
4	1 nuts	26	0.77	0.074	9.6

During Period 1, when 2 kg fresh matter/head of compound nuts were allocated, three animals (numbers 5, 7 and 36) did not consume any compound feed at all, which was reflected in the absence of chromium in their respective faeces samples. Cow 23 also consumed very little compound nuts in Period 1 and consequently had a very low faecal chromium concentration (0.06 g/kg DM). The corresponding faecal magnesium concentration of these four animals 5, 7, 36 and 23) were also low (2.74, 3.33. 3.98 and 3.69 respectively). Indeed, inclusion of animals 5, 7 and 36 in the group increased the coefficient of variation of faecal chromium concentration from 40.9% in Period 1 to 61.1%. The corresponding increase in the coefficient of variation of faecal magnesium concentration, by inclusion of 5, 7 and 36 in the group, was from 14.5% to 17.5% in Period 1. Perhaps if the preliminary period had been longer than three days (e.g. 7-10 days) this effect may not have been observed, as these animals would have become accustomed to coming forward at feeding time.

It was not possible to obtain a faecal sample from all the cows, as some were empty at the time of sampling. The mean concentrations of faecal chromium, when 1 kg of cobs or nuts was allocated per head (Table 73), is approximately half that obtained when 2 kg of cobs or nuts were allocated, suggesting that grass consumption is fairly consistent between periods, irrespective of possible changes in dry matter digestibility. A similar effect is not observed, however, with the mean concentrations of faecal magnesium (Table 73) which is likely to reflect the marked difference in the magnesium concentration between the compound cobs and nuts (23.352 g/kg DM and 7.068 g/kg DM respectively), whereas the chromium concentrations of cobs and nuts were comparable (0.991 g/kg DM and 1.090 g/kg DM respectively).

The coefficient of variation for the faecal chromium concentrations, when compound nuts were allocated, were 40.0% and 61.1% for 1 and 2 kg FM/head respectively. The corresponding coefficients of variation, when cobs were allocated at a rate of 1 and 2 kg FM/head were 19.6% and 28.4% respectively. These results are of the same order obtained in Experiment 5.3 when magnesium was used as an indicator of intake.

However, the coefficients of variation for faecal magnesium concentrations were fairly similar (17.5%-23.4%) throughout the present experiment and do not complement the coefficient of variation obtained for faecal chromium, which is perhaps anomalous in view of the

statistically significant correlation coefficients between faecal chromium and magnesium concentrations.

The mean plasma magnesium concentrations are shown in Table 74. The mean concentration of plasma magnesium declined from Period 1 (0.91 mmol/l) to Period 4 (0.77 mmol/l), although the values obtained were well above the critical concentration of 0.4 mmol/l where symptoms of hypomagnesaemia may be observed. The variation within the group of the plasma magnesium concentrations was fairly small and similar between periods (CV 8.2-10.5%).

The extent of the consistency of faecal chromium and magnesium concentrations, and their corresponding ranking orders, between Periods 1 to 4 (and therefore between type and level of allocation of compound feed) were investigated and the resulting correlation coefficients are presented in Table 75. The absolute correlation and rank order correlation coefficients for faecal chromium concentration were consistently statistically significant within type of compound feed (i.e. either within cobs or within nuts). When 2 kg FM/head compound nuts were allocated the correlation and rank order coefficients were statistically significant between cobs, at both 1 kg FM and 2 kg FM per head. However, this was not repeated when 1 kg FM/head of compound nuts were compared with either 2 kg FM or 1 kg FM/head of compound cobs. The correlation and rank order correlation coefficients were not statistically significant ($P>0.05$, Table 75), which indicates that a different pattern of compound feed intake is produced when either 1 kg/head of compound nuts is allocated to the group instead of 1 or 2 kg FM/head of compound cobs.

The corresponding correlation and rank order correlation coefficients for faecal magnesium concentrations (Table 75) were not completely analogous in their statistical significance to the coefficients produced by using faecal chromium concentrations, even although the correlation and rank order correlation coefficients for 2 kg cobs/1 kg cobs were statistically significant (0.701, $P<0.001$ and 0.619, $P<0.01$ respectively). Indeed, the correlation and rank order correlation coefficients for 1 kg cobs/1 kg nuts were statistically significant (0.587, $P<0.01$ and 0.549, $P<0.05$ respectively), which was not repeated by using faecal chromium concentrations. The remaining correlation and rank order correlation coefficients were not statistically significant.

Absolute correlation and rank order correlation coefficients were

computed between the faecal chromium and magnesium concentrations within each period. The correlation coefficients are presented in Table 76. All the computed correlation coefficients were statistically significant except the rank order correlation between faecal chromium and magnesium concentrations when 1 kg FM/head of compound cobs were allocated which may reflect the comparatively smaller variation (with consequent multiple overlapping of the ranking orders) in the concentrations of faecal chromium and magnesium (CVs were 19.6% and 17.6% respectively) within the group when 1 kg FM/head of compound cobs were allocated.

Table 75 Absolute correlation (r) and rank order (ro) correlation coefficients within and between type (i.e. either compound nuts or cobs) and between level of allocation (1 or 2 kg FM/head) of compound feeds on offer

(i) Faecal chromium concentration (g/kg DM)

	2 nuts/ 2 cobs	2 nuts/ 1 cob	2 nuts/ 1 nuts	2 cobs/ 1 cobs	2 cobs/ 1 nuts	1 cobs/ 1 nuts
r	0.602**	0.622**	0.640**	0.767***	0.371	0.427
ro	0.623**	0.546*	0.610**	0.572**	0.359	0.401

(ii) Faecal magnesium concentration (g/kg DM)

r	0.339	0.337	0.462	0.701***	0.443	0.587**
ro	0.246	0.326	0.421	0.619**	0.322	0.549*

* P<0.05, ** P<0.01, *** P<0.001

Table 76 Absolute correlation and rank order correlation coefficients between faecal chromium and magnesium concentrations within each period.

Period	Feed kg FM/head	Correlation coefficient	Rank order correlation coefficient
1	2 nuts	0.784***	0.809***
2	2 cobs	0.826***	0.683***
3	1 cobs	0.479*	0.358
4	1 nuts	0.787***	0.709***

* P<0.05 ** P<0.01 *** P<0.001

Rank order correlations were computed with the faecal chromium and magnesium concentrations, respectively, from the present experiment, and the faecal magnesium concentrations obtained in Experiment 5.3, where compound nuts and cobs had been allocated in the spring. The rank order correlation coefficients are presented in Table 77. Not one of the coefficients was statistically significant, although two did approach statistical significance (0.439 and 0.521 at 12 df respectively).

Table 77 Rank order correlation coefficients between spring and autumn faecal chromium (autumn only) and magnesium concentrations.

SPRING	AUTUMN	
Faecal Mg	Faecal Mg	Faecal Cr
1 cobs	0.139	0.002
2 cobs	0.376	0.447
1 nuts	-0.025	0.160
2 nuts	0.439	0.521

Discussion

Comparison of the coefficients of variation for faecal chromium concentration for each period suggests that greater uniformity of compound feed intake is more likely to be achieved by offering compound cobs (CV% of 19.6-28.4%) compared to compound nuts (CV% of 40.0-61.1%) to animals at grass. This result supports that obtained in Experiment 5.3 where cobs gave rise to a more uniform intake (CV% of 13.8-15.5%) compared to nuts (CV% of 27.5%), albeit using faecal magnesium concentrations as the internal marker. The rates of consumption were fairly similar in the present experiment (5-10 minutes per kg fresh matter cobs or nuts), although the consumption rate for cobs was marginally slower, but not as slow as in Experiment 5.3, where the slow rate of consumption of the cobs (20 minutes per kg fresh matter) is likely to have contributed to the uniformity of intake of cobs.

In the comparison of the coefficients of variation of faecal chromium concentration, between periods, it was assumed that grass dry matter intake within each period, was similar between the animals. The grass dry matter intake was also likely to be similar between periods, as the mean concentration of faecal chromium was reduced by approximately 50% when 1 kg fresh matter per head of cobs or nuts were allocated compared to 2 kg fresh matter per head of these compounds.

The coefficient of variation for the mean faecal magnesium concentrations, obtained in the present experiment, did not complement their respective coefficient of variation of mean faecal chromium concentration. Indeed, the coefficients of variation obtained were very similar and ranged from 17.5% for 2 kg fresh matter/head of compound nuts to 23.4% for 2 kg fresh matter/head of compound cobs. The mean faecal magnesium concentrations ranged from 3.65 g/kg DM to 9.61 g/kg DM in the present experiment, compared to a range of 5.78 g/kg DM to 7.74 g/kg DM in Experiment 5.3. This would suggest that a confounding factor of disparity in the supply of magnesium from the compound feed occurred in the present experiment, which may affect the interpretation of the faecal magnesium concentrations.

The pattern of compound intake within the group, as illustrated by the computed correlation coefficients using faecal chromium concentration, was consistent within type of compound feed and between cobs and nuts except for between allocations of 2 kg FM cobs/1 kg FM nuts and 1 kg FM cobs/1 kg FM nuts, where neither the correlation or rank order correlation coefficients were statistically significant.

The relative speed with which 1 kg FM/head compound nuts was consumed (usually in less than 5 minutes) compared to the cobs, at both allocations, may have precluded a consistent pattern of intake within the group compared to that obtained when cobs were allocated.

The corresponding correlation coefficients, calculated from faecal magnesium concentrations, did not reflect those obtained from faecal chromium concentrations, except for the correlation and rank order coefficients between 2 kg FM/head cobs and 1 kg FM/head cobs (0.701, $P<0.001$ and 0.619, $P<0.01$) and indeed, the correlation and rank order correlation coefficients between 1 kg FM/head cobs and 1 kg FM/head of nuts were significant (0.587, $P<0.01$ and 0.549, $P<0.05$ respectively) which was not observed when faecal chromium concentrations were used. The inconsistencies may be fortuitous and reflect the marked differences in the quantity of magnesium supplied by the feed (23.352 g/kg DM and 7.068 g/kg DM from compound cobs and nuts respectively) with subsequent differences in the mean faecal magnesium concentrations for each period. Nevertheless, the statistically significant correlation coefficients between faecal chromium and magnesium concentrations, within periods (and hence type of allocation) completely confound the dissimilarity of the correlation coefficients computed for faecal magnesium between periods and with those computed for faecal chromium between periods.

The results from Experiment 5.3, where faecal magnesium was the internal marker, suggested that compound cobs promoted a more uniform intake of feed than compound nuts at grass, which was supported by the use of faecal chromium in the present experiment, where the coefficients of variation for each supplement were of the same order between experiments. However, the pattern of compound feed intake within the animals was dissimilar in the present experiment to that observed in Experiment 5.3, as shown by the absence of any statistically significant correlation and rank order correlation coefficients between faecal chromium and magnesium (respectively) concentrations from the present experiment with faecal magnesium concentrations from Experiment 5.3. This effect may not be surprising in view of the change in physiological state between the spring (post parturient) and the autumn (5-6 months into lactation), which may have an effect on the appetite of the individuals in the group.

The mean plasma magnesium concentrations were fairly similar in Periods 1 and 2 (0.91 mmol/l and 0.92 mmol/l respectively) and declined

in Periods 2 and 3 to 0.75 mmol/l and 0.77 mmol/l respectively, as grass availability declined, and allocation of compound feed was reduced. The coefficients of variation for the plasma magnesium concentrations were low (8.2-10.5%) and indeed were lower than the corresponding values obtained in Experiment 5.3 (8.7-15.9%). All of the plasma magnesium concentrations were well above the critical concentration of 0.4 mmol/l, where symptoms of hypomagnesaemia may be observed.

An increase in the coefficients of variation for faecal chromium concentration may have been expected as the quantity of both compound cobs and compound nuts was reduced from 2 kg to 1 kg FM/head/day (e.g. Foot and Russel, 1973, Kendall et al., 1980). The rate of feed consumption marginally increased from 10 minutes/kg and 7.5 minutes/kg when 2 kg/head cobs or nuts were allocated respectively to less than 10 minutes/kg and less than 5 minutes/kg when 1 kg/head of cobs or nuts was allocated respectively. The marginal increase in the rate of feed consumption, when a reduced quantity of either compound cobs or nuts was allocated, may have been insufficient to promote a greater variation in compound feed intake.

However the coefficients of variation of faecal chromium concentration were similar when either 1 kg or 2 kg/head of compound nuts were allocated (i.e. 40.0% and 40.9% respectively) if the mean faecal chromium concentration for Period 1 (2 kg nuts/head) is calculated by omission of the three zero values of faecal chromium concentration obtained from three cows which did not come forward to eat the allocation of compound nuts during Period 1. This similarity in the coefficient of variation perhaps reflects the fairly similar rates of feed consumption at each level of compound nut allocation, albeit a marginally faster rate of feed consumption when 1 kg/head of compound nuts were allocated.

The reduction in the coefficient of variation when 1 kg of compound cobs was allocated perhaps reflects difficulty in prehension of this type of compound feed whereby the animals could not consume the feed at a very much faster rate. Indeed salivary production may be more apparent as a limiting factor to rate of feed consumption (Church, 1976) when compound cobs were allocated compared with compound nuts. The cobs, at both levels of allocation, were well spread-out along the grass for a distance of 27 metres (1 metre/head). Consequently the cobs were very thinly dispersed along the ground under 1 kg/head cobs

(i.e. 35-40 cobs/kg FM) allocation rate and therefore any possible marked increase in the rate of feed consumption was discouraged. the cobs were possibly less accessible to the cows when they were more thinly dispersed along the ground, under 1 kg/head allocation, and this may have promoted the more uniform intake of cobs (coefficient of variation 19.6%).

In conclusion, within the given restraints and limitations of the experiment, it would appear that, with reference to the faecal chromium concentrations, allocation of compound cobs to cattle at grass is likely to promote a more uniform group intake, with consequent effects of intake of, for example, essential minerals i.e. magnesium, than is allocation of compound nuts.

Experiment 5.5 Influence of the method of allocation of a pelleted compound feed, containing magnesium oxide on the uniformity of the individual compound feed intake in a herd of dairy cows

Introduction

Various choices are available to increase the intake of available magnesium to prevent hypomagnesaemic tetany in cattle which is particularly prevalent at or around transfer to spring pasture after winter housing and, indeed, also later on in the grazing season during the autumn flush of grass, combined with adverse weather. The methods of prophylaxis include direct oral adminstration techniques (e.g. mineral supplements containing magnesium, loose concentrates, feed blocks, liquids with high magnesium content, addition of magnesium to drinking water), application of magnesium on to pastures and dosing with magnesium bullets or soluble salts (Stuedemann et al., 1984).

When compound feed containing magnesium oxide is used in the prophylactic treatment of hypomagnesaemia in dairy cattle at or around transfer to spring grass, there are two possible methods of allocation of the compound feed, i.e. individually in the milking parlour or in a group from troughs or from behind a feed barrier. It is possible that the variation in intake of the compound feed, if it is allocated in a group feeding situation, may have deleterious consequences should the magnesium intake by several animals in the herd be much below the magnesium requirement of, for example, 34 g/day for a a lactating cow of 600 kg liveweight and milk yield 25 kg/day (ARC, 1980). Symptoms of hypomagnesaemic tetany may therefore become apparent.

The present experiment examined the variation in faecal magnesium concentrations of the cows when they were offered magnesium-containing compound feed individually in the milking parlour or on a group basis.

Materials and Methods

The Cochno dairy herd of 80 British Friesian cows were housed in a cubicle building with access to a central feeding passage behind a barrier, where silage and/or compound feeds could be offered to the cows. The cows were offered 35 kg fresh matter/head of silage along the feeding passage, allowing 0.7 m/head, in two approximately equal feeds per day (08.30 h and 16.00 h). Shredded molassed sugar beet pulp was allocated at 09.00 h on top of the silage, at a rate of 1.25 kg fresh matter/head. The allocation of silage and sugar beet pulp

contributed to the maintenance metabolisable energy requirements plus the energy requirements 5 litres of milk for each animal.

During the fortnight prior to transfer to grass (end of April/ early May) a proprietary compound (M), in which magnesium oxide had been incorporated at approximately 15g/kg FM, was allocated to the cows individually in the milking parlour (Period 1) for seven days, following by group allocation (Period 2) for seven days.

During Period 1 the cows were allocated either 4 kg FM/head/day, 9kg FM/head/day or 12 kg FM/head/day of compound feed M according to milk yield, in the milking parlour, therefore supplying 60 g, 135 g or 180 g/head/day of magnesium oxide respectively. On day 7 faecal grab samples were taken per rectum from each animal at 16.00 h. The faeces samples were dried, milled and analysed for magnesium. The coefficients of variation for faecal magnesium concentration were thence calculated.

During Period 2, which proceeded immediately after Period 1, 2.5 kg FM/head/day of compound feed M was offered to the cows at 09.30 h, on top of any remaining sugar beet pulp and the silage allocation, along the feeding passage. Therefore compound M was allocated to supply 37.5 g/head/day of magnesium oxide. The remaining individual metabolisable energy requirements were supplied from either 4 kg FM/head/day, 9 kg FM/head/day or 12 kg FM/head/day of a second proprietary (low magnesium) compound feed (L), allocated in the milking parlour according to current milk yield. The allocations of compound M (if consumed uniformly between the animals) and compound L therefore supplied 55g, 76g and 89g/head/day of magnesium oxide respectively. The proximate analyses of the compound feeds (M and L), sugar beet pulp and silage are presented in Table 78.

On day 7 of Period 2 faecal grab samples were taken per rectum from each animal at 16.00 h. The faeces samples were dried, milled and analysed for magnesium. The coefficients of variation for faecal magnesium concentration were thence calculated.

Table 78 Proximate analyses of feeds

	Proprietary compound M	Proprietary compound L	Silage	Molassed sugar beet pulp
Dry matter g/kg	867	865	281	900
Composition of dry matter g/kg				
Crude protein	174	194	78	106
Crude fibre	78	75	337	144
Ether extract	33	48	21	6
Soluble carbohydrates	603	592	479	662
Ash	112	91	85	82
Magnesium	8.83	4.30	1.68	1.4

Results and Discussion

In Period 1 compound M (which contained 60 g magnesium oxide in 2 kg fresh matter) was readily consumed by the cows when it was individually allocated in the milking parlour. When 2.5 kg FM/head was allocated along the feeding passage in Period 2, the cows took 25 minutes to completely consume the ration, even although more than half of the animals had walked away from the vicinity of the feeding passage after 10 to 15 minutes. The animals which remained searched under the silage for compound M and continued to do so until the allocation had been completely consumed.

The mean concentrations of faecal magnesium for Periods 1 and 2 are presented in Table 79. When compound M was allocated individually in the parlour in Period 1, the mean concentration of magnesium in the faeces increased as the allocation of compound M was increased (i.e., 7.5 g/kg DM, 9.1 g/kg DM and 10.2 g/kg DM respectively). However, the mean faecal magnesium concentration did not increase in the same proportion as the allocation of compound M (e.g. increase of 4 kg FM/head to 9 kg FM/head was an increase of 225%, the corresponding proportionate increase in the faecal magnesium concentration was 121%). This discrepancy suggests that the individual silage intake of the animals may be influenced by the quantity of concentrates consumed

and/or the availability of magnesium has altered, due to increased throughput, with consequent lowered digestibility, when 9 kg FM/head was allocated instead of 4 kg FM/head.

Table 79 Mean concentrations (± S.dev.) of faecal magnesium (g/kg/DM) for Period 1 and Period 2

	Period 1			Period 2		
Faecal Mg (g/kg DM)	Quantity of compound M allocated in milking parlour (kg FM/head)			Group fed compound M 2.5 kg FM/head Quantity of compound L allocated in milking parlour (kg FM/head)		
	4	9	12	4	9	12
n	43	19	12	42	20	9
Mean	7.5	9.1	10.2	8.3	7.9	7.8
S. dev. ±	1.16	1.41	1.10	1.43	0.89	0.72
CV%	15.5	15.5	10.8	17.2	11.3	9.2

The coefficients of variation were fairly low within each rate of allocation of compound M, which is as expected, as the compound feed (M) has been individually allocated in the milking parlour.

In Period 2 the mean faecal magnesium concentration was marginally higher when 4 kg FM/head compared to 9 kg FM/head and 12 kg FM/head of compound L had been allocated in the parlour. The latter two rates of allocation should have resulted in a higher output of faecal dry matter with consequent dilution of the faecal magnesium to a larger degree than when 4 kg FM/head of compound L had been allocated, assuming uniformity of intake of silage and compound M.

The coefficient of variation was highest, 17.2%, where 4 kg FM/head of compound L was allocated in the parlour (Table 79). It is unlikely that variation in intake of group fed compound M has influenced the distribution of faecal magnesium concentrations, when 4 kg FM/head of compound L was allocated, due to the relatively small contribution of compound M to the total supply of magnesium in the diet. Compound M contributed 41.2%, 31.3% and 26.5% to the total supply of dietary magnesium, assuming uniformity of intake of compound M, when 4 kg, 9 kg and 12 kg/head of compound L were allocated respectively. However, perhaps variation in intake of compound M, where 4 kg/head of compound L has been allocated, was partly the cause of the relatively high coefficient of variation of 17.2%, due to the relatively high potential contribution of compound M (41.2%) to the total supply of magnesium.

The coefficients of variation for Period 1 and Period 2 were fairly similar, and suggest uniformity of magnesium intake irrespective of individual or group allocation of compound feed which contains magnesium oxide, assuming similar availability of magnesium and intake of silage dry matter within and between periods. Therefore, to ensure that cows consume an adequate quantity of magnesium in the late winter/early spring, prior to turnout, there would appear to be no advantage in individually allocating the compound feed in the milking parlour, compared with offering the compound feed behind a barrier on a group basis. However, use of magnesium as a marker to assess the variation of feed intake within a group may be debatable due to the possible fluctuations in its availability between animals and level of feed intake. Hence, it may be beneficial to repeat the present study using chromic oxide as the marker.

Experiment 5.6 An investigation into the possible influence of ostertagiasis in Friesian steers on the variation in individual hay intake during housing and on the variation in supplementary concentrate intake at grass

Introduction

The object of this investigation was to examine the variation in feed intake within three groups of Friesian steers (initial liveweight 225-250 kg) during their first winter housing period, when they were 10 months old (at the beginning of the store period), and in the following grazing season. The steers had been reared under helminth-free conditions but differed in the severity of ostertagiasis damage to the gastrointestinal tract and worm burdens by the end of the first grazing season (i.e. immediately before the beginning of the present experiment). The steers were being used concurrently by C. Entrocasso for detailed studies on growth, nitrogen balance and diet digestibility and further details can be obtained from the thesis on this work (Entrocasso, 1984).

The previous grazing history of the animals was as follows:-

Group 1 consisted of nine steers which had been allowed to become naturally infected with O. ostertagi during the first grazing season and had no intended anthelmintic treatment. However, during the first grazing season (after 18 weeks of grazing) the steers in Group 1 were severely diarrhoeic and inappetant and were consequently given a therapeutic dose of levamisole (Nilvern, I.C.I. plc).

Group 2 consisted of seven steers which had been given fenbendazole (Panacur, Hoechst) at a rate of 7.5 mg/kg liveweight, once per fortnight throughout the grazing season beginning after one day at grass.

Group 3 consisted of eight steers which had each been given a mortantel tartrate sustained release bolus (MSRB Paratect, Pfizer Ltd.) at transfer to grazing in the spring.

Throughout the first grazing season regular parasitological, biochemical and liveweight measurements were taken (Entrocasso, 1984) which indicated that the steers in Group 3 (MSRB) had a different pattern of infection than the steers in the other groups and were only lightly infected with trichostrongyles. The liveweight gain per ha over the 150 day first grazing season was significantly greater for

Group 3 (MSRB) at 672 kg/ha than for Group 1 531 kg/ha ($P < 0.001$). At the end of the first grazing season (October) the plasma pepsinogen concentrations were fairly normal for the steers in Group 3 (mean 1.4 ± S.E. 0.1 i.U. tyrosine), in contrast to a marked elevation in concentration for the steers in Group 1 (mean 6.0 ± S.E. 0.4 i.U. tyrosine).

It was apparent, therefore, at the end of the first grazing season that there were three distinct groups of steers which differed in the extent of ostertagiasis infection and damage. The steers from Group 1 had exhibited the greatest effects of parasitic gastritis and the steers from Group 3 had shown very few deleterious effects. The steers in Group 2 had acted as a relatively clean control (in terms of worm burden and in comparison to Group 1), even although some gastrointestinal damage was exhibited by them. The variation between the groups in the severity of ostertagiasis may influence the pattern of feed intake between the steers in both the first winter housing period and possibly during the following grazing season. Consequently the individual intakes of group fed hay in the first housing period and the individual intake of group fed supplementary concentrates in the following grazing season were assessed for each of the groups of steers (by consideration of faecal chromium concentrations of grab samples).

Materials and Methods

First winter housing period

The three groups of Friesian steers (liveweight range 225-250 kg), previously described, were housed on 20th October, 1982, in three separate pens, on straw bedding, in an open fronted building allowing approximately 20 m^2 per group. Lock-in feeders were provided in each pen for the individual allocation of the concentrate ration to the steers. Two hay racks (2.5 metres in length) were also available in each pen for the allocation of hay to each group.

Between October and January the steers were individually allocated 3 kg FM/head/day of a proprietary beef fattening pelleted compound feed in two equal feeds at 07.30 h and 16.00 h. In January this allocation rate was increased to 4 kg FM/head/day, again given in two equal feeds. Hay was allocated to each group at a rate of 5 kg FM/head/day in two approximately equal feeds, immediately after the concentrate allocation had been completely consumed. The proximate analyses of the feeds are presented in Table 80.

Table 80 Proximate analyses of the feeds allocated during the winter housing period and subsequently during the second grazing season

	HOUSING					GRAZING
	Proprietary compound feed (1)	Hay	Barley/chromic oxide compound I	II	III	Proprietary compound feed (2)
Dry matter (g/kg)	853	841	860	849	844	880
Composition of dry matter (g/kg)						
Crude protein	138	69	117	108	99	148
Crude fibre	130	330	49	56	55	92
Ether extract	24	9	9	7	11	15
Soluble carbohydrate	575	535	765	784	798	621
Ash	133	57	60	45	37	124
Chromium	-	-	13.50	7.19	6.94	1.19

There were three experimental periods, each of 14 days, during the winter housing period, in December, February and May. During each respective experimental period, 0.25 kg FM/head of a barley/chromic oxide pelleted compound (proximate analysis in Table 80) was individually given to the steers once a day in addition to their allocation of the proprietary compound feed at 07.30 h. During days 8 to 14 inclusive of each respective experimental period (i.e., circa 14th December, 24th February and 20th May respectively), faecal grab samples were taken from the steers per rectum twice a day at 07.30 h and 16.00 h when the steers were in the lock-in feeders. The samples for each steer were amalgamated over the seven day collection period. At the end of each respective collection period, the faeces samples were dried, subsampled and analysed for chromium.

Second Grazing Season

In May the three groups of steers were transferred on to the same respective grass paddocks as they were allocated during the first growing season. At the beginning of the grazing season the steers in Group 3 were each given a second MSRB bolus. The steers in Group 2 were treated fortnightly with fenbendazole. Group 1 remained untreated.

In the early part of the second grazing season, there was no real opportunity to examine variation in grass intake between the animals. However, later on in the grazing season, in September and October, grass availability declined and the opportunity was taken to determine the variation in individual intake of a proprietary pelleted compound feed, which was allocated to each group at a rate of 4 kg FM/head/day in order to supplement the grass intake of the steers between 9th September and housing (19th October). Chromic oxide had been incorporated into the proprietary compound feed at a rate of 5 g/kg FM. The proximate analysis of the compound feed is presented in Table 80. The compound feed was allocated to each group in two troughs at 08.00h, allowing approximately 0.6 m head space (measured on one side only).

Between September and October (housing), single faecal grab samples were taken from the steers on four separate occasions (15th September, 21st September, 7th October and 18th October respectively at 11.0h). The grab samples from each separate collection day were dried, milled and analysed for chromium.

Results

During the winter housing period the individual allocations of the proprietary compound feed were readily consumed by the steers, although several of them, particularly nos. 7 and 92 in Group 1, consumed their allocations relatively more slowly than the others. Nevertheless, the compound feed was usually completely consumed within 15-20 minutes at each feeding time. When the allocations of the chromic oxide containing barley compound were additionally given to the steers with the morning concentrate feed, it too was readily consumed by the steers. The allocations of hay were also readily consumed by all of the steers, although the steers in Group 1 were observed to waste relatively more hay than the steers in Groups 2 and 3. The steers in Group 1 tended to pull hay out of the racks and trample it into the bedding straw. However, it is likely that not more than 10-20% of the hay allocation was wasted in this way. The allocations of hay were usually completely consumed within 45 minutes.

When supplementary compound feed was allocated to the steers later on in the second grazing season, the steers usually took 45-60 minutes to consume about 80% of their respective allocations and they tended to return during the day to completely finish off the allocations of compound feed. All of the steers initially came forward to consume the feed immediately after it had been placed in the troughs, and they all usually remained at the troughs until most of the allocation had been consumed.

The mean faecal chromium concentrations of the grab samples from both the winter housing and later in the ensuing second grazing season are presented in Table 81. The number of steers within each group was not consistent for each of the sampling period in the winter housing period (samples I, II and III) as some of the steers were being simultaneously used for nitrogen balance and digestibility studies in metabolism crates. During sampling Period I, chromic oxide had erroneously been incorporated into the pelleted barley compound at the rate of 10 g/kg FM. In subsequent batches of this compound, chromic oxide was incorporated at a rate of 5 g/kg FM and consequently the mean faecal chromium concentrations from sampling Periods II and III were approximately half the mean faecal chromium concentrations from Period I. In the second grazing season, the number of steers within each group was not consistent between sampling Periods IV to VII because occasionally the steers were empty at the time of faecal sampling.

Table 81 Mean faecal chromium concentration (± S. dev.) of the steers in Group 1, Group 2 and Group 3 during the first winter housing period and later in the following second season at grass.

Sampling period	Faecal chromium concentration (g/kg DM)											
	Group 1				Group 2				Group 3			
	n	Mean	S.dev.±	CV%	n	Mean	S.dev.±	CV%	n	Mean	S.dev.±	CV%
First winter housing												
I	8	1.05B	0.107	10.2	6	0.72A	0.044	6.1	8	0.79A	0.103	13.0
II	7	0.41B	0.035	8.5	6	0.36A	0.016	12.1	7	0.34A	0.025	7.3
III	9	0.39	0.072	18.4	6	0.34	0.013	3.8	8	0.34	0.042	12.3
Second grazing season												
IV	9	1.22	0.360	29.8	6	1.29	0.252	19.5	8	1.32	0.196	14.9
V	8	1.23	0.230	18.5	7	1.37	0.157	11.5	7	1.58	0.192	12.2
VI	8	0.86	0.241	28.3	6	0.90	0.156	17.4	8	0.86	0.174	20.3
VII	8	1.00	0.142	14.2	7	0.86	0.152	17.7	7	1.14	0.01	8.9

Within each sampling period means with different letters (A or B) are significantly different

(A, B $P < 0.01$)

During sampling Periods I and II (first winter housing period), the mean faecal chromium concentrations of the steers in Group 1 were significantly greater (1.05 g/kg DM and 0.41 g/kg DM) than the mean faecal chromium concentration of the steers in Group 2 and Group 3 ($P < 0.01$). Indeed the mean faecal chromium concentration of the steers in Group 1 during sampling Period III was also greater (0.39 g/kg DM) but not significantly so than the corresponding mean faecal chromium concentration of the steers in Group 2 and Group 3 (0.34 g/kg DM and 0.34 g/kg DM respectively). The mean faecal chromium concentrations of the steers in Group 2 and Group 3 were similar throughout sampling Periods I, II and III. The differences in the mean faecal chromium

concentration between the steers in Group 1 and the steers in Groups 2 and 3 may reflect the relatively lower hay intake of the steers in Group 1 (assuming similarity in the overall diet dry matter digestibility between the groups) as they were observed to waste more hay than the steers in Groups 2 and 3. Consequently the indigestible component from the individual hay intakes will be reduced in the faeces of the steers in Group 1 and the concentration of chromium in the faeces will increase (chromium intake constant between all the steers). The coefficients of variation of the faecal chromium concentrations ranged from 3.8% to 18.4% from sampling Periods I to III and there was no particular pattern between the groups. The relatively low coefficients of variation suggested that hay was fairly uniformly consumed by the steers within each group. Nevertheless, the relatively high coefficient of variation of faecal chromium in Group 1 during sampling Period III (18.4%) may reflect the clinical incidence of the type II phase of ostertagiasis observed only in these steers (Entrocasso, 1984) immediately before transfer to grass, with possible consequent influences on the individual intake of group fed hay depending on the variation in the degree of the clinical symptoms (and therefore the degree of inappetence) between the steers in Group 1.

During the second grazing season the mean faecal chromium concentrations were very similar for all three groups of steers on all four sampling occasions which may indicate that grass availability and digestibility in the respective grass paddocks and the quantity of grass consumed were uniform for each of the three groups of steers. However, coefficients of variation of the faecal chromium concentrations for Group 1 were greatest in three out of four of the sampling periods (29.8%, 18.5% and 28.3% for sampling Periods IV, V and VI respectively) with the highest value of 29.8% being recorded in mid-September, which compared with values of 19.5% and 14.9% for Groups 2 and 3 respectively. These observations suggest that the supplementary compound feed was generally more uniformly consumed by the steers within Groups 2 and 3 respectively than by the steers within Group 1.

Discussion

The significantly greater mean faecal chromium concentrations of the steers in Group 1 during the sampling Periods I and II during their first winter housing period, probably reflected the observed wastage of group fed hay by these animals, assuming that the overall diet dry matter digestibility coefficients for the steers from Groups 1, 2 and 3 were similar. However, parallel digestibility studies (Entrocasso, 1984) indicated that the mean overall diet dry matter digestibility coefficients were 0.52, 0.56 and 0.57 for Groups 1, 2 and 3 respectively. The relatively lower mean overall dry matter digestibility coefficient (0.52) of the steers in Group 1 serves to emphasise how much hay was indeed wasted by the steers in Group 1, in order to significantly elevate the mean faecal chromium concentrations (i.e. the mean faecal chromium concentration of the steers in Group 1 should have been lower than the corresponding concentrations of the steers in Group 2 and Group 3, due to the lower overall dry matter digestibility coefficients of Group 1, had all the animals consumed the same quantities of feed).

The deleterious effects of ostertagiasis in the steers of Group 1, in the first grazing season, have probably caused this relative degree of inappetance for the hay offered to them, in comparison with the steers of Groups 2 and 3 which were not particularly badly affected by ostertagiasis in their first grazing season. Indeed, when clinical symptoms of ostertagiasis (Type II phase) were apparent (diarrhoea and elevated faecal egg counts) in the steers of Group 1 immediately prior to turnout (corresponding with sampling Period III), the coefficient of variation of faecal chromium concentration increased from the previous levels of 10.2% and 8.5% (sampling Periods I and II) to 18.4%, compared with 3.8% and 12.5% in Groups 2 and 3 respectively, which may suggest that the steers within Group 1 were variably affected by this Type II infection and, consequently, a more variable effect on individual appetite for hay was observed within the group at this time. Indeed, several of the steers in Group 1 were particularly affected by Type II infection, as indicated by marked elevations in plasma pepsinogen levels of up to 7.3 i.U. of tyrosine (Entrocasso, 1984).

During the sampling periods between September and October of the second grazing season, the similarity of the mean faecal chromium concentrations between the groups may not have been expected in view of the probably poorer diet dry matter digestibility of the steers in

Group 1 which were showing further symptoms of ostertagiasis throughout the second grazing season, in comparison to the steers in Group 2 and Group 3 which were fairly clear of infection (Entrocasso, 1984). This was perhaps reflected in the relatively greater coefficients of variation of the faecal chromium concentrations in Group 1 (18.5% to 29.8%) in three out of four sampling period, compared with the corresponding values in Groups 2 and 3 (8.9% to 19.5%). The apparently more variable range of supplementary compound intake in the steers in Group 1 may have reflected variation in the degree of inappetance caused by the diferential effects of ostertagiasis between the steers in this group. The range of supplementary compound intake, as illustrated by the coefficient of variation of faecal chromium concentration, was similar between the steers in Groups 2 and 3.

Therefore, ostertagiasis was observed to influence the variation of feed intake in growing Friesian steers. Effects on appetite were observed in the first winter housing period, where steers which had been deleteriously affected by ostertagiasis in their first grazing season (Group 1) tended to waste more hay than those which were relatively unaffected by ostertagiasis in their first grazing season (Groups 2 and 3).

The range of appetite within the groups of steers was again observed in the second grazing season, when supplementary compound feed was allocated later on in the season. Again, the steers which had been deleteriously affected by ostertagiasis in their first grazing season (Group 1) and subsequently later in the winter housing period (prior to turnout), exhibited a more variable intake of compound feed than the steers in Groups 2 and 3, which probably reflected the variation in inappetance of the group caused by further deleterious effects of ostertagiasis in the second grazing season.

SECTION 6 ASSESSMENT OF INDIVIDUAL SILAGE INTAKE IN THREE HERDS OF GROUP FED DAIRY COWS

In the present section the possible influences of the method of access to silage (i.e. self-feed or easy-feed access) and time of access on the variation in individual silage intake were examined in three commercial dairy herds. Silage was allocated either on a restricted basis, where it was designed to supply the maintenance metabolisable energy requirements plus the metabolisable energy equivalent of 5 litres of milk, or on a more liberal basis where it was designed to supply the maintenance metabolisable energy requirements plus the metabolisable energy equivalent of up to 14 litres of milk. Differences in silage intake between cows and first-calving heifers, within herds, have been particularly noted.

Experiments 6.1 and 6.2 investigate the individual intake of silage under both easy-feed access and self-feed access respectively in two dairy herds where silage was allocated under more liberal feeding conditions and restricted feeding conditions respectively. Experiments 6.3.1 and 6.3.2 examine the variation in individual silage intake in two dairy herds where silage was allocated on a restricted easy-feed basis and a more liberal easy-feed basis respectively. Experiments 6.4.1 and 6.4.2 assess the individual intake of silage in the same dairy herd where the observations were taken in two separate winter feeding periods.

Experiment 6.1 Assessment of individual silage intake under self-feed and easy-feed access in a herd of dairy cows

Introduction

The individual intake of self-feed silage was monitored in the Cochno dairy herd at regular intervals over a nine-week period between December and January. Silage had been on offer to the cows on a self-feed basis for six weeks prior to the beginning of the present study. Immediately following the nine-week period of self-feed access to the face of the silage pit, during which time individual silage intake was measured on four occasions, silage was offered to the cows on an easy-feed basis from behind a feed barrier, at a similar daily rate of allocation to the daily quantity which had been consumed by the cows under self-feed access. Individual silage intake was determined under easy-feed access after one week (week 10, Easy-feed 1) of presentation of the silage by this method. Immediately following week 10, silage was again offered to the cows on an easy-feed basis for a further period of one week (week 11, Easy-feed 2) with a more generous allocation of silage and feeding space than during week 10. An extra block of silage (approximately 150 kg DM) was offered to the herd from a feedring and the feedring was replenished with silage as required. Individual silage intake was again determined towards the end of week 11.

A comparison between the pattern of silage intake in the herd under two methods of access to silage (either self-feed or easy-feed) was therefore effected.

Materials and Methods

The Cochno dairy herd of British Friesian cows, which consisted of 17 first-calving heifers (of mean liveweight 488 ± 45 kg and condition score 2.9 ± 0.51) and 53 cows (mean liveweight 567 ± 52 kg and condition score 3.1 ± 0.57) in early and mid lactation at the beginning of the present experiment, were housed in a cubicle building with access to both a feeding passage, behind a feed barrier, and a silage pit (12.2 m wide). Thirty to forty of the animals were additionally allowed access to two out-of-parlour feeders and were each fitted with a transponder around the neck for this purpose.

The metabolisable energy requirements for maintenance plus 14 litres of milk were supplied from the basal ration of silage, barley,

and molassed sugar beet pulp pellets. Barley and sugar beet pulp pellets were both offered at 09.30 h, each at a rate of 2 kg fresh matter/head/day, along the feeding passage behind a wooden barrier (neck rail),allowing 1.3 m space allowance/head. The intake of barley and sugar beet pulp was assumed to be uniform between the animals in the herd and, indeed, the contribution of their indigestible contents to the total faeces output of approximately 5 kg DM was expected to be not more than 10%. Any variation in the intake of the barley and/or sugar beet pulp from cow to cow (relative to possible variation in silage intake) was considered to be quite small.

Silage was available on an ad libitum basis over the full 24 hours from one pit of 12.2 m in width, which provided a more generous space allowance, i.e. 1.05 m/head) than the MAFF (1977) recommendation of 0.69 m/head for one sixth of the animals in the herd. The silage was anticipated to contribute 40 kg fresh matter/head/day to the basal diet. Direct contact with the silage face was prevented by a widthways metal bar connected to an electric fence unit. The bar was maintained at a constant distance of 0.2 m from the silage face, as the cows ate into the silage during the course of the experiment.

The remaining individual metabolisable energy requirements were supplied from parlour-fed proprietary, pelleted compound feed (A) at two rates according to milk yield, either 4 kg fresh matter/head/day (in two feeds) or 1 kg fresh matter/head/day (in one feed) to cows in Group 1 (n = 50-60) and Group 2 (n = 7-10) respectively. The number of cows in each group fluctuated during the experiment as cows calved or were dried off. Chromic oxide had been incorporated into compound feed A (which was offered in the parlour) at a rate of 5 g/kg fresh matter.

Additionally, 35 of the cows in Group 1 also had access to compound feed A (in which no chromic oxide had been incorporated) from electronically controlled out-of-parlour feeders which dispensed compound feed in discrete allocations of 0.5 kg fresh matter. The range of compound A (no chromium) on offer from the out-of-parlour feeders was 1-9 kg fresh matter/day, allocated according to individual milk yield.

The proximate analyses of the feeds on offer to the cows are presented in Table 82. The proximate analyses of compound A presented in the parlour and from the out-of-parlour feeders were somewhat different and represent normal batch-to-batch variation (apart from the chromium concentration of compound A allocated in the parlour).

Table 82 Proximate analyses of the feeds

	Compound feed A (parlour)	Compound feed A (out-of-parlour)	Silage	Barley	Molassed sugar beet pulp pellets
Dry matter (g/kg)	862	863	220	860	900
Composition of dry matter (g/kg DM)					
Crude protein	182	174	155	108	106
Crude fibre	94	100	328	53	144
Ether extract	46	51	27	17	6
Soluble carbohydrates	610	584	429	795	662
Ash	68	91	61	26	82
Chromium	1.681	-	-	-	-

The pattern of concentrate allocation, just described, was maintained from the 4th December until the 20th February of the following year (i.e. 11 weeks of the experiment), even although several cows, particularly from Group 1, would be allocated too much concentrate feed in relation to their milk yield towards the end of the experiment. This was tolerated to enable comparisons to be made between silage intake of the same animals under self-feed ad libitum access (4th December - 5th February) with silage intake under easy-feed access (6th February - 20th February).

During the nine week period of self-feed access to the silage (beginning on 4th December) faecal grab samples were taken from each animal at 16.00 hours on four different days at approximate intervals of 2-3 weeks (11th December, 31st December, 22nd January and 5th February respectively). The samples from each collection day were dried, milled and analysed for chromium. The faecal chromium concentrations were used to calculate the individual silage intakes of the animals (Appendix 3). Dry matter digestibility coefficients of 0.85 were used for the barley and sugar beet pulp (MAFF 1984). The dry matter digestibility coefficients (in vivo, Appendix 2) for the silage, parlour compound cake and out-of-parlour concentrate cake were 0.78 , 0.77 and 0.77 respectively.

The cows were weighed and body condition scored on the 6th December and the 5th February.

On the 6th February the silage was offered to the animals on an easy-feed basis (Easy-feed 1) behind a 56 metre barrier, along the feeding passage. The same total daily intake as had been consumed under ad libitum access was offered. The total daily allocation was calculated from the estimated total volume of silage consumed under self-feed access (182.3 cubic metres over 62 days) and its known density of 927 kg/cubic metre, i.e. 2.72 tonnes of fresh matter/day was consumed by 60-65 cows (between 41.9 and 45.3 kg FM/head) between the 4th December and 5th February. The average number of lactating cows had increased to 68 at the end of January/early February. Consequently, 2.88 tonnes of fresh matter was allocated each per day to the herd (42.3 kg FM/head/day) for a period of seven days. The silage was cut into blocks and weighed on the tractor-mounted block cutter (fitted with a weighing device) and the allocation for each day was placed along the feeding passage behind the feed barrier. The space allowance was 82 cm/head. Approximately half of the allocation for each day was placed in front of the cows at 08.30 h and the remaining half was offered to the cows at 16.00 h. The allocation of compound feeds was the same as when ad libitum self-feed silage was on offer.

On the 13th and 14th February faecal grab samples were taken from each animal at 16.00 h. The faeces samples were amalgamated, dried, milled and analysed for chromium.

Immediately after this initial nine-day period of easy-feed silage allocation, there followed a second period of seven days when the same total daily allocation of 42.3 kg FM/head/day of silage was allocated along the feeding passage. Additionally, silage was available from a feedring (16 spaces were available, each of 30 cm separated by vertical bars) which was kept well stocked with silage during the seven day period (Easy-feed 2). The feedring provided extra space (i.e. 480 cm in total) for any additional cows and consequently allowed extra trough space for all of the cows. Approximately 90 cm of space/head was available. Any refusals of silage were weighed at the end of the seven day period. It was therefore possible to ascertain whether or not the cows had, in fact, been receiving their full voluntary capacity under self-feed access (and also easy-feed access from 6th - 14th February).

On the 19th and 20th February, faecal grab samples were taken from each animal at 16.00 h. The faeces samples were amalgamated, dried, milled and analysed for chromium.

The determined individual faecal chromium concentration were used, as previously, to calculate the individual silage intakes of the cows.

Results

The cows usually consumed the barley and sugar beet pulp pellets allocations within 15-20 minutes. All the cows persevered behind the feed barrier and there was no obvious bullying. It was therefore assumed in the calculations of individual silage intake that the animals had uniformly consumed the allocations of barley and sugar beet pulp pellets. It was difficult to observe the behaviour of the cows when the silage was available for 24 hours under self-feed access. Nevertheless, most of the cows were seen to go forward to the silage face at some time during the access period, with the exception of three of the 17 first-calving heifers (36, 37 and 38) who were notably reluctant to persevere at the silage face.

When the cows were offered easy-feed silage in two approximately equal allocations (at 08.30 and 16.00 h) from behind the feed barrier at the same daily rate as had been consumed under self-feed silage (i.e. 42.3 kg FM/head), the allocation was usually completely consumed within 1-2 hours per feed. Most of the cows were keen to come forward

to consume the silage and persevered at the feed barrier until the allocation was completely cleared. However, several of the first-calving heifers (37 and 38) were reluctant to come forward to the barrier immediately after the silage had been placed behind it. Nevertheless, after 10-15 minutes, they did in fact settle down to eat the silage. The cows also seemed anxious to consume more silage, as they became very restless after the silage had been consumed, particularly after the 16.00 h allocation. During the second period of seven days when easy-feed silage was offered from behind the feed barrier and an additional block of silage (approximately 500 kg FM) was offered from a feedring, the cows consumed the silage from behind the feed barrier in a similar manner as in the previous week. However, the silage from the feedring was not readily consumed, even although several animals were usually observed in its immediate vicinity throughout the day and it could perhaps be concluded that the cows, as a group, were already consuming as much silage as they were able to under easy-feed access and self-feed access.

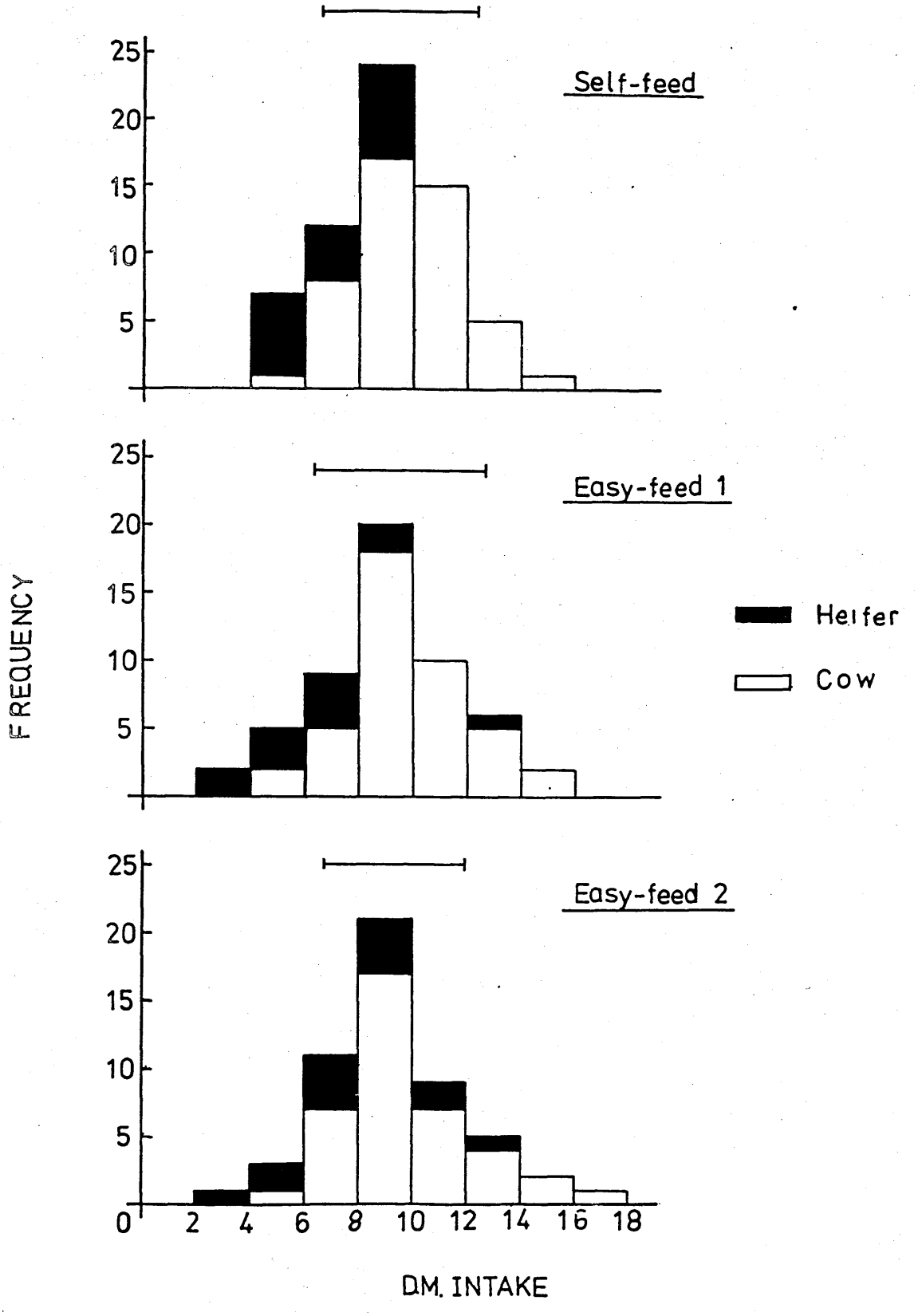
The mean calculated silage dry matter intakes (± S. dev.) from between two and four observations, taken on four separate days, under self-feed access to silage and from the two observations (each consisting of two faecal grab samples taken on two consecutive days) taken when easy-feed silage was available, are presented in Table 83 and Figure 6. The numbers of individual data (n) used in the calculations of the mean silage dry matter intake fluctuated as cows calved or were dried off. Also some of the animals were empty at the time of sampling. The overall mean intake of silage dry matter of the cows under self-feed access was 9.0 ± 2.36 kg (coefficient of variation 26.2%). The mean dry matter intake when silage was allocated to the cows from behind the feed barrier was equivalent (9.0 ± 2.67kg) to the mean intake under self-feed access which was as expected, since the same quantity of silage fresh matter had been intentionally allocated. However, the coefficient of variation for easy-feed access was marginally larger (29.7%).

When silage was additionally offered from a feedring, under otherwise easy-feed access conditions from behind the feed barrier, the mean silage dry matter intake appeared to increase from 9.0 to 9.3 kg. However, the difference of 0.3 kg DM was not statistically significant ($P > 0.05$) which was probably due to the relatively large standard error of ± 0.36 associated with the mean intake of 9.0 kg DM.

Table 83: Mean silage dry matter intake (kg) ± S.dev for self-feed (4 observations) and easy-feed (2 observations) access

	Self-feed access					Easy-feed access	
Observations	1	2	3	4	Mean	1	2 (+feedring)
n	46	48	46	58	64	54	53
Mean	8.8	8.9	8.3	9.5	9.0	9.0	9.3
S.dev ±	2.62	2.65	2.43	2.87	2.36	2.67	2.55
Range	2.5 - 14.5	3.6 - 15.1	2.2 - 12.8	3.3 - 16.2	4.3 - 15.5	3.3 - 14.9	4.3 - 14.3
CV%	29.8	29.8	29.3	30.2	26.2	29.7	27.4

Figure 6 Frequency histograms of silage DM intake (kg) for each type of access (⊢⊣ indicates ± S.dev of the mean).


Self-feed
Easy-feed 1
Easy-feed 2
FREQUENCY
25
20
15
10
5
0
2
4
6
8
10
12
14
16
18
DM. INTAKE
Heifer
Cow

The coefficients of variation for mean silage dry matter intake were fairly similar throughout the experiment (26.2% - 30.2%) and indicate a similar range of silage dry matter intake within this group of animals, irrespective of method of silage presentation.

Absolute correlation coefficients and rank order correlation coefficients were computed within the four calculated observations of silage intake obtained under self-feed access and within the two observations of calculated silage intake obtained under easy-feed access. The overall mean silage intake data calculated from the four sets of data under self-feed access were correlated with the silage intake data for easy-feed access and easy-feed and feedring access respectively. The absolute correlation and rank order correlation coefficients are presented in Table 84 I and II . All the computed correlations were statistically significant. The cows showed marked consistency of silage dry matter intake and ranking order within and between the sampling days under self-feed and easy-feed access. This pattern of consistency perhaps indicates the accuracy and repeatability of the technique.

The mean intake of silage dry matter of the cows was compared with that of the first-calving heifers (Table 85) within each method of silage presentation. This is also illustrated in Figure 6. The mean silage dry matter intake of the four observations was used in the comparison between first-calving heifers and cows under self-feed access. The cows consistently consumed more silage dry matter than the first-calving heifers for each type of access. Indeed, several of the first-calving heifers (i.e. 36, 37 and 38) had been observed to be reluctant to consume the silage, irrespective of method of access. Under self-feed silage, the cows consumed 2.5 kg DM more than the first-calving heifers ($P < 0.001$). When the silage was offered under easy-feed access, the cows consumed 2.9 kg DM more than the heifers ($P < 0.001$). When silage was additionally offered from a feedring as well as on an easy-feed basis, from behind the barrier, the cows consumed 1.6 kg DM more than the heifers ($P < 0.05$). Heifers 36, 37 and 38 consistently consumed less silage than the other animals (range of 4 -6 kg DM/head). It is possible that during the first period of easy-feed access to the silage the first-calving heifers (particularly 36, 37 and 38) were less familiar with the new access conditions than the cows and this may have been reflected by the increased coefficient of variation (40.0%) of silage intake of the heifers during this period of access

Table 84: Absolute and rank order correlation coefficients for silage dry matter intake computed within observations for each type of access (I) and between type of access (II).

I	Self-feed access						Easy-feed access
	1/2	1/3	1/4	2/3	2/4	3/4	1/2
Correlation coefficient	0.312*	0.391**	0.331*	0.604***	0.356*	0.642***	0.413**
Rank order correlation coefficient	0.280*	0.331**	0.386**	0.618***	0.327*	0.682***	0.442**

II	Self-feed access^{+}/Easy-feed (1)	Self-feed access^{+}/Easy-feed(2)
Correlation coefficient	0.562***	0.456**
Rank order correlation coefficient	0.478***	0.478**

1, 2, 3 and and.4 denote observations under self-feed access.

* P < 0.05 ** P< 0.01 *** P< 0.001 $^{+}$Overall mean from ≤ 4 observations/cow

Table 85: Mean silage dry matter intake of cows and first-calving heifers within each type of access to silage

	Self-feed access+			Easy-feed access (1)			Easy-feed access (2) (+ feedring)		
	All	Cows	Heifers	All	Cows	Heifers	All	Cows	Heifers
n	64	47	17	54	42	12	53	40	13
Mean	9.0	9.7^{A}	7.2^{B}	9.0	9.7^{A}	6.8^{B}	9.3	9.5^{c}	8.0^{d}
S.dev ±	2.36	2.19	1.75	2.67	2.28	2.72	2.55	2.09	2.09
Range	4.3-15.5	4.6-15.5	4.3-10.0	3.3-14.9	5.9-14.9	3.3-12.5	4.3-14.3	5.6-14.3	4.3-11.4
CV%	26.2	22.6	24.3	29.7	23.5	40.0	27.4	22.0	26.1

Within each type of access (self-feed and easy-feed (1 and 2) means with different superscripts, between cows and heifers, are significantly different.

A,B $P < 0.001$ c,d $P < 0.05$

+ Mean of 2-4 observations per animal

(compared with 24.3% under self-feed access).

The possible effect of liveweight on silage intake was removed by expressing individual silage intake (kg DM) per 100 kg liveweight. The mean silage dry matter intakes, expressed in this way, for each method of silage access are presented in Table 86. The mean silage dry matter intakes (kg DM 100 kg liveweight) for all the animals were similar under self-feed access and easy-feed access (1) to silage (1.59 and 1.54 kg/DM 100 kg liveweight respectively) which again was as expected as the allocation of the silage under easy-feed access was the equivalent of the quantity consumed under self-feed access. When silage was additionally offered from a feedring, under otherwise easy feed access conditions from behind the feed barrier, the mean silage dry matter intake (kg DM/100 kg liveweight) appeared to increase from 1.54 to 1.66 kg. The difference was not statistically significant.

The relatively lower coefficients of variation under self-feed access when the effect of liveweight is removed (18.8% for n = 40 animals) suggests that liveweight had a greater influence on the uniformity of silage intake in the group under self-feed access than under easy-feed access, where the coefficients of variation were similar for silage intake expressed in kg DM and kg DM/100 kg liveweight.

There were no statistically significant differences, within each type of silage access, between the mean silage dry matter intake (kg DM/100 kg liveweight) of cows and first-calving heifers. However, the difference between the mean silage dry matter intakes of cows and first-calving heifers, irrespective of the influence of liveweight, was more marked under self-feed access (0.19 kg DM/100 kg liveweight) compared with easy-feed access (0.15 and 0.08 kg DM/100 kg liveweight for easy-feed access (1) and (2) respectively). Indeed, the difference in mean silage intake (kg DM/100 kg liveweight) between the cows and first-calving heifers was much reduced (0.08 kg DM/100 kg liveweight) during the second period of easy-feed access, when silage was also available from a feedring.

The discrepancies in the numbers of animals in Table 85 and Table 86 were caused by the absence of the corresponding liveweight data for some of the animals and for self-feed access, the mean silage intakes were calculated only for those animals which had complete sets of four observations.

Absolute and rank order correlation coefficients were computed

Table 86: Mean silage dry matter intake of cows and first-calving heifers (kg DM/100 kg liveweight) within each type of access to silage.

	Self-feed access (mean of 4 observations)			Easy-feed access[1] (no feedring)			Easy-feed access[2] (+ feedring)		
	All	Cows	Heifers	All	Cows	Heifers	All	Cows	Heifers
n	40	30	10	49	37	12	47	34	13
Mean	1.59	1.64	1.45	1.54	1.58	1.43	1.66	1.68	1.60
S.dev ±	0.299	0.267	0.367	0.431	0.368	0.589	0.456	0.451	0.484
Range	0.81-2.05	0.81-2.05	0.84-2.03	0.65-2.72	0.84-2.50	0.65-2.72	0.77-2.93	0.98-2.93	0.77-2.41
CV%	18.8	16.3	25.3	27.9	23.3	41.2	27.5	26.9	30.3

None of the differences in silage dry matter intake kg/100 kg liveweight between cows and heifers, within each type of access to silage, was significant ($P > 0.05$)

between silage intake and liveweight considering cows and first-calving heifers separately. The results are presented in Table 87 . None of the absolute correlation coefficients was statistically significant. However, the absolute correlation coefficients were larger for both the cows and first-calving heifers (0.299 and 0.325 respectively) under self-feed access compared with both methods of easy-feed access (0.131 and 0.003 for easy-feed access (1) and (2) for the cows and 0.055 and 0.074 for easy-feed access (1) and (2) for the first-calving heifers).

The rank order correlation coefficient between the silage intake and the corresponding liveweight of the cows, under self-feed access was statistically significant (0.405, $P < 0.05$). None of the rank order correlation coefficients between silage intake, under easy-feed access, and liveweight of cows was statistically significant. The rank order correlation coefficients for silage intake under self-feed access and the corresponding liveweight of the heifers was 0.345 and, even although it was not statistically significant, it indicated a better ranking order relationship between silage intake and liveweight than did the rank order correlation coefficients computed under both methods of easy-feed access (0.053 and 0.196 respectively). The greater influence of liveweight on silage intake under self-feed access compared with easy-feed access was again indicated by these observations.

The mean silage intakes under self-feed access (mean of 2-4 observations per animal) were correlated against the respective number of days into lactation of the animals (taken at the mid point of the 62 days of access to self-feed silage, i.e. 31 days after the beginning of the experiment). The correlation coefficient was - 0.523 $P < 0.001$ (Table 88). The relationship was further described by the regression equation $y = 11.0 - 0.0157x$ (y = silage dry matter intake; x = number of days into lactation at the mid point of the 62 days of access to self-feed silage). The error associated with the prediction of the mean silage intake (i.e. 9.0 kg DM) was $\pm$ 1.178 and r^2 was 27.4% ($P < 0.001$).

Similarly, the mean silage intakes (kg DM) per 100 kg of liveweight (mean of 4 observations per animal) under self-feed access were correlated against the number of days into lactation of the animals (31 days after the beginning of the experiment). The correlation coefficient was - 0.542 ($P < 0.001$) (Table 88). The

Table 87: Absolute (r) and rank order correlation (ro) coefficients for individual silage dry matter intake related to liveweight of cows and first-calving heifers.

	Liveweight (cows) $\bar{x}$ = 567 ± 52 kg			Liveweight (first-calving heifers) $\bar{x}$ = 488 ± 45 kg		
Silage intake (access type)	Self-feed	Easy-feed(1)	Easy-feed(2)	Self-feed	Easy-feed(1)	Easy-feed(2)
r	0.299	0.131	0.003	0.325	0.055	0.074
ro	0.405*	0.174	0.128	0.345	0.053	0.196

Easy-feed (2) access indicates additional trough space was available from a feedring. * $P < 0.05$

relationship was further described by the regression equation y = 1.90 - 0.0024x (y = silage dry matter intake kg per 100 kg of liveweight; x = number of days into lactation at the mid point of the 62 days of access to self-feed silage). The error associated with the prediction of the mean silage intake (i.e. 1.59 kg DM/100 kg liveweight) was ± 0.255 and r^2 was 29.4% ($P < 0.001$).

Table 88 Correlation coefficients between silage intake (kg) and silage intake (kg) per 100 kg liveweight respectively and the corresponding number of days into lactation for each type of silage access

	Number of days into lactation		
Silage intake	Self-feed	Easy-feed without feedring	Easy-feed with feedring
DM (kg)	- 0.523***	- 0.370**	- 0.022
DM/100 kg liveweight	- 0.542***	- 0.346*	- 0.060

* P <0.05 ** P <0.01 *** P <0.001

The corresponding correlation coefficients between both silage dry matter intake (kg) and silage dry matter intake (kg) per 100 kg liveweight (respectively) and the number of days into lactation (calculated up to the day when the second faeces samples were taken) for each type of easy-feed access to silage are presented in Table 88. The correlation coefficients were statistically significant for the first period of easy-feed access only, when silage was only available from behind a feed barrier (- 0.370 $P < 0.01$ and - 0.346 $P < 0.05$ for silage DM intake (kg) and silage DM intake (kg) per 100 kg liveweight respectively). The corresponding regression relationships were described by equations $y = 11.2 - 0.0158x$ (error associated with prediction of $y = 2.300$ and $r^2 = 13.7\%, P < 0.01$) where y = silage dry matter intake and x = number of days into lactation, and $y = 1.96 - 0.0281x$ respectively (error associated with prediction of $y = 0.412$ and $r^2 = 11.9\%, P < 0.05$) where y = silage dry matter intake (kg) per 100 kg liveweight and x = number of days into lactation. The corresponding regression relationships where silage was additionaly offered from a feedring, under otherwise easy-feed access, were not statistically significant. All the latter regression equations are presented in Table 89 .

Correlation and rank order correlation coefficients (n = 14) were computed for silage dry matter intake related to individual allocation of out-of-parlour concentrate feed allocation for those animals allocated 4 kg of concentrate feed in the milking parlour. The calculated coefficients were very small and ranged between - 0.243 to +0.197 and not one of the coefficients was statistically significant. Indeed four of the correlation coefficients approached zero which indicates that silage dry matter intake was not influenced by individual allocation of out-of-parlour compound feed.

The mean body condition scores of the cows and first-calving heifers at the beginning of the 11-week experimental period were 3.13 $\pm$ 0.541 and 2.85 $\pm$ 0.555 respectively. The difference of 0.28 condition score was not statisticaly significant. However, during week 11 the mean body condition scores of the cows and first-calving heifers were 3.24 $\pm$ 0.405 and 2.88 $\pm$ 0.569 respectively, and the mean difference of 0.36 was statistically significant ($P < 0.05$). However, the changes in the mean body condition score within the groups of cows and first-calving heifers from the beginning of the experiment until week 11 were not statistically significant (+ 0.11 and + 0.03 respectively).

Table 89: Regression equations between silage intake (kg DM) and silage intake (kg DM) per 100 kg liveweight respectively and the corresponding number of days into lactation for each type of silage access.

y	Silage DM intake (kg)				Silage DM intake (kg)/100 kg liveweight			
x	Number of days into lactation							
	Equation	Error associated with prediction of y	r^2%	P	Equation	Error associated with prediction of y	r^2%	P
Self-feed access	y = 11.0 - 0.0157x	± 1.178	27.4	0.001	y = 1.90 - 0.0024x	± 0.255	29.4	0.001
Easy-feed access (without feedring)	y = 11.2 - 0.0158x	± 2.300	13.7	0.01	y = 1.96 - 0.0281x	± 0.412	11.9	0.05
Easy-feed access (with feedring)	y = 9.42 - 0.0012x	± 2.644	0.05	N.S.	y = 1.58 + 0.0006x	± 0.457	0.4	N.S.

N.S. = $P > 0.05$

These observations probably reflect the difference in body size of the cows and first-calving heifers whereby the first-calving heifers gain weight during their first lactation before increasing body condition. Nevertheless, the difference between the cows and first-calving heifers became significant (0.36) after 11 weeks of predominantly self-feed access to silage (9 weeks) and may reflect the significant difference in the mean silage intake between them (9.7 ± 2.19 kg DM and 7.2 ± 1.75 kg DM for cows and first-calving heifers respectively, under self-feed access).

Discussion

The distribution of silage dry matter intake around the mean was fairly similar for each type of silage access (coefficients of variation 26.2 - 30.2%, see Table 83), although when silage was offered on an easy-feed basis, the coefficient of variation was marginally larger (29.7%) than when self-feed silage (26.2% mean of 4 observations) was on offer. This is perhaps further exemplified by the differences in the mean silage dry matter intake between the cows and first-calving heifers (+ 2.5 kg DM and + 2.9 kg DM for self-feed and easy-feed respectively) which has perhaps helped to produce the larger distribution of silage dry matter intakes around the mean under easy-feed access compared with self-feed access.

During the second week of easy-feed access, when silage was additionally offered from a feedring, the coefficient of variation was reduced slightly to 27.2% with a corresponding reduction in the difference between the mean silage dry matter intakes of the cows and heifers to 1.6 kg DM. The difference of 1.6 kg DM was statistically significant ($P < 0.05$). The additional availability of silage from the feedring and/or the possibility that the heifers had had more time to adjust, after two weeks, to the new method of feeding silage (i.e. easy-feed) may have contributed to the reduction in the mean difference between the silage dry matter intakes of the cows and heifers, and the reduced coefficient of variation for silage dry matter intake in the second week of easy-feed access, compared with the first week of easy-feed access. Indeed, the coefficient of variation of silage dry matter intake by the heifers, for the first week of easy-feed access, was 40.0% compared with 26.1% in the second week of easy-feed access (+ feedring) which perhaps further substantiates the need for a greater period of adjustment for the heifers compared with the cows

(coefficients of variation of 23.5% and 22.0% respectively). A period of adjustment was not apparent under self-feed access as the cows and heifers had been allocated self-feed silage for up to six weeks prior to the beginning of the experiment and, consequently, an established pattern of silage intake was monitored during weeks 1 to 9 of the present experiment.

The statistically significant differences in silage dry matter intake between the cows and first-calving heifers for each method of silage presentation was observed to be substantially caused by differences in liveweight. Removal of the effect of liveweight by expressing silage intake (kg DM) per 100 kg liveweight indicated that there were no statistically significant differences in silage intake between the cows and first-calving heifers for each method of silage presentation. However, the difference between the silage intakes (kg DM/100 kg liveweight) of the cows and first-calving heifers was larger (0.19 kg DM) for self-feed compared with easy-feed access (0.15 kg DM and 0.08 kg DM for easy-feed (1) and (2) respectively), which suggests that the first-calving heifers are likely to consume less silage than the cows under self-feed access, caused by factors other than liveweight differences, than under easy-feed access. Such factors may include the dominance ranking order of the herd, where first-calving heifers are likely to be at the lower end of the pecking order, and the possible prehension difficulties that first-calving heifers may encounter with the consumption of self-feed silage due to their probable mixed incisor dentition (i.e. temporary and permanent incisors are both likely to be present).

Consideration of cows and first-calving heifers as separate groups indicated that absolute correlation coefficients between silage intake (kg DM) for each type of silage presentation and liveweight were not statistically significant, even although the correlation coefficients were larger for both the cows and first-calving heifers (0.299 and 0.325 respectively) under self-feed access than under easy-feed access. Indeed, the significant rank order correlation coefficient ($0.405, P < 0.05$) between silage intake and liveweight of the cows indicates that within the cows and first-calving heifers the influence of liveweight on silage intake was more readily apparent under self-feed access to silage than under easy-feed access. This may suggest that, in order to eliminate or reduce the effects of liveweight on individual silage intake, particularly between cows and first-calving heifers, in a dairy

herd, easy-feed access to silage may be preferable to self-feed access.

A further effect of the difference in silage dry matter intake between the cows and first-calving heifers was observed in the significant mean difference of 0.36 in the body condition score ($P < 0.05$) between the cows (3.24 ± 0.405) and first-calving heifers (2.88 ± 0.569) which became apparent at the end of the 11 week experimental period, in contrast to the difference of 0.28 condition score at the beginning of the experiment, which was not statistically significant. Access to easy-feed silage throughout the 11 week experimental period may have prevented this significant difference.

Silage had been allocated to supply 97.2 MJ ME/head/day (9.0 x 10.8 MJ ME/kg DM) which contributed towards the maintenance energy requirements plus metabolisable energy for 14 litres of milk (134 MJ ME in total). The observed range of ME intakes were 46.4 - 167.4 MJ ME for self-feed silage (mean of 2 to 4 observations), 35.6 - 161.0 MJ ME for easy-feed silage and 46.4 - 154 MJ ME for easy-feed silage (with feedring). The individual silage dry matter intakes and corresponding ME intakes for some of the animals, particularly the heifers, is well below (as low as 37% of) the allocation of both silage dry matter and ME and is likely to produce inadequate individual milk fat percentages which may have a cumulative effect on the overall milk fat production of the herd. The individual silage intake of some animals is apparently contributing to as much as 172% of the allocated ME intake (92.2 MJ) from silage and indicates an inefficient allocation of resources, particularly if the additional ME is being stored as fat.

The grab sampling technique and the calculation of individual silage intake from faecal chromium concentrations (by apportionment) has produced consistent results in the present experiment, as observed by the statistically significant correlation and rank order correlations computed between the individual observation for each type of access. The accuracy and repeatability of the technique has thus been substantiated. Nevertheless, some of the extreme observations of silage dry matter intake (e.g. 2.2 and 15.5 kg DM) may be justifiably questioned, particularly those at the upper end of the distribution, in view of definitive total dry matter intake capacities. Those silage intake values at the lower end of the distribution may, however, have been caused (e.g.) by oestrus behaviour or lameness problems in the animals.

The statistically significant correlation coefficients computed between silage dry matter intake (kg DM and kg DM/100 kg liveweight) and the number of days into lactation, for self-feed access and easy-feed access without feedring, were perhaps as would be expected, indicating that silage dry matter intake significantly declined as lactation progressed. However, a more curvilinear relationship than the relatively linear relationship obtained here may have been expected in order to conform with the classic dry matter intake versus stage of lactation curve (eg, Greenhalgh and McDonald, 1977), given that full voluntary access to silage was observed in the present experiment.

The relatively low, statistically non-significant correlation coefficients between silage dry matter intake (kg DM and kg DM/100 kg liveweight) and the number of days into lactation under easy-feed access, where silage was additionally offered from a feedring (- 0.022 and - 0.060 respectively) may indicate that a more constant intake between the animals is being observed and, consequently, r is approaching 0. This may suggest that the cows and first-calving heifers have adapted to easy-feed presentation of silage after two weeks of access more so than under easy-feed access (without feedring) and uniformity of silage intake was, indeed, promoted under easy-feed access. Alternatively, it may be that the total dry matter intake itself is approaching an almost zero gradient in the dry matter intake/stage of lactation curve previously mentioned, particularly as the correlation coefficient between silage intake under easy-feed access (2) and stage of lactation was determined 47 days after the corresponding correlation coefficient under self-feed access (when the mean number of days into lactation was 128 $\pm$ 66).

The absence of statistically significant correlation coefficients between the silage dry matter intake and the allocation of out-of-parlour compound feed to those animals on 4 kg FM compound feed in the parlour, indicates that the relatively restricted allocation (i.e. not ad libitum) of compound feed, in the present experiment, did not influence the individual silage dry matter intake. Allocation of out-of-parlour compound feed on an ad libitum basis is perhaps more likely to produce a substitution effect, particularly if the silage had been of poorer quality (in terms of 'D' value).

Comparison of the ability of self-feed access or easy-feed access to silage to promote uniformity of silage intake in the Cochno herd (by

observations of the respective coefficients of variation of silage dry matter intake) indicated that there was perhaps no advantage in allocation of silage under self-feed or easy-feed access, given that the silage was of reasonable quality and the fermentation characteristics had been favourable in terms of acceptability.

However, by reducing the influence of some of the factors which possibly contributed to the disparity in silage intake within a group of animals, particularly between cows and first-calving heifers, i.e. liveweight, it was observed that easy-feed access to silage may promote a more constant (and therefore uniform) intake of silage within the group in this particular situation than self-feed access.

Experiment 6.2 Assessment of individual variation in silage intake of dairy cows offered self-feed silage during a seven day period followed by access to easy-feed silage for a further seven days.

Introduction

In Experiment 6.1, when silage was offered to the cows on an *ad libitum* basis, (full 24 hour access) the variation in silage dry matter intake was fairly similar under self-feed and easy-feed access (coefficients of variation of 26.2% and 29.7% respectively). In the present experiment the variation in silage dry matter intake was assessed under self-feed and easy-feed access to silage in the Dykescroft dairy herd, where the time of access to silage was restricted to eight hours between milking times (i.e., between 08.00 h and 16.00 h). The cows had been accustomed to self-feed access for two to three months before the individual silage intakes were determined. However there was only an introductory period of one week on easy-feed access before the silage intake of the cows was determined. Nevertheless the cows had readily adapted to easy-feed access to silage in this time.

The cows were divided into three groups, according to milk yield, which were respectively allocated three different mixtures of linseed cake, barley and bread to provide the remaining metabolisable energy requirements. All the cows had access to silage together.

Again, differences in silage intake between cows and first-calving heifers were particularly noted.

Materials and Methods

The Dykescroft herd of British Friesian cows (mean lactation yield 4000 litres) was housed overnight in two byres throughout the year. During the winter the animals had access to self-feed precision chopped silage from two pits, where access to the silage face was controlled with an electric wire. The silage was produced from a mixed grass sward which was cut at the short ear stage, wilted for 24 hours and precision chopped by contractors. No additives were used. At 16.00 h the cows were tied up in the byres for milking and remained in their respective stalls until after morning milking when they were untied at 08.00 h to allow access to the silage pits. All the cows, irrespective of concentrate feed allocation, consumed silage together.

In December the animals in Groups 1, 2 and 3 (early, mid and

late/dry lactation animals respectively) were offered three different mixtures of linseed cake, barley and bread, hereafter called mix B, once a day in their individual standings after they were tied up for afternoon milking. Mix B was allocated approximately on the basis of stage of lactation and milk yield (Table 90).

For two consecutive periods, each of seven days duration (Period 1 and 2), during December, 0.5 kg fresh matter of a pelleted fishmeal, barley and chromic oxide compound (Compound C, Table 90), was additionally offered once a day with mix B, to the animals in Groups 1 and 2. Group 3 animals were not included in the study as there were only six animals in the group.

During Period 1, the animals had access to self-feed silage from two pits (24 metres long per pit, 0.6 metres per head) between 08.00 h and 16.00 h. On day seven of Period 1, faecal grab samples were taken from the animals at 16.00 h. The faeces samples were dried, milled and analysed for chromium.

During Period 2, the animals had access to the two pits, as in Period 1, however the silage was presented on an easy-feed basis having been forked down behind the barrier at the silage face. Full access to the silage on offer was sustained throughout the eight hour period. The barrier had been placed directly against the silage face to prevent the animals from having direct contact with the silage face. On day seven of Period 2, faecal grab samples were taken from the animals at 16.00 h. The faeces samples were dried, milled and analysed for chromium.

The faecal chromium concentrations for Period 1 and 2 were used to calculate the individual intakes of silage dry matter. In the calculations, the digestibility coefficients for mix B and compound C were assumed to be 0.85 and the digestibility coefficient for the silage was assumed to be 0.65.

Table 90 Feeds on offer

	Total quantity of mix B offered/day kg fresh matter	Composition of mix B			Compound C 0.5 kg FM		Silage
		Linseed cake	Barley	Bread	Fish meal	Barley	
Group							
1	9.10	1.14	3.98	3.98	0.30	0.20	-
2	6.83	0.91	2.96	2.96	0.30	0.20	-
3	3.64	-	1.82	1.82	-	-	-

Composition of feeds g/kg DM

Dry matter	874	835	627	869	208
Crude protein	344	107	147	429	113
Crude fibre	106	71	8	24	326
Ether extract	85	21	6	42	33
Soluble carbohydrate	409	775	804	334	446
Ash	56	26	35	171	82
Chromium	-	-	-	12.38	-

Results

The overall calculated mean intakes of silage dry matter, presented in Table 91, were 8.3 kg (Period 1, self-feeding at the face) and 9.8 kg (Period 2, easy-fed silage) and this difference was significant ($P<0.001$). There is a discrepancy in the total number of animals for each period (66 and 75 animals in Period 1 and 2 respectively). This is because faecal samples were not obtained from all the animals is Period 1, and also several suspiciously very low faecal chromium concentrations leading to large calculated silage intake values, obtained in Period 1 (e.g. 80 kg silage DM), were omitted from the overall mean intake figures.

Within each separate period cows in Group 1 (9.1 kg mix B) consumed the same mean amounts of silage DM as those in Group 2 (6.8 kg mix B) (Table 91). The increases in intake of each group resulting from the provision of easy-feed silage were 1.4 kg (9.1 kg mix B) and 1.5 kg (6.8 kg mix B) and both were significant ($P<0.01$).

Table 91 Mean daily dry matter intake for Period 1 (self-feed) and Period 2 (easy-feed).

Intake of silage kg DM	Period 1 Self-feed			Period 2 Easy-feed		
	Group 1	Group 2	All	Group 1	Group 2	All
n	34	32	66	38	37	75
Mean	8.4	8.2	8.3	9.8	9.7	9.8
s.dev.±	2.02	2.52	2.26	2.19	2.39	2.27
Range	5.4-13.6	3.2-14.5	3.2-14.5	4.8-15.1	5.3-14.9	4.8-15.1
CV%	24.0	30.7	27.4	22.4	24.6	23.3

Difference between mean intakes for Group 1 and 2 within periods

0.2^{NS} 0.1^{NS}

Comparison of the coefficients of variation for access type (i.e either self-feed or easy-feed) indicated similarity in the distribution of the populations around the mean. The coefficient of variation for self-feed (all data) was slightly larger (27.4%) than the corresponding value under easy-feed access (23.3%).

The correlation coefficient and rank order correlation coefficient (after removing missing values) between access types were 0.136 and 0.115 respectively. Neither was statistically significant. However the correlation coefficient and rank order correlation coefficient computed for the difference in silage dry matter intake under easy-feed compared with self-feed access (an overall increase of 1.5 kg) versus silage dry matter intake under self-feed access produced highly significant coefficients of -0.644 ($P<0.001$) and -0.571 ($P<0.001$) respectively.

Eight of the animals in Groups 1 and 2 were heifers which had overall mean dry matter intakes of 9.1 ±2.93 kg and 9.5 ±2.14 kg with self-feed and easy-feed access to silage respectively. The difference of 0.4 kg dry matter was not significant. The heifers appeared to eat rather more silage dry matter than the cows when self fed (9.1 vs 8.3 kg) but not when easy-feed silage was offered (9.5 vs 9.8 kg).

Discussion

The similarity of mean silage dry matter intake for Groups 1 and 2 under each type of silage access (self-feed or easy-feed access) is likely to reflect the restricted time available for the herd to consume silage. The concentrate part of the ration contributed 7.2 kg and 5.5 kg dry matter to the total dry matter intake for animals in Groups 1 and 2 respectively. Consequently the total dry matter intake with self -feed access to the silage was 15.6 kg and 13.7 kg for Groups 1 and 2 respectively. For easy-feed access to silage the corresponding figures were 17.0 kg and 15.2 kg dry matter for Groups 1 and 2 respectively. The total dry matter figures thus obtained under self-feed and easy-feed access are well within accepted total dry matter intake figures for dairy cows in early and mid lactation (Greenhalgh and McDonald, 1977). Therefore the 1.6 kg difference in the concentrate allocation for Groups 1 and 2 is not likely to produce a marked difference in the silage intake between the groups.

The overall mean intake of silage dry matter was significantly ($P<0.001$) larger by 1.5 kg DM for easy-feed access than self-feed access which reflects the relative ease of prehension of the silage under easy-feed access. The choice between self-feed and easy-feed access to silage is one which reflects a multitude of factors, of which total quantity of silage available for the winter feeding period is a major influence. Nevertheless, with the same eight hour period of access to silage a change in the method of presentation of silage to easy-feed access at Dykescroft improved the mean silage intake by 18%. In terms of production of milk from an additional 1.5 kg of silage dry matter, (assuming 10 MJ ME/kg DM) an extra 15 MJ ME, equivalent to the requirements for 3 litres of milk, may be produced per animal (on average).

In the comparison of the mean intake of silage by the eight heifers from Group 1 (7.2 kg concentrate dry matter) and Group 2 (5.5kg concentrate dry matter) it was surprising to observe that the intakes were similar between the heifers for type of access and comparable with cow intakes for both methods of access to the silage. The coefficient of variation for the heifers was rather larger under self-feed access (32.3%) than under easy-feed access (22.4%) which may reflect a more competitive regimen under self-feed than easy-feed even although dry matter intake was similar for both. However the similarity in intake for heifers and cows may reflect the breeding policy at Dykescroft

where heifers usually calve for the first time at 30 months of age and hence are fairly well grown by the time they enter the milking herd and perhaps better able to compete effectively with the other animals at the silage face.

The correlation coefficient and rank order correlation coefficient for self-feed versus easy-feed were small (0.136 and 0.115 respectively) and non significant, suggesting that the ranking of animals for individual silage dry matter intakes did not follow the same order for self-feed as for easy-feed access. The animals therefore have demonstrated a different pattern of silage intake under the two access conditions studied, even although the coefficients of variation for self-feed and easy-feed were fairly similar (27.4% and 23.3% respectively). However, the correlation coefficient and rank order correlation coefficient computed for the difference in silage intake under easy-feed access compared with self-feed access (an overall mean increase of 1.5 kg DM) versus the corresponding self-feed access intake data were -0.644 ($P<0.001$) and -0.571 ($P<0.001$) respectively. This suggests that the poorer eaters (i.e. < 6 kg DM) under self-feed access showed a proportionately greater increase in intake under easy-feed access than the animals which consumed > 6 kg of silage under self-feed, fourteen of which consumed rather less silage under easy-feed access. Hence access to easy-feed compared to self-feed silage encourages uniformity of intake within a group of animals which has implications in terms of the forage concentrate ratio and milk composition.

Experiment 6.3.1 Assessment of the individual intake of silage, allocated on a restricted easy-feed basis, by a herd of dairy cows

Introduction

In the present experiment the individual silage intakes by the cows from the Cochno Farm dairy herd (average annual milk yield per cow 5700 kg) were determined. There were three groups of cows within the herd which differed in their respective allocation rates of the chromic oxide containing compound feed (either 12 kg or 6 kg or 2 kg FM/head/day according to milk yield) individually given in the milking parlour. The basal diet consisted of relatively restricted quantities of silage, which was offered to all the cows together (40 kg FM/head/day in two approximately equal feeds) on an easy-feed basis from behind a feed barrier, and sugar beet pulp pellets (2.3 kg FM/head/day) which were offered on top of the morning silage allocation. The silage and sugar beet pulp had been formulated to supply the maintenance metabolisable energy requirements and the metabolisable energy requirements equivalent to 5 kg of milk.

The differences in silage dry matter intake between the cows and first-calving heifers, for each of the three subgroups of animals (divided according to compound feed allocation in the milking parlour), were noted.

Materials and Methods

The dairy herd (91 cows) was divided into 3 groups, A, B and C on the basis of current milk yield (Table 92). Groups A, B and C were offered 12 kg, 6 kg and 2 kg of fresh matter per head per day, respectively, of a proprietary high protein pelleted compound cake in the parlour at milking times. Chromic oxide had been incorporated into the proprietary compound cake at a rate of 5 g/kg FM. Under this regimen it was inevitable that some cows within each group would be either offered somewhat too much or too little concentrate to suit their ME requirements. This was tolerated as it was necessary to produce three worthwhile groups, in terms of number of animals, within which intake of cake and hence chromic oxide was the same. The cows were in the parlour for a sufficient time for ingestion of the cake on offer. The feeders were regularly calibrated to ensure that the correct quantity of cake was dispensed.

Table 92 Mean daily milk yield (kg) and mean number of days into lactation for Groups A, B and C.

	Group A	Group B	Group C
Days calved. ±S.dev	50 ±24	170 ±71	277 ±42
Milk yield. ±S.dev kg/day	24 ±5	17 ±4	9 ±3
Compound cake allocated per head/day (kg fresh matter)	12	6	2
Number of animals	37	37	17

Table 93 Proximate analysis of feedstuffs

	Proprietary compound cake	Silage	Molassed sugar beet pulp pellets
Dry matter (g/kg)	860	171	900
Composition of dry matter g/kg			
Crude protein	191	184	106
Crude fibre	83	311	144
Ether extract	51	34	6
Soluble carbohydrate	583	399	662
Ash	92	72	82
Chromium	1.046	-	-
ME (MJ/kg DM)	11.9*	10.0**	12.2***

* ME = determined DE x 0.832 ** Predicted *** MAFF 1984

The basal diet consisted of silage and sugar beet pulp pellets and was formulated to provide maintenance energy requirements plus 5 kg of milk per day (MAFF 1984). The silage was offered on a restricted easy-feed system, behind a 56 metre barrier (0.6 m/head) at a rate of 40 kg fresh matter per head per day. The silage was cut into blocks from the silage pit once a day, the blocks having been weighed on the tractor's block cutter. About half the fresh silage was placed behind the barrier at 09.30 h; the remainder was offered after the evening milking. The sugar beet pulp pellets were offered at a rate of 2.3 kg of fresh matter per head at midday. The cows were presumed to eat and digest the sugar beet pulp uniformly throughout the herd. Its contribution to faecal dry matter produced was assumed to be only 0.3 kg/day. The proximate analyses of the feedstuffs on offer in this experiment are presented in Table 93.

After a period of ten days, faecal grab samples were taken from each cow on two consecutive mornings. The faeces were amalgamated for each cow, dried and subsequently analysed for chromium. The faecal chromium concentrations were then used to calculate silage dry matter intake for each cow, using previously determined (Appendix 2) values of dry matter digestibility for the compound cake (in vivo 0.79) and silage (in vitro 0.62). The dry matter digestibility value used for sugar beet pulp pellets was 0.85 (MAFF 1984).

Results

When the fresh silage was placed along the barrier in front of the cows at 09.30 h and 16.00 h the cows were keen to eat, although several heifers showed reluctance. Indeed some of these heifers, notably 102, failed to begin eating until 30 minutes after the silage had been placed along the barrier. After 30 minutes, some of the cows started to move away from the barrier, even although as much as half the allocated quantity of silage remained. Several of the cows from Group A seemed less keen to persevere with the silage after 45 minutes, with those from Groups B and C tending to stay longer at the barrier. After one hour and fifteen minutes the silage was usually completely consumed.

The sugar beet pulp pellets were readily eaten by all the animals when offered at midday. Within 10 minutes the allocation had been cleared and all the animals continued to eat for this period. This pattern of behaviour was repeated at subsequent observation periods.

Table 94 shows the calculated mean silage dry matter intake for Groups A, B and C. The differences in dry matter intake between the groups were statistically significant. The coefficients of variation for each group were fairly low and similar, suggesting that silage intake was uniform within the groups, the largest being 22.4% for Group A. The overall mean silage dry matter intake ±S.dev. for all the animals was 7.3 (±1.89) kg which is close to the allocated 6.8 kg dry matter/head.

Consideration of the silage dry matter intake for cows versus heifers (Table 95) indicated that the mean intakes were not significantly different between them, within a range of categories. The coefficients of variation were consistently greater for cows than heifers, although the values were fairly low, indicative of a relatively larger range of dry matter intake for cows compared to heifers. Group C was not considered separately in this respect as there were only two heifers in this group.

Table 94 Mean daily silage dry matter intake (kg)

Group	A	B	C	Overall Mean
n	37	37	17	91
Mean	8.4a	7.2b	5.1c	7.3
±S.dev	1.88	1.27	0.99	1.89
CV%	22.4	17.6	19.5	26.1

Group means with different letters differ significantly
ab $P<0.01$; ac $P<0.001$; bc $P<0.001$

Table 95 Mean daily silage dry matter intake (kg) of heifers and cows.

	All Animals		Groups A+B		Group A		Group B	
	Heifers	Cows	Heifers	Cows	Heifers	Cows	Heifers	Cows
n	23	68	21	53	12	25	9	28
Mean	7.6	7.2	7.9	7.7	8.4	8.3	7.2	7.2
±S.dev	1.66	1.97	1.31	1.84	1.32	2.12	1.04	1.35
CV%	21.8	27.4	16.7	23.9	15.7	25.5	14.4	18.8

Within each category there were no significant differences between the mean values.

Discussion

Given the inherent difficulties of observing large numbers of animals, although several of the animals from Group A tended to be the first to leave the silage feeding area the mean silage intake (8.4 kg DM) for Group A was significantly larger than the mean intakes for Groups B and C (7.2 and 5.1 kg DM, $P<0.01$ and $P<0.001$ respectively). The cows and heifers from Group A have perhaps ingested the silage more keenly than those from the other groups, and to have reached sateity (not necessarily full appetite) more quickly than the others in view of their larger cake allocation (10.3 kg DM/head/day). Several of the animals from Groups B and C tended to persevere at the silage feeding area, perhaps in a less keen manner, and cleared up the remains of the silage. The mean silage dry matter intake for Group B was significantly ($P<0.001$) larger (7.2 kg) than for Group C (5.1 kg). The mean intake of silage dry matter for the separate groups appears to be in the same order as their respective ME requirements, with the more recently calved animals of Group A showing the largest intake even although a restricted silage feeding regimen is present, with silage intake expected to meet only the maintenance ME requirements of the animals. Indeed the mean intake of Group A animals was 20% greater than the overall mean intake (7.3 kg DM, n = 91) and suggests that silage intake of these animals in early lactation is supplying more than the maintenance energy requirement (probably M + 2 litres).

This pattern of silage dry matter intake between the groups is

perhaps unexpected in that the more recently calved animals from Group A may be anticipated to have a more restricted appetite, with peak dry matter intake occurring 90-100 days after calving. The animals from Group B may therefore have been expected to show the maximum silage dry matter intake. However the mean number of days of lactation in Group B was 170 days, which is likely to be well passed the peak dry matter intake at approximately 120-140 days into lactation. Furthermore, the restricted silage feeding regimen in this experiment is likely to prevent this occurrence, as well as a possible group effect, in that some animals in Group A should perhaps have been placed in Group B.

The difference between the estimated overall mean dry matter intake of 7.3 kg and the allocated 6.8 kg of dry matter is +7.4%. The difference is largely experimental error and may have been due to possible inaccuracies of the silage weighing device on the tractor, possible inaccuracy in the silage dry matter estimation, inefficiencies in the grab sampling technique and likely inaccuracies in the determination of the in vitro silage digestibility coefficient or that of the compound cake. Nevertheless it provides a reasonably adequate justification of the technique.

The coefficient of variation for silage dry matter intake for each group is fairly low and comparable to those obtained under easy-feed access to silage, i.e., Experiments 6.1, 6.2 and 6.3.2. The largest coefficient of variation was 22.4% for Group A and suggests a larger range of appetite in this group compared to Groups B and C and perhaps reflects the inclusion, in Group A, of ten animals which had calved within 30 days of the faecal collection period (mean silage dry matter intake of 7.8 ($\pm$1.47) kg) with animals two to three months into their lactation (mean silage dry matter intake 8.4 ($\pm$1.87) kg). The difference of 0.6 kg DM silage intake was not statistically significant. However it is possible that if the ten post-parturient animals exhibit a reduced appetite, it would be manifested by incomplete consumption of the parlour fed compound cake allocation (12 kg fresh matter). If this is the case, the resulting silage intake data is exaggerated and the mean intake for the post-parturient animals may indeed be less than 7.8 kg of silage dry matter.

In the comparison of the silage intake of heifers versus cows (Table 95) it is perhaps surprising to observe that the heifers have very similar silage dry matter intakes (overall 7.6 kg) as the cows (overall 7.2 kg) and indeed the dry matter intake per kg of liveweight

is likely to be larger for the heifers than the cows (liveweight data were not available). Although some of the heifers appeared reluctant (e.g. 102, intake of 7.4 kg DM silage) to compete with the cows, this was not reflected in the silage dry matter intake data. The coefficient of variation for silage dry matter intake of the cows was consistently larger (about 27%) than that of the heifers (22%) in all the categories considered in Table 95. The most marked difference is for cows and heifers within Group A where the coefficients of variation were 26% and 18% respectively. This perhaps reflects the possibly larger liveweight range of the cows than the heifers.

The sugar beet pulp pellets were assumed to be eaten uniformly between the animals. Observation of the animals, when the pellets were offered, suggested that this would be the case because the animals stayed behind the barrier and persevered to clear the allocation very quickly (10 minutes). Its small contribution of only about 0.3 kg to faecal dry matter was accounted for in the calculation of silage dry matter intake.

Conclusion

The individual silage dry matter intakes, measured under a restricted, easy-feed situation in this experiment, were fairly uniform within the Groups A, B and C (12, 6 and 2 kg compound cake fresh matter respectively). Although the silage had been included in the ration to cover maintenance ME requirements, the animals in Group A apparently consumed more and those in Group C consumed less than their respective maintenance energy requirements, which can be tolerated in view of the difference in milk yield between these groups. Surprisingly the intakes of silage dry matter by the heifers were similar to the cows under these conditions. Under a self-feeding situation at the silage face and with or without ad libitum group intakes, this may not be the case.

Experiment 6.3.2 Assessment of the individual intake of silage allocated on an ad libitum easy-feed basis by a herd of dairy cows

Introduction

In the present experiment the individual dry matter intake of silage was determined in the Laigh Woodston dairy herd where silage was allocated on an ad libitum easy-feed basis to the cows. Silage was usually available to the cows throughout the 24 hr period. The herd was divided into two groups (high yielders and low yielders) and the cattle were allocated concentrate feed in the milking parlour accordingly. The high yielding group were offered first cut silage and the low yielding group were offered second cut silage. Sugar beet pulp nuts (allocated at 3.6 kg FM/head) and silage were expected to provide maintenance energy requirements and metabolisable energy equivalent to 2 litres of milk for the first 100 days of lactation. Similar quantities of concentrate feed as were allocated to the cows in Experiment 6.3.1 were allocated to the cows in the milking parlour (i.e. 9.1 kg or 5.5 kg or 1.8 kg FM/head/day).

Differences in silage intake between the heifers and cows were particularly noted.

Materials and Methods

The Laigh Woodston herd of 55 lactating pedigree British Friesian cows and heifers (lactation yield 6,000 - 7,000 litres) was divided into two groups on the basis of current milk yield (high yielders, Group H, and low yielders, Group L). The mean number of days into lactation for Group H and Group L were 128 ± 60 days and 245 ± 43 days respectively. There were 22 cows and 6 heifers in Group H (two of the heifers had not yet calved and were present in Group H to allow them to become accustomed to the herd) and 19 cows and 8 heifers in Group L. The body condition score of the animals in the herd was generally within the range of 2.0 to 3.5. The two separate groups, H and L, were housed in a partitioned cubicle shed where the animals had access to a shared central feeding passage separated from the cubicle areas by two feed barriers with diagonally fitted bars. The feed barriers were each 20 metres long allowing approximately 0.8 m/head. The cubicles were bedded with four bales of straw (approximately 70 kg) in total per day.

Silage was offered to the cows on an ad libitum easy-feed basis

along the central feeding passage. Fresh silage was placed along the barrier once a day at 11.00 h. The animals in Group H were offered first cut silage and those in Group L were offered second cut silage. Sugar beet pulp was offered to the cows at 10.00 h at a rate of 3.6 kg fresh matter/head to Group H and 1.4 kg fresh matter/head to Group L. Silage and sugar beet pulp were calculated to meet maintenance ME requirements + 2 litres of milk for the first 100 days of lactation, maintenance ME requirements + 5 litres of milk for days 100-200 and maintenance ME requirements + 8 litres of milk for days 200-300 of lactation.

Three rates of concentrates (9.1, 5.5 or 1.8 kg fresh matter/day) were dispensed in the parlour at milking time to fulfil the remaining individual ME requirements of the animals. Chromic oxide had been incorporated into the parlour-fed concentrate. The proximate analyses of the feeds offered are presented in Table 96.

Table 96 Proximate analyses of silage, sugar beet pulp and parlour fed concentrate

	1st cut silage	2nd cut silage	Molassed sugar beet pulp	Proprietary compound cake
Dry matter g/kg	255	200	843	858
Composition of dry matter g/kg				
Crude Protein	117	129	110	198
Crude Fibre	367	334	295	80
Ether Extract	33	35	1	58
Soluble carbohydrates	389	405	506	569
Ash	94	97	88	95
Chromium	-	-	-	1.08
DM digestibility coefficient	0.60+	0.55+	0.80+	0.79++

(+ Assumed; ++ Determined by digestibility study (Appendix 2))

Faecal grab samples were taken from the animals once on the eighth day after the chromium labelled cake had been introduced. The faeces were dried, milled and analysed for chromium. Faecal chromium concentrations were thence used to estimate individual silage intake, using 0.79 as the digestibility coefficient for the parlour fed cake (determined by digestibility study, Appendix 2), and assumed digestibility coefficients for the first cut silage, second cut silage and sugar beet pulp of 0.6, 0.55 and 0.85 respectively (MAFF 1984).

Results

The animals were keen to eat the sugar beet pulp and remained at the barrier until the allocation had been consumed. The cattle in Group H usually consumed their allocation within 15 minutes, and the cattle in Group L consumed their allocation within 5-10 minutes. Most of the animals were already waiting when the fresh silage was placed behind the barrier for each group. However, several animals had to be moved from the cubicle area to the silage barrier. The animals from Group L seemed slightly more keen to consume the silage than those from Group H. After 40 minutes several cows from Group L began to move away from the barrier and returned to the cubicle area. After 30 minutes several cows from Group H returned to the cubicle area. Both groups left more than half of the silage allocation after the initial feeding period. The animals returned to consume small amounts of silage on several occasions throughout the day. There was no obvious bullying, even although several animals repeatedly changed their position along the barrier.

The mean daily intakes of silage dry matter for Groups H and L are presented in Table 97. Within Group H the mean daily silage dry matter intakes for the cows and heifers, calculated separately, were 9.1 $\pm$ 2.38 kg and 8.7 $\pm$ 3.43 kg respectively. The difference of 0.4 kg was not statistically significant ($P > 0.05$). Within Group L the mean daily silage dry matter intakes for the cows and heifers were 10.1 $\pm$ 3.16 and 7.9 $\pm$ 2.49 kg respectively. The difference of 2.2 kg was not statistically significant ($P > 0.05$). Faeces samples were not obtained from six cows in total, as they were empty at the time of collection.

Table 97 Mean daily intake of silage dry matter (kg)

	Concentrate feed DM(kg) allocated in parlour			
	Group H		Group L	
	7.8	4.7	4.7	1.5
n	14	10	8	16
Mean	10.1[a]	7.6[b]	12.1[c]	7.5[d]
S.dev. ±	2.32	2.35	1.97	2.88
Range	5.8 - 13.2	4.8 - 12.5	7.9 - 14.7	1.5 - 14.2 (5.4)+
CV%	23.1	30.1	16.3	38.4 (31.8)+

+ Reduced range and CV% when one quite anomalous value of 1.5 kg silage DM/day is excluded.

Within each group mean values with different superscripts differ significantly (Group H, $P < 0.05$ and Group L, $P < 0.001$).

Discussion

The mean silage dry matter intakes for cows allocated 7.8 kg DM and 4.7 kg DM of concentrate feed in the parlour, within Group H, were 10.1 ± 2.32 kg and 7.6 ± 2.35 kg respectively. The difference of 2.5 kg of silage dry matter was significant ($P < 0.05$). The mean total dry matter intakes for cows allocated 7.8 kg and 4.7 kg of concentrate dry matter in the parlour were therefore 21.1 kg (7.8 + 3.2 + 10.1) and 15.5 kg (4.7 + 3.2 + 7.6) respectively, assuming uniformity of intake of sugar beet pulp pellets. The attainment of a mean total dry matter intake of 21.1 kg/head is perhaps possible in the former subgroup (7.8 kg of concentrate feed in parlour) as the mean number of days into lactation were 108 ± 60 days and mean milk yield of 25.3 ± 3.58 litres, indicating that faeces were sampled from the animals at and around their peak dry matter intakes. The animals allocated 4.7 kg DM of concentrate feed in the parlour had a mean total dry matter intake of 15.5 kg/head which is perhaps a fairly low estimation as the mean number of days into lactation was 128 ± 60 days and the mean milk yield was 21.7 ± 3.47 litres for this subgroup, which are not greatly

different to the corresponding mean values for animals allocated 7.8 kg DM of concentrate feed in the parlour. Indeed, the similarity of positions on the lactation curve for the two subgroups does not warrant the significant difference of 2.5 kg DM silage intake.

Within Group H the mean silage dry matter intake for the heifers and cows were calculated separately and, although the cows consumed an average of 0.4 kg DM more than the heifers, the difference was not significant. Indeed, two of the heifers (allocated 4.7 kg DM of concentrate feed in the parlour) were not producing milk and were only present to become accustomed to the herd; their silage intakes were 5.8 and 12.5 kg DM. Although these values are rather different and the low value of 5.8 kg DM is below the mean heifer intake (8.7 kg DM) in Group H, it is nevertheless within one standard deviation (3.43 kg) of the mean. The easy-feed ad libitum access to silage at Laigh Woodston perhaps allows uniformity of silage intake between the heifers and cows.

Within Group L (sub-divided in terms of concentrate feed allocation in the parlour of 4.7 kg and 1.5 kg DM) there was a significant ($P < 0.001$) difference in silage dry matter intake of 4.6 kg between the subgroups which resulted in total mean apparent dry matter intakes of 18.0 kg and 10.2 kg respectively. In view of the fairly similar stages of lactation and milk yield within Group L (237 $\pm$ 60 days and 12.3 $\pm$ 2.06 litres and 250 $\pm$ 34 days and 10.9 $\pm$ 2.43 litres for those allocated 4.7 kg and 1.5 kg DM concentrate feed in the parlour), the mean silage intake of the latter subgroup may have been expected to be greater than 7.5 kg DM. The disparity in number of animals in this comparison ($n = 8$ and $n = 16$ respectively) may have exacerbated a bias, if those animals on 4.7 kg concentrate feed in the parlour did not produce a truly representative mean silage intake. Indeed, there was only one heifer in this subgroup compared with seven heifers in the subgroup where 1.5 kg DM of concentrate feed was allocated in the parlour. Furthermore, the mean silage dry matter intake of all the heifers in Group L was 2.1 kg less than that of all the cows. However, this difference was not significant which may indicate again that under ad libitum easy-feed silage access there is a better chance of uniformity of intake of the silage.

There were two subgroups within both Group H and Group L which were allocated 4.7 kg DM/head of concentrate feed in the parlour. The animals from this subgroup in Group L consumed 4.5 kg DM silage more

than the animals in the similar subgroup in Group H, albeit different quality silage (first cut silage allocated to Group H and second cut silage allocated to Group L) in terms of digestibility. The difference in silage intakes indicates total dry matter intakes of 15.5 kg and 18.0 kg for Group H and Group L respectively, where 4.7 kg DM concentrate feed had been allocated in the parlour, which is anomalous in terms of milk yield and stage of lactation differences. The digestibility coefficients for the first and second cut silage dry matter were perhaps different to the assumed values of 0.6 and 0.55 respectively used in the calculations.

Experiment 6.4.1 Assessment of individual silage intake under self-feed access in the Dykescroft dairy herd

Introduction

In the present experiment which was carried out in January, 1985, the individual silage intake of the cows and first calving-heifers in the Dykescroft dairy herd was determined when the animals had self-feed access to silage. To determine if the silage intake of the individual cows remained in the same order from year to year, the ranking order of the silage intake of the cows only, in the present experiment was compared with their equivalent ranking orders, under self-feed access to silage, in the previous winter (Experiment 6.2). In the latter experiment, the individual silage intakes of the cows had been determined at the same time of year and at a comparable stage of lactation. In effect there were 53 cow/cow comparisons in the ranking order of silage intake from year to year.

Materials and Methods

The Dykescroft herd of 80 British Friesian cows and heifers and the winter housing arrangements thereof have been described previously in Experiment 6.2. In the present study the animals were allowed access to self-feed silage from two comparable pits, allowing 0.6 metres/head, between 08.00 and 16.00 h.

The concentrate part of the diet was based on mixtures of barley and linseed cake for animals in early and mid-lactation (Groups 1 and 2 respectively), and barley only to animals in late lactation (Group 3) (Table 98). The concentrate ration was offered to the animals in their individual troughs once a day immediately before afternoon milking. All the animals, irrespective of concentrate feed allocation, consumed silage together between the morning and evening milkings but not during the night.

For seven days during January, 0.72 kg fresh matter of a proprietary 18% crude protein compound cake (Compound C) was additionally offered, with the concentrate ration once a day to each animal in Groups 1, 2 and 3. Chromic oxide had been incorporated into Compound C (Table 98).

Table 98 Composition and proximate analyses of feeds

Group	Concentrate ration kg fresh matter	Constituents of concentrate ration		Proprietary Compound C kg fresh matter	Silage
		Linseed Cake	Barley		
1	6.92	1.60	4.60	0.72	-
2	6.52	1.20	4.60	0.72	-
3	3.52	-	2.80	0.72	-
Dry matter g/kg		903	841	889	210
Composition g/kg DM					
Crude Protein		383	118	197	160
Crude Fibre		96	60	75	380
Ether Extract		67	17	38	35
Soluble carbohydrate		396	779	601	345
Ash		58	26	89	80
Chromium		-	-	1.859	-

On day seven faecal grab samples were taken from each animal at 16.00 h. The faeces samples were dried, milled and analysed for chromium. Faecal chromium concentrations were used to calculate the individual silage dry matter intakes of the animals. In the calculations assumed dry matter digestibility coefficients of 0.85 and 0.65 were used for the concentrate ration and silage respectively. The dry matter digestibility coefficient of Compound C was taken as 0.76 from digestibility studies using wether sheep (Appendix 2).

A rank order correlation coefficient was computed between the ranking order of individual silage intakes of the cows in the present experiment and their equivalent ranking orders from Experiment 6.2, where individual silage intake had been determined in the previous winter. In effect there were 53 cow/cow comparisons between years.

Results

When the animals were let out of the byres at 08.00 h, they immediately went forward to the silage pits and remained in the vicinity of the feeding areas until 16.00h. Individual animal behaviour was difficult to observe. However, most of the animals were seen to be at the silage faces several times during the eight hour access period. There was no obvious bullying.

Silage dry matter intake data is presented in Table 99. The mean dry matter intake for the cows was 2.5 kg DM ($P < 0.01$) and 0.4 kg DM ($P > 0.05$) more than that of the heifers in Group 1 and Group 2 respectively. There were only relatively few heifers in each group (n = 6, Group 1; n = 4, Group 2) which may not be a representative enough sample to give accurate mean intake data. Consideration of the data of all the animals indicated that the mean silage dry matter intake of the cows from Groups 1, 2 and 3 was 1.9 kg more than that of the heifers. The difference was statistically significant ($P < 0.01$). The difference in mean intake of silage dry matter of 1.6 kg for all the animals in Groups 1 and 2 (n = 51 and 17 respectively) was statistically significant ($P < 0.01$).

Table 99 Mean silage dry matter intake (kg)

	Group 1			Group 2			Group3+	ALL	
	All	Cows	Heifers	All	Cows	Heifers	All	COWS	HEIFERS
n	51	42	9	17	13	4	8	63	13
Mean	8.3	8.7	6.2	6.7	6.8	6.4	7.8	8.2	6.3
S.dev.±	2.19	1.99	2.00	1.45	1.45	1.64	1.96	2.02	1.83
Range	2.5-13.1	5.6-13.1	2.5-8.8	4.6-9.2	4.9-9.4	4.6-8.5	4.2-10.9	4.2-13.1	2.5-8.8
CV%	26.4	22.9	32.3	21.6	21.3	25.5	25.3	24.6	29.1

Difference in mean intakes(kg) between cows and heifers within groups:

2.5** 0.4NS - 1.9**

** $P < 0.01$ N.S. = difference not statistically significant

+ Heifers not present in Group 3

The coefficients of variation for silage dry matter intake were consistently greater for heifers (32.3% and 25.5%) than for cows (22.9% and 21.3%) in Group 1 and Group 2 respectively, although again the disparity in the number of heifers and cows may not represent this with full accuracy.

The rank order correlation coefficients, computed between the rankings of silage intake of cows from the present experiment and their corresponding rank order of silage intake in Experiment 6.2 ($n = 53$), was 0.212 which was just not significant at $P = 0.05$.

Discussion

The significantly larger dry matter intake of silage by the cows compared with the heifers in Group 1 (8.7 kg DM and 6.2 kg DM for the cows and heifers respectively $P < 0.01$) may reflect a liveweight difference between the cows and heifers. In effect, the mean overall dry matter intakes (concentrates and silage) of the cows and heifers in Group 1 were 14.7 kg and 12.2 kg, which are both well within comparable dry matter intake limits for dairy cows in early lactation, whereby equation 22 (MAFF, 1984), for example, defines the overall dry matter intake of a dairy cow of 600 kg and producing 25 litres of milk at 17.5 kg DM in total. The restricted time of access which the animals had to the silage (between 08.00 and 16.00h) has probably influenced the relatively low overall dry matter intakes obtained.

The silage dry matter intakes of the cows and heifers from Group 2 were similar (6.8 kg DM and 6.4 kg DM respectively) and the overall mean for the group (6.7 kg DM) was significantly lower by 1.6 kg DM than the corresponding overall mean intake of Group 1 (8.3 kg DM) $P < 0.001$, which may be surprising in view of the likely appetite restrictions of the animals in Group 1, which tended to be in early lactation compared with those in Group 2. Nevertheless, the restricted time of access to the silage pits was probably masking any possible appetite restriction in Group 1. Indeed, the total mean dry matter intakes of the cows and heifers in Group 2 were only 12.4 kg DM and 12.0 kg DM respectively, which may be much lower than expected.

The ranking order of silage intake of the cows in the present experiment and their corresponding ranking orders from Experiment 6.2, which was conducted at the same time of year and stage of lactation one year previously, were indicated to be similar (rank order correlation coefficient 0.212) but the rank order correlation coefficient was not

statistically significant (at 51 df statistically significant rank order correlation coefficient indicated by 0.273 at $P < 0.05$). Nevertheless, there is a suggestion that the cows maintained a similar ranking order pattern. However, the dynamic nature of the herd structure (related to mean number of lactations of the cows which alters from year to year) from year to year has probably prohibited the establishment of a rigid ranking order relationship in silage intake.

Experiment 6.4.2 Assessment of individual silage intake under self-feed access in the Dykescroft herd

Introduction

In the present experiment the individual intake of silage by cows in the Dykescroft herd was determined under self-feed restricted access (8 hours/day access time). The herd was divided into three groups in relation to milk yield and allocated concentrate feed accordingly. All the cows, irrespective of concentrate feed allocation, consumed silage together. The opportunity was taken to assess silage intake in relation to body condition score within each group. Comparisons were also made of silage intake between cows and first-calving heifers within each group.

Materials and Methods

The Dykescroft herd of 80 British Friesian cows (mean lactation yield of 4000 litres) was housed overnight in two byres throughout the year. During the winter the animals had access to self-feed precision chopped silage from three pits (24 metres per pit allowing 0.9 metres per head) between 08.00 h and 16.00 h. Access to the silage face was controlled with an electric wire. At 16.00 h they were tied up in the byres for milking and remained in their respective stalls until after morning milking when they were untied at 08.00 h to allow access to the silage pits. All the cows, irrespective of concentrate feed allocation, consumed silage together.

The concentrate part of the diet consisted of three different mixtures of soya bean meal, barley and bread (mix A) allocated to Groups 1, 2 and 3 on a fairly arbitrary basis, but approximately related to the stage of lactation or milk yield (Table 100) (Group 1, 34 cows were in early lactation (mean 91 days); Group 2, 34 cows were in mid-lactation (mean, 135 days) and Group 3, six cows were in later lactation). Mix A was offered to the animals in their individual troughs, once a day immediately before the afternoon milking.

The body condition score of the cows was assessed (Lowman, et.al. 1973). All were within the range 2.0-4.0 with about half below score 3.0 and half with score equal to or greater than 3.0.

For eight days, during February, 0.5 kg fresh matter of a pelleted fishmeal, barley and chromic oxide compound (compound B, Table 100) was additionally offered, once a day with mix A, to each animal in Groups 1

and 2. The animals from Group 3 were omitted as they were only six in number.

On days seven and eight faecal grab samples were taken from each animal in Groups 1 and 2 at 16.00 h. The faecal samples were amalgamated for each animal, dried, milled and analysed for chromium.

The faecal chromium concentrations were used to calculate the intake of silage dry matter by each animal. In order to calculate this it was assumed that the dry matter digestibility coefficients for mix A and compound B were 0.85 (by reference to MAFF, 1984). The digestibility coefficients for silage was taken as 0.65.

Table 100 Composition and proximate analyses of feeds

	Constituents of mix A				Compound B 0.5 kg		Silage
Group	Mix A kg FM	Soya bean meal	Barley	Bread+	Fishmeal	Barley	
1	8.7	0.9	5.2	2.6	0.30	0.20	-
2	6.4	0.5	3.9	2.0	0.30	0.20	-
3	4.5	0	3.0	1.5	-	-	-
Dry matter g/kg		865	798	662	879		270
Composition g/kg DM							
Crude protein		435	103	149	410		99
Crude fibre		13	53	5	30		339
Ether extract		14	17	18	39		20
Sol carbohydrate		473	804	794	395		463
Ash		65	23	34	126		79
Chromium		-	-	-	11.38		-

+ Purchased as broken pieces < 2.5 cm square and treated with propionic acid. It mixed readily with the other ingredients.

Results

When the animals were offered their daily allocations of concentrates in the byres, they were keen to consume their respective allocations although some animals took up to an hour to consume their individual rations. When the animals were let out of the byres at 08.00 h they immediately went forward to the silage pits and remained in the vicinity of the feeding areas until 16.00 h. It was difficult to observe the behaviour of individual animals between 08.00h and 16.00h, however most were observed at the silage faces several times during the eight hour access period. There was no obvious bullying.

The mean intakes of silage dry matter and the coefficients of variation for Groups 1 and 2 were fairly similar and are presented in Table 101. The mean dry matter intakes for cows and heifers considered separately within each group indicate that the cows in Group 1 consumed 1.0 kg more silage dry matter than the heifers in Group 1. Conversely the cows in Group 2 consumed 0.8 kg silage dry matter less than the heifers. Neither of these differences was statistically significant.

Within the groups, the distribution of silage DM intake around the mean for Group 1 heifers (25.9%) was less than for the cows (31.9%). In Group 2 the corresponding coefficients of variation were 34.8% for heifers and 21.4% for cows.

Silage dry matter intake was considered in terms of body condition score, with the mean intake for animals of body condition score of 3 and over (inclusive) and less than three, treated as two distinct subgroups within each group (Table 102). For Group 1 the intake of silage for each subgroup was very similar. In Group 2 however, the mean dry matter intake for animals of condition score greater than or equal to 3 was 1.3 kg less than those animals of condition score less than 3, where 11 of the 21 animals were heifers. This difference was however not significant ($P>0.05$). The overall mean intake of silage dry matter for animals of body condition score less than 3, from Group 1 and Group 2, was 0.6 kg greater than that of animals of body condition score greater than 3, from Group 1 and Group 2. This difference was however, not significant ($P>0.05$).

Table 101 Mean daily silage dry matter intake (kg)

	Group 1 91 ± 44 days in lactation			Group 2 136 ± 65 days in lactation		
	All	Cows	Heifers	All	Cows	Heifers
n	34	27	7	34	20	14
Mean	8.9	9.1	8.1	8.7	8.4	9.2
S.dev ±	2.80	2.90	2.09	2.49	1.79	3.20
Range	3.8*-18.7	3.8*-18.7	5.3-11.9	4.6-16.9	4.6-11.8	5.7-16.9
CV %	31.5	31.9	25.9	28.7	21.4	34.8

* Cow which had calved only 6 days before faecal sampling.

Table 102 Mean silage dry matter intake (kg) according to condition score subgrouping.

	Group 1		Group 2	
Condition score	>3	≤3	>3	≤3
n	18	16	13	21
Mean	9.0	8.9	7.9	9.2
S.dev ±	1.8	3.6	1.44	2.85
Range	5.3-12.4	3.8-18.7	5.7-10.3	4.6-16.9
CV %	20.0	40.4	18.2	30.9

Discussion

The mean silage dry matter intake for Groups 1 and 2 (8.9 and 8.7 respectively) were fairly similar, even although the animals in Group 2 had reached their maximum dry matter intake phase at four to five months of lactation. However under the restricted access here it is unlikely that they would be able to express maximum intake. It is arguable that such a relatively large mean intake of silage dry matter, after only eight hours of access under self-feeding conditions, is possible. The assumption of a 0.65 digestibility coefficient for the silage may be too generous. A digestibility coefficient of 0.6 for silage reduces the mean intake for each group by 12% (mean silage dry matter intakes of 7.8 and 7.7 kg for Groups 1 and 2 respectively). Nevertheless using the former silage dry matter intake figures produces a mean total dry matter intake (including the concentrate) for the animals in Group 1 and Group 2 of 15.6 kg and 13.6 kg respectively. These figures are fairly reasonable for the performance achieved. Therefore it may be valid to accept the original intake figures.

The heifers in Group 1 consumed, on average, 1.0 kg of silage dry matter less than the cows in Group 1. This difference in intake was not significant. The imbalance in numbers in this comparison (7 heifers and 27 cows) perhaps questions its validity. For the same reason, comparing the coefficients of variation of 25.9% for heifers and 31.9% for cows in Group 1 is possibly erroneous. One cow in Group 1 apparantly consumed 3.8 kg silage dry matter (43% of the group mean) due to inappetance following parturition, as she had only calved six days before faeces had been sampled.

In Group 2 the heifers consumed 0.8 kg silage dry matter more than the cows. The range of intake and variation of intake was also greater (CV 34.8%) for heifers than for the cows (CV 21.4%). Since the animals in Group 2 were approaching or were presumed to be at their maximum dry matter intake (mean days of lactation for Group 2 was 136 + 65 days) and have passed their peak yields, energy can be diverted to liveweight gain and growth of the foetus (plus growth of the heifers). The extra energy required by heifers in later lactation for replenishment of energy stores and the completion of their own growth has probably contributed to the larger intake of silage and the larger coefficent of variation of intake for heifers than cows in Group 2, even although the difference of 0.8 kg dry matter between the heifers and cows was not significant ($P>0.05$).

The thinner animals of Group 1 (early lactation, condition score less than 3) consumed a similar mean quantity of silage dry matter as animals of condition score greater than, or equal to 3. Dry matter intake restrictions inherently present in the animals in the initial stages of lactation are likely to contribute to this similarity. The range of intake for the thinner animals in Group 1 is fairly extensive and suggests that this subgroup includes animals with high milk yields and animals which have just calved. In Group 2 (later lactation) the thinner animals (condition score less than 3) consumed 1.3 kg silage dry matter more than those in better body condition (condition score greater than 3) in this group but the difference was not significant. The thinner animals are replenishing reserves of energy in later lactation and thence their consumption of silage is correspondingly larger. Indeed 11 of the 21 animals of condition <3 in Group 2 were heifers, of which there were only 14 in total in Group 2. This confirms the suggestion that the heifers are expressing their energy requirements, in late lactation, within the given constraints of somewhat restricted silage feeding conditions. Examination of the silage dry matter intake for all animals of body condition score less than three (from Groups 1 and 2) indicates that the mean silage intake is 0.6 kg greater than that of animals of body condition score greater than or equal to 3 (from Groups 1 and 2). Although the difference is not significant, it suggests that those animals of poorer body condition score are either storing energy in later lactation, or are mobilising energy stores and still consuming larger quantities of silage in an attempt to achieve their innate milk production potential.

SECTION 7 ASSESSMENT OF THE INDIVIDUAL INTAKE OF GROUP FED OUT-OF-PARLOUR COMPOUND FEED BY DAIRY COWS

In high yielding dairy herds there is frequently insufficient time available in the milking parlour for the cows to completely consume their individual allocations of concentrates (Clough, 1972). Parlour fed concentrates are usually dry pelleted compound feeds which require 2.18 - 3.10 minutes/kg FM for consumption (Broster, 1975). Indeed, Leaver (1983) suggested that the maximum quantity of compound feed which can be consistently consumed is approximately 4 kg FM per milking.

In recent years there has been a trend towards feeding between milking sessions, sometimes on a frequent basis (Owen, 1979). In these circumstances feeding outside the milking parlour is usually at a flat rate where the herd may be divided into yield groups. The mean group yield is used to calculate the flat rate allowances to be fed. The compound feed is usually offered either along a feeding passage, or in troughs either once or several times during the day. Hand feeding of a flat rate of compound feed in this way presents the cheapest option for out-of-parlour feeding for many farmers (Leaver, 1983), in contrast to electronic concentrate dispensers for example.

The uniformity of intake of the flat rate allowances of the compound feed between the cows is particularly relevant in terms of efficient utilisation of an expensive resource. In Experiments 7.1, 7.2 and 7.3 the individual intakes of a pelleted compound feed were determined in three dairy herds. The compound feed was offered at various flat rate allocations once per day. The intakes of silage by the cows in all three herds had been previously determined in Experiments 6.2, 6.3.1 and 6.3.2 respectively.

In Experiment 7.4 the variation in individual intake of a novel sugar beet pulp based loose mix out-of-parlour feed was compared with that of a conventional pelleted compound feed in the Cochno dairy herd. The possible influences on milk yield and/or milk composition were also assessed in this investigation.

Experiment 7.1 Assessment of the individual intake of group fed compound feed by the Dykescroft dairy herd

Introduction

In the present experiment the individual intakes of a pelleted compound feed, allocated at 3.1 kg FM/head, were determined in 40 of the cows from the Dykescroft herd. The cows had access to self-feed silage on a restricted basis (eight hours access during the 24 hour period). The individual intakes of the compound feed were calculated using the assumption that the individual silage intake data previously determined in Experiment 6.2 (conducted one month before the present experiment) were representative of the current individual silage intakes in the present experiment.

Materials and Methods

Forty lactating animals from the Dykescroft herd of British Friesian cows and heifers (previously described in Experiments 6.2, 6.4.1 and 6.4.2) were offered 3.1 kg fresh matter (2.7 kg DM) per head per day of a proprietary 18% protein pelleted compound concentrate at 08.45 h. The concentrate was placed on the ground, behind a barrier, directly in front of the 24 metre silage face of one pit, allowing 0.6 metres per animal. Chromic oxide had been incorporated into the pelleted concentrate (composition g/kg DM 863, CP 200, CF 80, EE 49, Ash 101, CHO 570, Cr 1.384). The animals had access to self-feed silage from 08.00 to 16.00 h, and were individually allocated in the byre, either 9.1 kg or 6.8 kg fresh matter of a loose concentrate mix, composed of linseed cake, barley and bread (Experiment 6.2, Table 90) depending on the stage of lactation and milk yield (Groups 1 and 2 respectively).

On the eighth day after the first allocation of the proprietary pelleted concentrate to the animals faecal grab samples were taken from each animal at 1600 h. The faeces samples were dried, milled and analysed for chromium.

The individual intakes of the group fed concentrate were calculated using the assumption that individual silage dry matter intake data of the 40 animals corresponded with the individual intakes calculated under self-feed access in Experiment 6.2. The digestibility coefficients used in the calculations were 0.85 for the loose mix, 0.79 for the concentrate (determined using wether sheep in a digestibility

study Appendix 2) and 0.65 for the silage (estimated).

Results

The animals were very keen to eat their allocation of group fed concentrate and it was usually completely consumed within 15 minutes. The mean group intakes are shown in Table 103. The difference of 0.3 kg DM between Groups 1 and 2 was not statistically significant. The coefficients of variation and ranges of intake were fairly large for both groups.

Table 103 Mean daily dry matter intake (kg) of group fed proprietary concentrates.

	Group 1	Group 2	Overall
n	17	15	32
Mean	2.7	2.5	2.6
S. dev ±	1.12	0.83	0.99
Range	1.1 - 6.2	1.1 - 4.4	1.1 - 6.2
CV %	41.5	33.2	38.1

There were only two heifers in the experiment and their dry matter intakes were 2.6 kg and 1.9 kg (Group 1 and Group 2 respectively).

The total number of animals used for the calculations was 32 from the original 40. The eight faecal chromium concentrations were omitted from the calculations due to absence of the corresponding silage intake data from Experiment 6.2.

Discussion

The interpretation of the results of this experiment relies upon the premise that individual intake of silage dry matter was truly represented by data obtained one month prior to the present experiment. Differences in the silage intake data between sampling periods may have been caused by differences in the weather, current oestrus or lameness for example. The acceptability of the individual concentrate intake data may therefore be questioned.

The overall range of intake (n = 32) was between 1.1 and 6.2 kg dry matter which, in terms of ME intake (10.3 MJ ME/kg concentrate dry matter) is 11.3 to 63.9 MJ ME for Group 1 and 11.3 to 45.3 MJ ME for Group 2. This, in turn, is equivalent to a range of 2-13 litres of milk for Group 1 and 2 to 9 litres for Group 2. Indiscrimimate allocation of expensive proprietary concentrate can therefore be seen to perhaps lead to an inefficient use of resources in terms of feed efficiency.

The two heifers in the study consumed 93% and 78% of their respective group's (Groups 1 and 2 respectively) mean intake of concentrate, both of which are well within one standard deviation of the mean intake. The fairly adequate space allowance of 0.6 metres/head is likely to have contributed to this equality in intake between heifers and cows. A tighter space allowance may have produced a more disparate effect in terms of concentrate intake for the heifers and for the group as a whole, in terms of increasing the range of concentrate dry matter intake.

Experiment 7.2 Assessment of the individual intakes of group fed out-of-parlour compound feed by the Cochno dairy herd

Introduction

In the present experiment the individual intakes of group fed pelleted compound feed (which was the same as that allocated in Experiment 7.1) were determined in the Cochno dairy herd which was divided into two groups according to milk yield (Group 1 and Group 2). The out-of-parlour compound feed was allocated at a rate of 4 kg FM/head/day to Group 1 and 1 kg FM/head/day to Group 2. The individual intakes of the out-of-parlour feed were calculated using the assumption that the individual silage intake data previously determined in Experiment 6.3.1 (conducted one month before the present experiment) were representative of the current individual silage intakes of the present experiment. The total daily compound feed intake (from in-parlour and out-of-parlour compound feed), assuming that the out-of-parlour compound feed allocations were to be uniformly consumed by the cows, were similar for Experiment 6.3.1 and the present experiment.

Materials and Methods

Seventy-four lactating cows were divided into two groups (1 and 2) each of 37 cows. Group 1 consisted of 24 cows and 13 heifers and the mean milk yield was 22.3 kg. Group 2 consisted of 30 cows and 7 heifers and the mean milk yield was 13.8 kg. Each was group fed silage behind a barrier allowing 0.76 metres/head.

Silage was offered to each group on a restricted easy-feed basis at 09.00 h and 16.00 h such as to allow a total of 40 kg fresh matter/head/day. Additionally an allowance of 2.3 kg fresh matter/head of molassed beet pulp nuts were spread on the silage behind the barriers at 09.30 h.

Chromic oxide was incorporated into a proprietary cubed compound feed (B), at a rate of 5 g/kg of fresh matter, which was offered to the animals behind the feed barrier (0.76 metres/head) when all the morning silage allocation had been consumed (usually at 12.00 h). The cows in Group 1 were given 4.0 kg fresh matter/head/day and the cows in Group 2 were given 1.0 kg fresh matter/head/day of compound B. Additionally, further amounts of a second proprietary compound nuts (containing no chromium) were given at each of the two milkings/day in the milking

parlour. Within Group 1 either 8.0 or 2.0 kg of compound feed and within Group 2 either 5.0 or 1.0 kg of compound feed were given in the parlour. The total allocations of feed are summarised in Table 104. The composition of the compound feeds are presented in Table 105. The composition of the silage and sugar beet pulp nuts are given in Table 93, Experiment 6.3.1.

After eight days on this regimen faecal grab samples were obtained from the cows on two consecutive mornings. The two faeces grab samples from each cow were amalgamated, dried, milled and analysed for chromium. Thence, the faecal chromium concentration for each cow was used to estimate the individual intake of proprietary compound cake which had been offered behind the barrier. The individual silage intake data for each cow obtained from Experiment 6.3.1, which was carried out immediately before the present experiment, were used in these calculations.

Table 104 Allocation of supplementary feeds (kg fresh matter/head)

	Group 1 (22.3 kg milk)	Group 2 (12.8 kg milk)
Feeds given behind barrier		
Sugar beet pulp nuts	2.3	2.3
Compound nuts + Cr	4.0	1.0
Compound feed given in parlour		
	8.0 or 2.0	5.0 or 1.0
Total compound feed	12.0 or 6.0	6.0 or 2.0

Table 105 Proximate analysis of compound feeds (g/kg)

	Proprietary compound cake, fed in parlour	Chromium-containing compound cake, fed behind barrier
Dry matter	861	863
Composition of dry matter		
Crude protein	191	200
Crude fibre	83	80
Ether extract	51	49
Ash	92	101
Soluble carbohydrate	583	570
Chromium	-	1.384
ME (MJ/kg DM)	11.9	11.9

Results

When the compound cake was offered, behind the barriers, to the animals in Group 1, all the animals were keen to eat and stayed at the barrier until most of the allocation was consumed. On the first morning the animals took 40 minutes to completely clear their allocation; on the second and subsequent days the animals took 20-25 minutes to clear their allocation. First-calving heifers appeared to be equally keen as the cows to remain at the barrier until the cake was consumed. The animals in Group 2, offered 1 kg fresh matter/head, readily consumed their allocation within 10-15 minutes, with all the animals remaining at the barrier until the ration was cleared. The silage and sugar beet pulp pellets were consumed readily as in Experiment 6.3.1.

The mean individual intake data for the proprietary compound feed given behind the barrier are shown in Table 106.

Table 106 Mean daily intake of compound feed dry matter (kg) presented behind the barrier and the metabolisable energy (MJ) supplied+

	Group 1 (Allocated 3.45 kg DM/head)			Group 2 (Allocated 0.86 kg DM/head)		
	All	Cows	Heifers	All	Cows	Heifers
n	37	24	13	37	30	7
Mean	2.87	3.14a	2.37b	0.97	0.99c	0.85c
S.dev.±	0.90	0.89	0.69	0.30	0.29	0.31
Range	0.94-4.93	2.14-4.93	0.94-3.56	0.42-1.53	0.42-1.53	0.42-1.22
CV %	31.2	28.3	29.4	30.8	29.6	36.1
ME MJ* supplied	41.1	45.0	33.8	10.2	10.5	9.0

Within each group mean values with different letters differ significantly ($P<0.05$).

* Metabolisable energy supplied data adjusted to allocated mean DM
i.e., Group 1, (calculated DM intake) x 1.2 x 11.9 MJ
Group 2, (calculated DM intake) x 0.89 x 11.9 MJ

The apparent mean dry matter intake for Group 1 (2.87 kg) was 83% of the 3.45 kg dry matter offered per cow. In Group 1, the dry matter intake of the heifers was 0.77 kg less than that of the cows. The difference was statistically significant ($P< 0.05$). The mean dry matter intake for Group 2 (0.97 kg) was 12% above the allocated mean of 0.86 kg dry matter/head. The difference in dry matter intake of 0.14 kg between heifers and cows of Group 2 was not significant. The mean intakes of group fed compound feed dry matter for all the cows ($n = 53$) from Groups 1 and 2 versus all the heifers ($n = 21$) from Groups 1 and 2 were 1.9 ± 1.25 kg and 1.8 ± 0.93 kg. The difference was not significant ($P> 0.05$).

Within Group 1 the mean dry matter intakes of group fed compound feed for animals on total compound feed allocations of 12 kg and 6 kg fresh matter/day ($n = 30$ and $n = 70$), were 3.0 ± 0.81 kg and 2.2 ± 1.05 kg DM respectively. The difference of 0.8 kg DM was statistically significant ($P<0.05$). The coefficients of variation were 27.0% and 47.7% respectively. Within Group 2, the mean dry matter intakes of group fed compound feed for animals given total compound feed allocation of 6 kg and 2 kg fresh matter/day ($n = 24$ and $n = 13$) were 1.1 ± 0.29 kg and 0.8 ± 0.24 kg DM respectively. The difference of 0.3 kg DM was statistically significant ($P<0.05$). The coefficients of variation were 26.4% and 30.0% respectively.

Correlation and rank order correlations were computed for individual intake of group fed compound feed of Group 1 and Group 2 versus (A) current milk yield (SMMB milk recording service) and (B) stage of lactation (number of days in milk). The correlation coefficients are shown in Table 107. The correlation and rank order correlation coefficients for Group 1 intake of compound feed versus current milk yield were highly significant $P< 0.001$ (0.73 and 0.79 respectively). For Group 2 the rank order correlation for compound feed intake versus stage of lactation was -0.35 and significant $P<0.05$.

Table 107 Correlation (r) and rank order (ro) correlation coefficients for individual dry matter intake of barrier presented compound feed versus (A) current milk yield and (B) stage of lactation.

Individual intake of barrier presented compound feed.

	Group 1		Group 2	
	r	ro	r	ro
Current milk yield	0.73***	0.79***	0.16	0.20
Stage of lactation	0.24	0.30	-0.31	-0.35*

* $P < 0.05$ *** $P < 0.001$

Discussion

The under and over estimation of the mean dry matter intakes of group fed compound feed for Groups 1 (-17%) and 2 (+12%) respectively is likely to be due to experimental error as previously mentioned. The silage dry matter intake data, obtained from Experiment 6.3.1, used in the calculations may have been inappropriate, even although they had been determined only two weeks before the present experiment, in that it is assumed that the silage intake remains the same. This may not be correct, if, for example, a cow(s) was(were) in oestrus on or around the day of faecal sampling in the present experiment, and may not have eaten the previously determined quantity of silage. However the mean compound dry matter intake estimations are within 20% of the allocated quantity, which perhaps justifies the technique used in this, and similar, investigations.

The coefficient of variation of compound feed intake for Groups 1 and 2 were very similar (30%). A larger coefficient of variation of compound feed intake may have been expected in Group 2 than in Group 1 as the allocation rate of compound feed to the cows in Group 2 was 25% of that offered to the cows in Group 1. The relatively lower allocation rate (0.86 kg DM/head) may have been anticipated to result in a higher rate of consumption of the compound feed by the animals in Group 2 and consequently produced a large variation in individual

intake in the group. Indeed, the rate of consumption of the compound feed by the animals in Group 2 was lower than that in Group 1 (averages of approximately 14 and 6 minutes/kg DM respectively). This may reflect differences in physiological demands between the cows in each group. Nevertheless, the differences in consumption rate were not reflected in larger coefficients of variation in compound feed intake by Group 1. It is possible that the cows in Group 1 began to eat their allocation at a fast rate and then slowed down as salivary production became a limiting factor to ingestion. This may have contributed to the similarity in the coefficients of variation between the animals in each group.

The overall difference in intake of group fed compound feed dry matter for cows from Groups 1 and 2 versus heifers from Groups 1 and 2 was small (0.1) and not significant. However the difference in dry matter intake of 0.77 kg between the heifers and cows in Group 1 was significant ($P<0.05$). This is perhaps a biased comparison, in that there were 13 heifers compared with 24 cows, which may be further exacerbated by a possible appetite effect due to liveweight differences, and also five of the 13 heifers in Group 1, and none of the 24 cows had calved within the last 30 days. The adjusted difference between the heifers and cows in terms of metabolisable energy is 11.0 MJ (1.2 x 0.77 x 11.9 MJ ME/kg), which is approximately equivalent to 2.2 litres of milk.

The compound feed cake had been allocated to Group 1 at a rate of 3.45 kg DM/head which is equivalent to 8.2 litres of milk. The range of metabolisable energy (adjusted to allocated group fed quantity of compound feed) and hence milk produced by the animals in Group 1 indicated that between 6.1 and 14.1 litres and between 2.7 and 10.2 litres of milk were produced by the cows and heifers respectively, from the compound feed given outside in a group.

For Group 2, the group fed compound feed was allocated to supply 2.1 litres of milk per head. The adjusted ranges of 0.9-0.32 litres and 0.9-2.6 litres for the cows and heifers respectively. The allocation of compound feed in a group feeding situation to the cows in Group 2 is perhaps not as critical in that storage of metabolisable energy as liveweight gain is as likely to be taking place as declining production of milk in animals in later lactation. This is perhaps indicated further by considering the correlation coefficients for milk yield and individual intake of group fed compound feed. The

correlation coefficients were low and non-significant which may indicate that energy is being stored as fat. This is further substantiated in view of the subdivision in Group 2 in terms of total compound allocation, where the intake of group fed compound feed was significantly greater by 0.3 kg DM ($P<0.05$) for those animals allocated 6 kg fresh matter of compound feed (parlour and group fed) than for those animals allocated 2 kg fresh matter compound feed in total. Therefore significant correlation coefficients may have been expected for intake of group fed compound feed versus current milk yield, due to existing difference in parlour fed compound feed allocation (related to milk yield) within Group 2. Nevertheless, the relatively small quantity of feed allocated (0.86 kg DM/head) may have prohibited the manifestation of these relationships. The influence of the established individually allocated range of compound feed intake within Group 2, on the significant difference of individual intake of group fed compound feed is perhaps indicated, however, by the existence of a significant negative rank order correlation (-0.35, $P<0.05$) for group fed compound feed versus stage of lactation.

Within Group 1, there were statistically significant correlation and rank order correlation coefficients (0.73, $P<0.001$ and 0.79, $P<0.001$ respectively) for mean intake of group fed compound feed versus current milk yield. Their statistical significance reflects the established range of intake from the allocation of compound feed (parlour and group fed) to the group, where indeed there is a significant difference of 0.8 kg DM ($P<0.05$) of group fed compound feed between those animals allocated 12 kg fresh matter and 6 kg fresh matter of compound feed in total. The correlation and rank order correlation coefficients for individual intake of group fed compound feed versus stage of lactation, although positive, are not statistically significant. Appetite effects, due to stage of lactation are likely to confound these relationships.

Conclusions

The animals in Group 1 had been allocated 3.45 kg dry matter per head on a group feeding basis. Assuming similar efficiencies of use of metabolisable energy for lactation between the animals, 29-143% of the desired quantity (8.2 litres) of milk is being produced from the compound feed within the group. In order to achieve the desired quantity of milk from each animal, it may be more pertinent to

individually feed the concentrate in the parlour. However, improvements in rumen function and digestion which arise by distribution of the feed allocation throughout the day, and consequent improved feed efficiency will be lost in this way.

The animals in later lactation (Group 2) which were allocated 0.86 kg dry matter/head are not likely to suffer, in terms of milk yield, by group feeding of part or the whole of their concentrate allocation.

Experiment 7.3 Assessment of the individual intakes of group fed out-of-parlour compound feed by the Laigh Woodston dairy herd

Introduction

In the present experiment the individual intake of group fed pelleted compound feed (which was the same as that allocated in both Experiments 7.1 and 7.2) was determined in the Laigh Woodston dairy herd which was divided into two groups according to milk yield (Group H and Group L). The out of parlour compound feed was allocated at 2.8 kg FM/head/day and 1 kg FM/head/day to Group H and Group L respectively. The individual intakes of out-of-parlour feed were calculated with the assumption that the individual silage intake data previously determined in Experiment 6.3.2 (conducted one month before the present experiment), were representative of the individual silage intakes in the present experiment, where silage was again allocated on an easy-feed ad libitum basis. However, the individual silage intakes may not in effect have been similar between experiments as the out of parlour compound feed was offered in addition to the in parlour compound feed intakes, which had not been reduced. Therefore the total compound feed intake (from in parlour and out-of-parlour compound feed) was not the same for Experiment 6.3.2 and the present experiment, and this may have altered the pattern of individual silage intake in the herd.

Materials and Methods

The Laigh Woodston herd and their winter housing arrangements have been previously described in Experiment 6.3.2. The present experiment was carried out four weeks after Experiment 6.3.2 using 52 lactating animals from the herd, which had been divided into a high yielding group (H) (n = 27) and a low yielding group (L) (n = 25). Ad libitum easy-feed silage (first cut to Group H and second cut to Group L) and sugar beet pulp pellets (3.6 kg and 1.4 kg fresh matter per head to Groups H and L respectively) were offered to the animals along each side of the central feeding passage, as in Experiment 6.3.2.

The remaining individual ME requirements were provided by parlour-fed pelleted concentrates (range of 1 to 9 kg fresh matter per head per day). Additionally, a midday meal was introduced to supplement the present individual ME allocations (unlike Experiment 7.2

where the parlour fed concentrates to each individual were reduced by a fixed amount which corresponded to the quantity of concentrate allocated per head along the feed passage). The animals in Group H were offered 2.8 kg fresh matter/head/day and those in Group L were offered 1.0 kg fresh matter/head/day of a proprietary dairy concentrate (B) along each side of the feed passage at 12.00 hrs, allowing 0.75 metres/head and 0.8 metres/head for individuals in Groups H and L respectively. Chromic oxide had been incorporated into concentrate B. The proximate analyses of the silages are presented in Table 96 (Experiment 6.3.2). The proximate analysis of Compound B is presented in Table 105, Experiment 7.2.

Concentrate B was offered to the animals for seven days and on day 7 faecal grab samples were taken once from each animal. The faecal grab samples were dried, milled and analysed for chromium. The faecal chromium concentrations were thence used to estimate the individual dry matter intakes of concentrate B. The dry matter digestibility coefficients, used in the calculations, for the parlour fed concentrate (0.77) and concentrate B (0.79) were determined from digestibility studies using wether sheep (Appendix 2). The assumed digestibility coefficients for the silage (first and second cut) and sugar beet pulp pellets were 0.60, 0.55 and 0.80 respectively and equivalent to those used in Experiment 6.3.2 (Table 96).

Results

The animals in both groups were keen to consume concentrate B. The animals in Group L usually cleared their allocation within five minutes and the animals in Group H usually cleared their allocation within ten minutes. Most of the animals persisted at the barriers until the concentrate had been consumed, with the intermittent changes of position.

Table 108 shows the mean dry matter intake of concentrate B for each group. It was possible to obtain faecal samples from only 12 cows and 4 heifers in Group H and 4 cows and 6 heifers in Group L. It seemed reasonable to accept that the sample obtained were a random selection. The estimated mean dry matter intakes of concentrate B for Groups H and L were both greater than the allocated quantities of 2.37 and 0.85 kg DM/head/day by 107% and 164% respectively.

Table 108 Mean calculated daily intake of concentrate B DM (kg)

	Group H	Group L
Compound feed allocated kg DM	2.37	0.85
Dry matter intake (kg)		
n	16	10
Mean	2.54	1.39
S.dev ±	0.862	0.313
Range	0.93-4.34	1.00-1.82
CV%	33.9	22.4

Statistical comparison between heifers and cows, within groups, was not justified due to the small numbers of animals involved. However, individual comparisons indicate that, for example, three of the four heifers in Group H had mean dry matter intakes (of concentrate B) of between 35% and 84% of the overall mean intake for that group. In Group L two of the six heifers had mean dry matter intakes of 79% and 86% of the overall mean grop intake of compound B.

Discussion

In the present experiment concentrate B was introduced to the groups as a straight supplement, in that part of the parlour fed concentrate ration was not reduced following the introduction of concentrate B as a midday meal (unlike Experiment 7.2). Hence it is possible that part of the silage ration is being substituted by concentrate B. Therefore use of the silage dry matter data obtained from Experiment 6.3.2, where there was no midday meal, may lead to error in the calculations of individual intakes of concentrate B if a substitution effect is present. The calculated mean dry matter intakes of concentrate B for Group H (2.54 kg) and Group L (1.39 kg) did not correspond to the quantities allocated per head of 2.37 kg and 0.85 kg respectively, which was probably due to the random selection of animals used to calculate the mean concentrate intake from Group H (16 animals out of 27) and Group L (10 animals out of 25). Therefore, the animals which had been selected at random were not truly representative of the group.

The coefficient of variation for Group L (22.1%) was smaller than

for Group H (33.7%) which is perhaps contrary to that which might be expected in view of the more restricted allocation of concentrate B to Group L compared to Group H. Nevertheless, the range of possible individual dry matter intakes is likely to be greater in the early lactation animals of Group H than in the late lactation animals in Group L.

Although statistical treatment of the results in terms of heifers versus cows within each group is not feasible due to the small numbers involved, consideration of heifer and cow intakes in Group H suggests that heifers did not eat their complete individual allocation of concentrate B which is likely to be due to successful competition from the other animals. In Group L, however, only two of the six heifers in this group ate less than their allocation, although proportionately the deficit was not as large as in Group H (e.g. 79-86% of the mean in Group L compared with 35-84% of the mean in Group H).

The range of intake of concentrate B in Group H is likely to represent a fairly inefficient way of offering the animals an extra meal, albeit beneficial in terms of allocating the concentrate ration in three compared to two meals. The resulting range of ME intakes is 10-48 MJ (ME of concentrate B was 12 MJ/kg DM, Appendix 1) which represents a range of 2-10 litres of milk approximately. A more discriminative approach to feeding the extra midday meal may be more beneficial in encouraging the individual animals to attain their potential milk yields.

Experiment 7.4 Assessment of the individual intakes of a novel sugar beet pulp feed compared with a conventional pelleted compound feed by dairy cows and the possible influences on milk yield and composition

Introduction

The present experiment investigated the individual intakes of a novel sugar beet pulp feed, in a loose form, compared with a conventional pelleted compound feed, each of which was offered to two groups of dairy cows in a crossover design. It is possible that the physical form of the feeds on offer (loose mix v. pelleted form) may influence the variation in individual intake of the feeds, in each of the groups of cows, through effects on the rate of consumption. The acceptability of the novel sugar beet pulp feed may also determine the extent of the variation in individual intake by the cows.

The possible effects of the feeds on offer on milk yield and composition were also assessed.

Materials and Methods

Seventy-four lactating cows, of annual milk yield 6500L/animal and 118 $\pm$ 91 days into lactation, were ranked and paired on the basis of current milk yield (estimated from the two most recent SMMB recordings) and lactation number. One animal from each pair was placed into either Group 1 or Group 2 so that there were 37 animals (20 cows and 17 first-calving heifers) with a similar mean (and distribution of) milk yield of 19 litres and mean lactation number 3 in each group. The two groups were housed separately within the same cubicle building where there was separate access to a feeding passage for each group, which permitted a space allowance of 0.76 m/head.

The basal diet consisted of an allocation of 40 kg fresh matter silage/head/day offered in two approximately equal feeds, at 09.00h and 16.00h, on easy-feed access along the feeding passage. Additionally, 2.3 kg fresh matter molassed sugar beet pulp nuts/head/day was offered at 09.30h on top of the silage. The silage and sugar beet pulp components of the diet were designed to supply the maintenance metabolisable energy demand plus energy equivalent to five litres of milk for each animal.

Chromic oxide was incorporated into two compound feeds (A and B) at a rate of 5 kg/tonne fresh matter. Compound A was a loose meal

consisting of finely shredded sugar beet pulp, fishmeal and palm nut oil. Compound B was a mixture in equal proportions of two proprietary high protein pelleted dairy feeds (s) and (t). Compound A and Compound B were allocated at a rate of 3.1 kg and 3.0 kg fresh matter to Group 1 and/or Group 2 to supply equal amounts of dry matter. These were given when the silage allocation had been substantially consumed at 12.00h.

Additionally, further amounts of a third proprietary compound nut were given (range of 0-9 kg fresh matter/day) at each of the two milkings/day in the milking parlour, in accordance with the remaining individual metabolisable energy requirements of the animals. The proximate analyses of the feeds on offer are shown in Table 109.

Table 109 Proximate analyses of feeds allocated

	Compound A	Compound B Equal proportions of components (s) & (t)		Parlour fed proprietary compound nut	Molassed sugar beet pulp nuts	Silage
Dry matter g/kg	886	864	855	861	900	171
Composition of dry matter g/kg						
Crude protein	222	172	201	191	106	184
Crude fibre	123	83	75	83	144	311
Ether extract	74	60	57	51	6	34
Soluble carbohydrate	481	595	577	583	662	399
Ash	100	90	90	92	82	72
Chromium	2.187	1.880		-	-	-
ME (MJ/kgDM)	13.2+	11.5+	11.3+	11.9+	12.2++	10.0++
DCP (g kg/DM)	168	129	152	-	-	-
DM digestibility coefficient	0.82*	0.75*		0.77*	0.85**	0.62***

+ ME = determined DE x 0.832 ; ++ MAFF 1984 ; +++ Calculated

* Digestibility Trial (Appendix 2); ** MAFF 1984; *** In vitro

The experiment consisted of two periods (I and II) each of four weeks duration, in a crossover design whereby Group 1 was allocated Compound A and Group 2 was allocated Compound B in Period I. In Period II Group 1 was allocated Compound B and Group 2 was allocated Compound A.

At 11.00h on day 14 of both Period I and Period II, faecal grab samples were taken from each cow. The faeces samples were dried, milled and analysed for chromium. The faecal chromium concentrations were used to calculate the individual dry matter intakes of Compound A and Compound B, with the assumption that the current individual silage dry matter intake was similar to that calculated in Experiment 6.3.1 which had been conducted immediately prior to the current experiment. The molassed sugar beet pulp nuts were assumed to be eaten uniformly within each group and were of high digestibility and would contribute little to the total faeces DM output. The digestibility coefficients used in the calculations are shown in Table 109.

All the animals were milk recorded (p.m. and a.m.) on days 16, 20, 24 and 28 of each period. The milk samples taken from each animal were submitted to the SMMB analytical laboratory for estimation of butter fat and milk protein concentrations.

Results

On the first day of Period I when the animals in Group 1 were offered 3.1 kg fresh matter/head of Compound A (the loose mix), they were initially reluctant to consume their allocation. However, after two to three minutes hesitation, the animals began to consume their ration of Compound A which was subsequently cleared within approximately 25-30 minutes with most of the animals persisting at the barrier. During subsequent observation periods, this initial reluctance was not repeated. As soon as the allocation of Compound A had been spread out behind the barrier, the animals were keen to eat it and the ration was usually completely consumed within 20-25 minutes. On the first day of Period I the animals in Group 2 began to consume their allocation of Compound B (the pelleted feed) as soon as it was placed behind the barrier and this behaviour was repeated at subsequent observation periods. The allocation of 3.0 kg fresh matter/head of Compound B was usually completely consumed within 10-15 minutes. Most of the animals persevered at the barrier until the allocation had been cleared.

During Period II on the first day Compound A was offered to Group 2. The animals were reluctant to consume their allocation and behaved in a similar manner to the animals from Group 1 on the first day of Period I. After several minutes the animals in Group 2 appeared to accept Compound A and completely consumed their allocation within 25-30 minutes. There was no obvious bullying between the animals and most of the group remained at the barrier until the ration had been consumed. During the rest of Period II the animals from Group 2 began to consume Compound A as soon as it was placed behind the barrier. The allocation was usually consumed within 20-25 minutes. Compound B was accepted immediately by the animals in Group 1 on the first and subsequent days of Period II and the allocation was usually completely consumed within 10-15 minutes. The animals persisted at the barrier until the allocation was cleared.

The mean calculated daily dry matter intakes of Compound A and Compound B during Period 1 and and Period II are shown in Table 110. Faecal grab samples could only be obtained from 63 of the 74 animals in Period I and 50 of the 74 animals in Period II. The samples and consequent calculated dry matter intake data were considered to be representative of each group. The coefficients of variation of intake of the animals sampled were slightly larger for Compound A (the loose mix) (40.8% and 42.5% for Periods I and II respectively) than for Compound B (33.3% and 38.3% for Periods I and II respectively). When the animals were allocated Compound A they apparently consumed between 30% and 230% of the allocated mean. When Compound B was allocated the animals consumed between 30% and 167% of the allocated mean.

Table 110: Calculated mean daily dry matter intakes (kg) of Compound A and Compound B

	Period I						Period II					
	Compound A Group 1			Compound B Group 2			Compound A Group 2			Compound B Group 1		
	A	C	H	A	C	H	A	C	H	A	C	H
n	33	20	13	30	17	13	26	15	11	24	14	10
Mean	2.8	3.1a	2.4a	3.0	2.9b	3.1b	2.7	3.1c	2.2d	2.4	2.4e	2.3e
S.dev.	1.19	1.19	1.14	1.00	0.95	1.10	1.11	1.12	0.88	0.92	0.95	0.93
Range	0.9-5.8	1.0-5.8	0.9-4.3	0.9-5.0	0.9-5.0	1.3-4.6	1.0-5.8	1.4-5.8	1.0-3.2	1.1-4.4	1.1-4.3	1.4-4.4
CV%	42.5	38.4	47.5	33.3	32.8	35.5	40.8	36.1	40.0	38.3	39.6	40.4

2.8 kg DM Compound A (loose mix) allocated per head

2.6 kg DM Compound B (pelleted feeds) allocated per head

Within groups means with different letters are significantly different ($P < 0.05$).

A = All animals, C = Cows, H = Heifers.

During Period II there was a statistically significant difference of 0.9 kg in the dry matter intake of Compound A between the heifers and cows in Group 2 ($P < 0.05$). Similarly in Group 1 during Period I there was an intake difference of 0.7 kg dry matter of Compound A between the heifers and cows. However, the difference was not statistically significant ($P > 0.05$). The mean dry matter intake of Compound B in both Periods I and II was fairly similar between the heifers and cows of each group. Indeed, in Period I the heifers in Group 2 apparently consumed 0.2 kg dry matter more than the cows. This difference was not statistically significant ($P > 0.05$).

The mean intake of Compound B in Periods I and II was apparently rather different (3.0 kg DM and 2.4 kg DM respectively) from the allocated quantity of 2.6 kg DM/head. This may have been caused by an inadvertent bias as all the animals were not sampled and consequently those which were sampled had apparently larger and smaller intakes respectively than the overall mean intake of the groups.

Rank order correlation coefficients were computed between the ranking order of dry matter intake of Compound A and Compound B, within Group 1 and Group 2 respectively. The correlation coefficients were 0.23 and 0.21 for Group 1 and Group 2 respectively. Neither was statistically significant ($P> 0.05$).

The influences of Compound A and Compound B on milk yield and milk composition are shown in Table 111. Only those animals ($n = 22$) with a pre-experimental milk yield of greater than 20 kg/day are represented. The mean milk yields for Compound A and Compound B were 20.6 and 20.3 kg respectively and the difference of 0.3 kg was not statistically significant. Milk fat was improved by allocation of Compound A and Compound B to 3.86% and 3.82% respectively. However, the improved milk fat concentrations were not significantly greater than the pre-experimental concentration of 3.68% and did not differ significantly with each other.

Compound B significantly improved the mean milk protein percentage from pre-experimental percentage of 3.20% to 3.30% ($P < 0.05$). Compound A slightly depressed the mean milk protein from 3.20% to 3.18%, although this effect was not statistically significant.

There was a significant period effect for mean milk yield with a decrease of 2.1 kg from Period I to Period II ($P < 0.05$). Similarly, the mean pre-experimental milk yield was 2.0 kg higher (23.5 kg) ($P < 0.01$) than that of Period I (21.5 kg). During Period I there was a

slight improvement in mean milk fat percentage from the mean pre-experimental percentage by 0.07% which was not statistically significant. There was an improvement in milk fat percentage during Period II compared to Period I of 0.18% which was not statistically significant, even although the improvement of 0.25% from the mean pre-experimental milk fat percentage to that achieved in Period II was significant ($P < 0.05$). The mean milk protein percentage during Period I was 0.03% less than the pre-experimental mean of 3.20%. The difference was not, however, statistically significant. The improvement in mean milk protein percentage of 0.14% from Period I to Period II was, however, statistically significant ($P < 0.01$), as indeed was the improvement of 0.11% from the mean pre-experimental milk protein percentage to that achieved in Period II. The period effects on milk yield and composition are presented in Table 112.

Table 111 Treatment effects on mean milk yield and milk composition

	Pre-experimental	Compound A	Compound B	SE diff. ±
Milk yield (kg)	23.5	20.6	20.3	0.676
Milk fat %	3.68	3.86	3.82	0.110
Milk protein %	3.20	3.18	3.30	0.045

Table 112 Period effects on mean milk yield and milk composition

	Pre-experimental	Period I	Period II	SE diff. ±
Milk yield (kg)	23.5	21.5	19.4	0.676
Milk fat %	3.68	3.75	3.93	0.110
Milk protein %	3.20	3.17	3.31	0.045

Discussion

The coefficients of variation of dry matter intake for Compound A were slightly larger (42.5% and 40.8%) than for Compound B (33.3% and 38.5%) for Periods I and II respectively, which may suggest that the animals from Groups 1 and 2 consumed Compound B more uniformly than Compound A. This probably reflects the time taken to clear the respective allocations of Compound A and Compound B by the groups, where the animals usually took 10-15 minutes longer to consume their allocation of Compound A than Compound B. The physical form of Compound A (i.e. a loose meal) is likely to slow down the rate of intake of the supplement, unlike the relatively more rapid consumption of material which is offered in a pelleted form (i.e. Compound B). Presentation of a loose meal to a group of animals is perhaps likely to produce a range of persistency of consumption among the animals which may be reflected in a greater range of dry matter intakes, even although this was not noticed when the animals were observed at feeding time.

This conjecture is perhaps clarified by the comparison of the mean dry matter intakes of Compounds A and B by the cows and heifers within each group during Periods I and II (Table 110). For Compound A (loose mix) the cows always apparently consumed about 0.7-0.9 kg more than the heifers, i.e. 3.1 v. 2.4 kg in Period I and 3.1 v. 2.2 kg in Period II. In contrast, cows and heifers appeared to eat comparable amounts of Compound B, i.e. 2.9 v. 3.1 in Period I and 2.4 v. 2.3 in Period II.

The explanation for this may be in the fact that for the heifers the loose Compound A was an entirely novel product which had not been offered previously. In contrast, the cows would have experienced many novel feeds, including other sugar beet pulp based products, and presentations thereof in this particular herd. From Table 110 the coefficients of variation of intake of Compound A averaged 37.3% (cows) and 43.7% (heifers) and for Compound B averaged 35.6% (cows) and 37.6% (heifers). It must be concluded that more of the heifers than the cows had either quite low or quite high intakes of Compound B. A low consumption might be expected to result in a depression in milk yield but a high one may not result in an increase.

The rank order correlation coefficients for intake of Compound A and Compound B within Group 1 and Group 2 were low and not significant (0.23 and 0.21 respectively) and, even although the relationships were positive, the non-significance suggests that individual animals did not

maintain their ranking position when Compound B, for example, was allocated to the group instead of Compound A (and vice versa). This effect may not truly reflect the allocation of either Compound A or Compound B but may be due to animal factors such as oestrus, feet problems which may affect appetite and were not present when the alternative compound had been allocated.

There were no significant differences in milk yield between treatments (Table 111) which might perhaps imply that the possible inefficiency of intake of Compound A for the heifers was not important. However, two factors possibly conceal any difference which might be apparent in other circumstances. Firstly, there were fewer heifers than cows. Secondly, the mean amounts of Compound A given to the cattle only accounted for about 20% of the ME required at a mean yield of about 20 kg milk per day. Accordingly, relatively small changes in individual intake of either Compounds A or B would perhaps not be reflected in changes in milk yield over as short a period as one month, as changes in liveweight might be an adequate compensatory factor.

To further evaluate the possible differences between individual intakes of Compounds A and B would require an experiment with heifers, rather than cows, and where the feeds were given in larger amounts than in the present experiment.

GENERAL DISCUSSION

The experimental work carried out in this thesis particularly examined the influence of several feed and management factors on the variation in individual feed intake under group feeding conditions. The contribution of inherent differences between animals in the group in, for example, physiological demands and social hierarchy (eg, feed intake of first-calving heifers compared with cows), to the extent of the variation in intake by the group, has usually been examined in each experiment.

The allocation of compound feeds in which are incorporated ingredients beyond their normally acceptable inclusion levels may be expected to promote a fairly uniform compound feed intake in a group mediated through a probable reduction in the rate of feed consumption, in comparison to allocation of a more palatable compound feed which is likely to be consumed fairly quickly. This effect was observed in a group of dry, non-pregnant ewes (Experiment 4.2) and beef cows in mid-pregnancy (Experiment 5.1), where relatively unacceptable compound feeds promoted uniformity in individual intake and were indeed consumed more slowly than more acceptable compound feeds. The more acceptable compound feeds were observed to encourage greater disparity in individual intake in the same or similar groups of animals.

For ewes at a later stage of pregnancy, however, (Experiment 4.3), this trend was apparently reversed. The individual intakes of the relatively unacceptable compound feed by the ewes were more disparate compared with the individual intakes of a more acceptable proprietary compound feed by a similar group of ewes which were also in late pregnancy. It is possible that the ewes were more particular about their feed in late pregnancy which was consequently expressed by a more variable intake within the group.

The influence of the physical form of compound feeds on the variation in individual feed intake was particularly demonstrated by allocations of compound nuts and compound cobs to suckler cows at grass (Experiments 5.3 and 5.4). The physical form of the feeds was sufficiently dissimilar to elicit a reduction in the rate of feed consumption when compound cobs were offered to the cows, compared with compound feed provided in pellet form. In effect, the variation in compound feed intake, which was illustrated by the chromium concentration of faecal grab samples, was much reduced when compound

cobs (about 3 cm x 3.5 cm x 2 cm) were offered.

Compound feeds which are eaten more slowly by the animals may, therefore, be anticipated to promote a more uniform intake of feed in the group. Nevertheless, allocation of a loose compound meal compared with a conventional pelleted diet (albeit of different composition) to dairy cows (Experiment 7.4) resulted in a similar variation (coefficient of variation 40.0%) in group intake for both feeds, even although the loose compound meal was consumed more slowly than the pelleted feed. However, the first calving heifers were observed to consume significantly less ($P < 0.05$) of the loose compound meal than the cows. This observation was not repeated when the pelleted compound was allocated to the herd. It is possible that the heifers were less able to adapt to the allocation of the novel loose compound meal than the cows. The loose compound meal may have been very much more palatable than the pelleted compound and consequently the cows may have been more persistent and able to compete more successfully with the first-calving heifers at the feeding barrier.

The choice of the physical form of the feed, particularly that of the compound or concentrate feed, has possible important implications in terms of promotion of uniformity of feed intake in the group. To ensure uniform intake of magnesium, for example, supplied from compound feed offered to animal at grass, it may be efficacious to choose a compound feed which is likely to be consumed relatively more slowly, e.g. compound cobs. Consequently, a more effective prophylactic treatment of hypomagnesaemia may be elicited, whereby most or all of the animals in the group receive an adequate intake of magnesium. In contrast, the use of feedblocks, for example, as a source of magnesium (or indeed other minerals and/or trace elements)for the prophylaxis of hypomagnesaemia has been observed to produce a rather large variation in individual dry matter intake (as illustrated by faecal chromium concentration) in a group of similar suckler cows on poor pasture (Kendall, 1977). Coefficients of variation of faecal chromium concentration of up to 147.6% were established. Allocation of magnesium in feedblocks may therefore be not entirely satisfactory for the prophylaxis of hypomagnesaemia. For dairy cows effective allocation of magnesium from feed resources is perhaps only ensured by individual rationing of magnesium enriched compound feed in the milking parlour.

The uniform intake of growth promoting substances from compound

feeds allocated to group-fed animals may be similarly affected by the choice of physical form of the feed.

Alteration of the quantity of feed supplied, i.e. compound feed or complete diets, did not result in a consistent effect on the variation of individual feed intake in group feeding situations. This was possibly due to inherent inadequacies in experimental design whereby examination of the effect of a reduction and/or increase in the quantity of feed supplied was usually carried out in the same group of animals in consecutive periods, some of which were more critical than others in terms of metabolisable energy demands (e.g. determination of individual intake of a group of ewes offered x quantity of feed in the fourth month of pregnancy compared with individual intake of ewes offered 2x/3x the quantity of feed in the fifth month of pregnancy, as in Experiment 3.1). Simultaneous allocation of the various quantities of feed to be examined to the appropriate number of groups of similar animals may have been more conducive to the achievement of any consistent effects.

It is possible that the influence of quantity of feed allocated on the variation in individual feed intake in the group is more likely to be observed in those less bulky feeds, i.e. pelleted compound feeds or processed grains, which are consumed fairly rapidly. The production of saliva may become the limiting factor to intake as the quantity of feed allocated is increased, and the feed under investigation is already ingested rapidly. Indeed, allocation of a pelleted compound feed to suckler cows at 2 kg FM/head/day and 3 kg FM/head/day resulted in a reduction of the coefficient of variation from 27.3% to 16.1% respectively (Experiment 5.2). However the mean intakes of compound feed dry matter each had errors of about $\pm$ 0.5 kg (or approximately 5 MJ ME).

Nevertheless, under conditions of fairly restricted allocation of compound feeds (or grain), which are rapidly ingested, it is possible that alteration of the quantity of feed offered to the group will not markedly influence the variation in compound feed intake in the group until the rate of feed consumption is indeed limited by saliva production (i.e. with more liberal allocation of compound feed). For similar reasons, the rate of compound feed consumption (and possible effects on the variation in individual feed intake) was not markedly altered by allocation of a given quantity of compound feed (i.e. 2 kg FM/head/day) in either one, two or three meals per day (Experiment

5.2). Therefore, frequency of feeding did not markedly influence the variation in individual feed intake in the group of suckler cows.

Presentation of feeds, i.e. a complete diet to ewes (Experiment 2.4) and a pelleted concentrate to suckler cows (Experiment 5.1) from a choice of feeding devices (either troughs, barrier or feedring for the ewes and choice of feedring or troughs for the cows) did not markedly affect the variation in individual feed intake in the respective groups of animals. However, the complete diet was consumed fairly slowly by the ewes and it is possible that allocation of a pelleted compound feed (or grain), which would possibly have been consumed more rapidly by the ewes, may have encouraged more competitive behaviour between the ewes and the influence of the choice of feeding device may have been observed.

Perhaps the greatest area of interest for dairy cows is the likely range of intakes of grass silage offered over the full 24-hour period or by somewhat limited access. Associated with this would be changes in the pattern of consumption between self-feed from the silage face, controlled by a wire, or from easy-feed presentation behind a barrier usually when replenished twice per day.

Table 113 summarises the results of eleven separate observations on the calculated mean silage dry matter intakes (± standard deviation) of dairy cows given access to grass silage. There is a fairly consistent finding that the coefficient of variation is generally in the order of 25-30% of the mean intake (i.e. cows and first-calving heifers considered together for each observation). For the seven situation where the animals in the group had access to the face of the silage clamp, the overall mean intake was 8.6 ± 2.29 kg DM. Where easy-feed silage was available (four observations) the overall mean intake was 9.0 ± 2.61 kg DM. The two sets of data were not fully comparable and it should not be implied from these particular data that easy feeding led to higher intakes of silage.

Table 113 Summary of variation in intake of grass silage dry matter in 11 observations (between 60-90cm of space/head at feeding place)

Silage presentation	Exp. No.	No. of cattle (i) Total (ii) Cows (iii) Heifers	DM intake (kg) Mean	S. dev. ±	CV%
Silage face 24h	6.1	64	9.0	2.36	26.2
		47	9.7C	2.19	22.6
		17	7.3D	1.77	24.3
Silage face 8h	6.2	66	8.3	2.26	27.2
		60	8.2	2.23	27.2
		6	8.6	2.79	32.4
" "	6.4.1	34	8.9	2.80	31.5
		27	9.1	2.90	31.9
		7	8.1	2.09	25.8
" "	6.4.1	34	8.7	2.49	28.7
		20	8.4	1.79	21.3
		14	9.2	3.20	34.8
" "	6.4.2	76	7.9	1.93	24.4
		63	8.2A	2.02	24.6
		13	6.3B	1.83	29.1

(Continued over page)

Table 113 contd.

Silage presentation	Exp. No.	No. of cattle (i) Total (ii) Cows (iii) Heifers	DM intake (kg) Mean	S. dev. ±	CV%
Easy-feed - silage offered 1x or 2x day, virtually to appetite					
"	6.1	54	9.0	2.67	29.7
		42	9.7C	2.28	23.5
		12	6.8D	2.72	40.0
"	6.1	53	9.3	2.55	27.4
		40	9.5a	2.09	22.0
		13	8.0	2.09	26.1
"	6.2	75	9.7	2.20	22.7
		67	9.8	2.28	23.3
		8	9.5	2.12	22.3
"	6.3.1	91	7.3	1.89	26.1
		68	7.2	1.97	27.4
		23	7.6	1.66	21.8
"	6.3.2	14	10.1	2.32	23.1
		11	10.2	2.27	22.3
		3	9.7	3.00	31.0
"	6.3.2	15	7.9	2.49	31.8
		8	8.3	2.96	35.7
		7	7.3	1.89	25.9

Within experiments mean intakes of cows and first-calving heifers with different letters are significantly different:-

a, b $P < 0.05$; A, B $P < 0.01$; C, D $P < 0.001$

If it is assumed that a generalised picture might be a mean intake of 8.8 kg DM, with a standard deviation of ± 2.5 kg DM, the following calculations (Table 114) can be made on the assumption that the observations of individual intakes are normally distributed around the mean.

Table 114 Calculated range of intakes of silage dry matter to include varying proportions of the population (mean 8.8 ± 2.5 kg)

Proportion of population %	Multiplier of S. dev.	Range around mean ±	Range of intake (kg)+
95	1.98	5.0	3.8 - 13.8
90	1.66	4.2	4.6 - 13.0
80	1.29	3.2	5.6 - 12.0
70	1.04	2.6	6.2 - 11.4
60	0.85	2.1	6.7 - 10.9
50	0.68	1.7	7.1 - 10.5

+ If the ME of the silage DM was 10.0 MJ, these values x 10 are equivalent to ME intakes.

The various estimates of silage dry matter intake derived from chromium determination in faeces are subject to errors which may arise in a variety of ways. The results of Experiment 1.1 indicate an overall error of about 5% due to inherent differences in the digestibility of dry matter by individuals. There are additional errors associated with the grab sampling of faeces (say 5%) and analysis (say 5%). Furthermore, individual animals may have disturbances to their appetite on the day of sampling (or the day or two before) due, for example, to oestrus, lameness or other abnormal factors. On a very few occasions it has appeared that individual cows

have only consumed 1 or 2 kg silage DM/day or as much as 20 kg silage DM/day, which are highly unlikely situations.

Accordingly, whereas in Table 114 it is indicated that 80% of the cows and first-calving heifers might have dry matter intakes in the range 5.6 - 12.0 kg, it is perhaps not unreasonable to consider that all the animals (in the absence of any gross error) would consume silage within that range. On a similar basis, perhaps three-quarters of the animals might consume about, say, 7.0 to 10.5 kg DM, i.e. 70 to 105 MJ ME. The possible range of 35 MJ ME intake from silage for three-quarters of the animals in the group is equivalent to approximately 3 kg DM of compound feed and perhaps questions the necessity of accurate individual compound feed allocation in the milking parlour or from electronic out-of-parlour feeding devices. However, the observed range of ME intake from silage between the animals in the group may reflect differences in liveweight and, therefore, accurate individual allocation of compound feed may indeed be necessary.

In four of the eleven observations (Table 113), it was apparent that the silage dry matter intake of the first-calving heifers was significantly less than that of the cows in the respective groups. Furthermore, in four of the remaining seven observations, the mean silage dry matter intake of the first-calving heifers was less than that of the cows, but these differences were not statistically significant. Nevertheless, expression of silage dry matter intake per 100 kg liveweight was observed to remove any statistically significant differences in intake between the cows and first-calving heifers (e.g. Experiment 6.1). However, under self-feed restricted access to silage (i.e. less than 24 hours), it may be anticipated that lower silage dry matter intakes (per 100 kg liveweight) may indeed by observed in first-calving heifers compared with the cows, due to possible prehension difficulties in the consumption of silage caused by their mixed lower incisor dentition. The low ranking order of the first-calving heifers may also contribute to their lower intakes under restricted self-feed access to the silage.

The limited information in this thesis available for group fed suckler cows suggests that the range in intake of hay presented in feedrings (Experiment 1.4) (mean 4.3 $\pm$ 1.24 kg, CV = 28.8%) suggests a pattern of intake comparable to silage by dairy cows. For barley straw presented in the same manner (Experiment 5.2), the mean intake was 4.6

± 0.59 kg (CV = 12.8%) and this is probably apparently more uniform as it represents consumption to capacity of unattractive material in the presence of limited concentrate intake.

In the various experiments described in this thesis compound feeds were always allocated to groups in restricted amounts. As the feeds were usually palatable, there must have been considerable competition between individual in respect of intake. Table 115 summarises the situation for six observations where dairy cows, fed grass silage, were given pelleted compound feeds (plus one situation where a loose mixed feed was given) behind a barrier allowing, generally, about 75 cm of space per cow.

For the four observations where pelleted feeds were given at 2.4 - 2.9 kg DM/day the mean intake was 2.6 kg, with an overall mean standard deviation of ± 0.92 kg, i.e. CV = 35.3%. Rather lower values of about ± 0.30 standard deviation were found where intakes were between 1.0 and 1.5 kg/day/ In contrast, a rather higher standard deviation was recorded when the loose mix was given in Experiment 7.4 (although this was largely associated with a product which was unfamiliar to heifers). This variation in intake is considerably larger than the range in intake for silage DM by the same cows. If the objective of giving 2.6 kg DM of a pelleted dairy feed was to give, say, 30 MJ ME, equivalent to the requirements for about 6 kg milk, then the range of intakes for the majority of cows (allowing 15-20% for experimental error) would be about 1.4 to 3.8 kg DM (based on S.dev. 0.92 x 1.29 = 1.19). This represents a realistic outside range of about 17-46 MJ ME with perhaps three-quarters of the cows receiving 22-41 MJ ME.

In two of the seven observations in Table 115 where it was possible to make statistical comparisons of compound feed dry matter intake (i.e. comparable numbers of cows and heifers in groups), the first-calving heifers were observed to consume significantly less compound feed than the cows (Experiments 7.2(i) and 7.4L). Furthermore, in four of the remaining five observations the mean intake of compound feed by the heifers was less than that of the cows (but not statistically different).

Table 115 Calculated mean intake of pelleted compound feed given to silage fed dairy cows in one meal behind a feed barrier.

Experiment No.	No. of cattle (i) Total (ii) Cows (iii) Heifers	Feed Intake Mean	S.dev. ±	CV%
7.1	32	2.6	0.99	38.1
	30	2.6	0.77	30.3
	(2)	(2.3)	(0.49)	(21.9)
7.2(i)	37	2.9	0.90	31.2
	24	3.1a	0.89	28.3
	13	2.4b	0.69	29.4
7.2(ii)	37	0.97	0.30	30.8
	30	0.99	0.29	29.6
	7	0.85	0.31	36.1
7.3 D	16	2.5	0.86	33.9
	12	2.6	0.64	24.3
	(4)	(2.3)	(1.44)	(63.4)
7.3 D	10	1.4	0.31	22.4
	(4)	(1.3)	(0.39)	(29.8)
	6	1.5	0.27	18.9
7.4	24	2.4	0.92	38.3
	14	2.4	0.95	39.6
	10	2.3	0.93	40.4
7.4 L	26	27	1.11	40.8
	15	3.1a	1.12	36.1
	11	2.2b	0.88	40.0

D Diagonal bars to restrict sideways movement, otherwise a straight neck/shoulder bar.

L Loose mix, otherwise pelleted concentrate.

Within experiments mean intakes between cows and first-calving heifers with different letters are significantly different.

a, b $P < 0.05$

Consequently, allocation of compound feed to dairy cows, on a group basis, may be particularly inefficient in terms of effective use of resources, in view of the lower intakes by first-calving heifers and the range of milk which is produced. Indeed, the compound feed energy consumed by some animals in the herd may be stored as fat. Appropriate grouping of the dairy herd may therefore be important, which may necessitate separation of the first-calving heifers from the cows for allocation of out-of-parlour compound feed. The alternative to such possibly effective grouping arrangements in loose housing conditions is allocation of out-of-parlour compound feeds from individual electronic feeding devices or, indeed, a return to the byre system where each animal can be fed individually. Nevertheless, accurate individual allocation of compound feeds may not be worthwhile is there is a large disparity in the individual intakes of group-fed roughage in the group.

Table 116 summarises the variation in compound feed intake in nine observations of group fed suckler cows given basal diets of either hay (Experiment 5.1), straw (Experiment 5.2) or grass (permanent pasture) (Experiment 5.4). The compound feed was allocated in one meal per day. In two of the observations the suckler cows were offered compound cobs (3 cm x 3.5 cm x 2 cm)(Experiment 5.4). The observations of compound feed intake were very varied between the groups of suckler cows (coefficients of variation between 16.1% and 61.1%). This effect may not be surprising due to differences in the compound feeds with respect to rates of allocation, physical form and ingestive features (e.g. compound cobs compared with compound nuts).

For those cows in Experiment 5.1, for example, the range of dry matter intakes for the majority of the cows (allowing 15-20% for experimental error) would be about 0.8 - 1.7 kg DM (based on S. dev.X 1.29). This would be equivalent to an outside range of 8.4 - 18.7 MJ ME (assuming 11 MJ ME/kg DM for the compound feed), and three-quarters of the animals would probably receive about 9.4 - 17.7 MJ ME.

Table 116 Variation in compound feed intake by group fed suckler cows (66-100 cm/head space)

Basal diet	Experiment No.	n	DM intake (kg) Mean	S. dev. ±	CV%
Hay	5.1 T	16	1.2	0.31	25.8
"	5.1 T	16	1.3	0.49	37.7
"	5.1 FR	16	1.3	0.29	22.3
Straw	5.2 T	21	1.8	0.48	27.3
"	5.2 T	21	2.6	0.43	16.1
Permanent pasture	5.4 T	21	0.43+	0.26	61.1
	5.4 T	22	0.29+	0.12	40.0
	5.4 C	24	0.49+	0.14	28.4
	5.4 C	24	0.22+	0.04	19.6

T, FR Pelleted compound feed presented from troughs or feedring.
C Compound cobs presented along ground.
+ Compound feed intake illustrated by faecal chromium concentrations. Individual intake data could not be easily calculated as individual grass intake data not known.

Nevertheless, the supply of ME from the compound feed allocated to suckler cows is not necessarily critical in the observations recorded in Table 116, as a considerable proportion of the ME allowances are supplied from the basal diet (i.e. hay, straw or grass). However, the supply of crude protein and/or mineral constituents (e.g. magnesium in Experiment 5.4) from the compound feed may be critical to the well-being of the suckler herd and consequently selection of a particular physical form of compound feed may determine the uniformity of compound feed intake by the animals.

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APPENDIX 1

ANALYTICAL METHODS

All the analytical methods used were established procedures.

(i) Dry matter

The dry matter (DM) of the feed and faecal samples was determined by heating 0.5 to 1.0 kg quantities of fresh matter in a hot air oven at 90°C. for 36 to 48 h until a constant weight was obtained.

(ii) Gross Energy

The gross energy of feed and faeces samples was measured using a Gallenkamp Adiabatic Bomb Calorimeter. Benzoic acid (Thermochemical standard, BDH) was used to calibrate the instrument. The samples and benzoic acid were pelleted using a die operated by a hydraulic press. The metabolisable energy content of feeds was calculated from the equation, M.E.= Digestible energy (determined) X 0.81 (M.A.F.F.,1984).

(iii) Total Nitrogen

The total nitrogen in feed and faecal sampales was measured by an Automated Kjeldahl technique (Kjel-Foss Automatic 16210). Before analysis fresh, undried faecal samples were macerated with distilled water and a small amount of toluene (Grassland Research Institute (C.A.B., 1961).

(iv) Ether extract, crude fibre and ash

The ether extract (EE), crude fibre (CF) and ash contents of the feed and faecal samples were determined by the standard methods (The Fertiliser and Feeding Stuffs Regulations, 1976).

(v) Chromium

The chromium content of feed and faecal samples was determined by atomic absorption spectrophotometry according to the method of Williams, David and Iismaa (1962). The samples were initially dry ashed.

(vi) Magnesium

The magnesium content of blood, feed and faeces samples was determined by atomic spectrophotometry (Perkin-Elmer, 1976). The samples of feed and faeces were analysed after acid digestion (with a 3:2:1 mixture of nitric, perchloric and sulphuric acid).

(vii) Copper

The copper content of feed, faeces and blood samples was determined by atomic spectrophotometry (Perkin-Elmer, 1976). The feed and faeces samples were digested in acid prior to spectrophotometric analysis.

(viii) Acetoacetate in plasma

The method used involved conversion of the ketone bodies to acetone, followed by distillation of acetone and subsequent colorimetric determination with ethanolic salicyclic aldehyde (Reid, 1960).

(ix) 3-hydroxybutyrate in plasma

The concentration of 3-hydroxybutyrate in plasma samples was determined by autoanalysis according to the method by Zivin and Suarr (1973).

(x) Non-esterified fatty acids in plasma

Gas chromatography was used to determined non-esterified fatty acids.

(xi) Milk composition

Samples of milk were analysed for milk fat and milk protein by the Scottish Milk Marketing Board. The technique used was an automated Milkoscan 33 Infra-Red Analyser (Foss Electric) as employed for routine milk quality testing.

APPENDIX 2

METHOD USED IN DIGESTIBILITY TRIALS WITH WETHER SHEEP HOUSED IN METABOLISM CAGES

Allocation of feed

The feedstuff under investigation was allocated to the wether sheep (40-50 kg liveweight) in quantities which would usually ensure complete consumption, i.e. rather less than full appetite (usually 1.0 kg FM/head/day in total). Determination of the digestibility coefficient of concentrate or compound feeds involved allocation of the feedstuff with dried grass of known digestibility, usually in the ratio of 6·7 : 3·3 (compound feed FM to dried grass FM). The digestibility coefficient of the compound feed was determined by difference.

The feed allocation for each separate day for the whole trial (usually of 14 days duration) was weighed into paper bags at the beginning of the experiment. A sample of the feed was taken simultaneously for proximate analyses and gross energy determination. The feed was offered twice daily at 07.30h and 16.00h. Water was provided in containers which were replenished twice daily.

Faecal collection

The wether sheep (clipped free of wool around the hind quarters) were each fitted with a standard type of leather harness which included a chest strap. A faecal collection bag was attached to the harness by four quick-release, spring loaded scissor-grip hooks. After a preliminary period of seven days, complete faecal collections were taken from each of the wether sheep during the subsequent seven day period. The faecal collection bags were removed daily and the faeces were emptied into numbered plastic buckets (each fitted with an airtight lid). The bags were then refitted to the animals.

The faeces collected over the seven days were weighed, thoroughly mixed and an appropriate subsample was dried and ground for analysis. Samples of fresh material were used for nitrogen determination.

Specimen calculations of dry matter digestibility coefficients for hay and for a pelleted compound dairy feed.

(a) Hay

Data: 4 wether sheep
480g DM/head/day chopped hay

Wether No.	Hay DM consumed g/day	Faeces DM produced g/day	DM digestibility coefficients
1	480	205.3	0.572
2	480	202.1	0.579
3	480	198.0	0.588
4	480	201.7	0.579
			Mean = 0.579 (± 0.007)

Therefore DM digestibility coefficient of hay was 0.579.

(DOMD may be calculated using the equation:-

$$\frac{\text{(Feed OM - Faeces OM)}}{\text{Feed DM}} \times 100\%$$

OM = organic matter
DM = dry matter

(b) Proprietary pelleted compound dairy feed (by difference)

Data: 4 wether sheep

580 g DM Compound dairy feed (Compound A)/head/day +
300 g DM dried grass/head/day

DM digestibility coefficient of dried grass (previously determined) = 0.536. Therefore faeces DM produced from 300 g DM of dried grass was 139.2 g/day.

Wether No.	Faeces DM	Faeces DM from dried grass	Faeces DM from Compound A	Compound A DM consumed	DM digestibility coefficients
	g/day	g/day	g/day	g/day	
1	286.5	-139.2	147.3	580	0.746
2	292.1	-139.2	152.9	580	0.736
3	290.2	-139.2	151.0	580	0.739
4	288.4	-139.2	149.2	580	0.743
					Mean 0.741
					(± 0.004)

Therefore DM digestibility coefficient of Compound A (by difference) was 0.741.

APPENDIX 3

ESTIMATION OF INDIVIDUAL FEED INTAKE FROM THE CONCENTRATION OF CHROMIUM IN FAECAL GRAB SAMPLES

In this thesis extrapolation to individual feed intakes from estimates of total faeces dry matter output (which was usually calculated from the equation:-

$$\text{Total faeces DM (kg)} = \frac{\text{Weight of chromium given g}}{\text{Mean concentration of chromium in faeces (g/kg)}} \quad \text{Equation A}$$

where faecal grab samples were taken from the animals), when both a concentrate feed (containing chromic oxide) and roughage were given, involved the apportionment of the calculated faeces dry matter output into the respective components of feed intake (i.e. concentrate and roughage).

Calculation of individual roughage intake

Example

x dairy cows were individually allocated 8 kg DM of a pelleted compound feed (*in vivo* DM digestibility coefficient of 0.85) which contained chromic oxide (0.75 g/kg DM). Silage (*in vitro* DM digestibility coefficient of 0.65) was offered to the group/herd on an easy-feed basis along a feeding passage behind a barrier. The silage allocation was estimated to provide the maintenance energy requirements of the cows. After 10 days of access to the chromic oxide-containing compound feed in the milking parlour, faecal grab samples were taken from each of the cows in the group at 16.00h. The faeces samples were dried, milled and analysed for chromium. The individual silage intake of the group was then calculated:-

Data: (one cow only)

Faecal chromium concentration (grab sample) = 1.56 g/kg DM
Total chromium given = 6.00 g
Faeces DM from allocated compound feed = 1.20 kg

Calculation

(i) Total faeces DM output = $\frac{6.00}{1.56}$ (Equation A)

= 3.85 kg

(ii) Faeces DM from silage = Total - faeces DM from compound feed

= 3.85 - 1.20

= 2.65 kg

(iii) Silage DM intake = $\frac{\text{Faeces DM from silage}}{\text{1-(DM digestibility coeff. of silage)}}$

= $\frac{2.65}{1 - 0.65}$

= 7.57 kg DM

Calculation of individual compound feed intake

Example

x dairy cows were allocated silage on a group basis and the individual intakes of silage had been calculated (as above). This example would also apply to experiments were the cattle/sheep were individually offered the roughage component of the diet, therefore the individual intake of roughage would be known. The cows were also group fed compound feed (which contained chromic oxide at 2.35 g/kg DM) along a feeding passage at a rate of 3 kg DM/head/day in one meal. After 10 days of access to the chromic oxide containing compound feed on a group basis, faecal grab samples were taken from each of the cows in the group at 16.00h. The faeces samples were dried, milled and analysed for chromium. The individual compound feed intake of the group was then calculated:-

Data: (one cow only)

Faecal chromium concentration from grab samples = 1.42 g/kg DM

Pelleted compound feed contains 2.35 g chromium/kg DM and dry matter digestibility coefficient of 0.750

Known intake of silage (DM digestibility coefficient 0.650) of 8 kg DM (determined 2-3 weeks previous to the faecal sampling date of this experiment)

Calculation

If the allocation rate of the compound feed is 3 kg DM/head and if each animal in the group consumes this quantity of feed, the quantity of chromium consumed will be 7.05 g (3 x 2.35)
Therefore the concentration of chromium in faecal grab samples (for the above dairy cow) would be 1.99 g/kg from:-

Faeces from 8 kg silage = 8 x 0.35 = 2.8 kg DM

Faeces from 3 kg compound feed = 3 x 0.25 = 0.75 kg DM

Total faeces output = 2.8 + 0.75 = 3.55 kg DM

Therefore the faecal chromium concentration of grab samples would be 7.05 / 3.55 = 1.99 g/kg DM

The dairy cow has therefore consumed less than 3 kg DM of compound feed. The above calculation is repeated until the correct faecal chromium concentration is established (i.e. 1.42 g/kg). This corresponds with 2 kg DM of compound feed intake.

The dry matter digestibility coefficients used in the calculations of intake in this thesis were determined by either in vivo or in vitro methods and, alternatively, where this was not possible estimates of dry matter digestibility coefficients of feeds were taken from Booklet 433 (MAFF 1984).

The periodicity of faecal chromium concentration in the faeces grab samples, particularly where single grab samples were taken, may cause either over- or under-estimation of the total faeces dry matter output and, consequently, the individual silage or compound feed dry matter intake may be over or under estimated. However, if the faecal grab samples are taken in such a way that the mean concentration of chromium in the faeces is similar to the overall concentration of chromium for a 24-hour period, this error will be avoided. Nevertheless, it was not usually practicable to determine the overall 24-hour concentration of chromium in the faeces and the estimated individual feed intake data were usually adjusted in proportion to the total input of feed (i.e. silage or compound feed) to the group, where this was known.