THE USE OF ELECTRONIC FEEDERS FOR INDIVIDUAL ROUGHAGE FEEDING OF LOOSE-HOUSED DAIRY COWS

by

J. PETER CAPPON

Thesis submitted to the University of Glasgow
for the degree of

MASTER OF SCIENCE

West of Scotland Agricultural College,
Auchincruive, Ayr.

December, 1969.

ACKNOWLEDGEMENTS

Grateful acknowledgement is made to the Governors and Principal J.S. Hall of The West of Scotland Agricultural College for providing the facilities with which to carry out the investigations, and to the Department of Agriculture for Scotland for supplying financial assistance. The author is especially indebted to Mr. J. Walker-Love of the Animal Husbandry Department for directing this investigation and providing helpful criticism and advice in the final preparation of the thesis.

Sincere thanks are also extended to Mr. N. Day, for help in conducting the trial, to Mr. R. Laird for statistical advice and to Miss Mary McGowan and Mr. H. Ferns of the Chemistry Department for the large number of analytical determinations.

The invaluable contributions made by Mr. R. Young, technical assistant; Mr. T. Logue, head dairyman; Mr. W. Boning, electrician; Miss Jeanette Sadler, typist; together with other members of the Animal Husbandry Department and College farm staff, are also gratefully acknowledged.

TABLE OF CONTENTS

Page

INTRODUCTION

Milk producers in the United Kingdom have been under increasing economic pressure to improve efficiency. While herd expansion, intensification and genetic upgrading have been used to raise the production output per acre, considerable attention has also been focussed on decreasing the costs of production. In the West of Scotland, 74 per cent of the total costs of production per cow were accounted for by feed and labour (Federation of the United Kingdom Milk Marketing Boards, 1968). Low cost producers have understandably concentrated on these items with the use of easy feed or self feed high quality roughages and low cost cubicle housing. This has enabled them to increase the margin per cow over concentrates and expand the numbers of cows per man.

In certain nutritional trials animals have performed differently under group feeding conditions than when penned individually (Kidwell et al., 1954; Barczy and Csako, 1962; Holt and Barr, 1962). Although this is not always the case (Jackson, Runcie and Greenhalgh, 1962), it would appear to be desirable to conduct trials in a similar environment to that in which the results will apply practically. Even under stall feeding conditions the mechanism of appetite control has not been fully elucidated, and Campling (1966b) has suggested the need for further work to examine the performance of cows being fed high quality hay or silage together with concentrate supplementation. Since the measurement of individual feed intake is essential to nutritional studies such as these, methods of establishing this factor in loose housing have been reviewed in this dissertation, and the individual electronic feeder developed by Broadbent (1967a) is the equipment used in the experimental work.

The objectives of this study are:-

(1) To examine the feasibility of using electronic feeders for the individual roughage feeding of loose housed dairy cows.

(2) To make recommendations on any design or component change that would increase the efficiency of performance of these feeders.

(3) To examine the influence of these feeders on cow performance and behaviour.

(4) To make a comparison of the individual feeding of hay or silage with supplementary concentrates in an identical loose housing environment.

REVIEW OF LITERATURE

S E C T I O N I

THE DETERMINATION OF INDIVIDUAL FEED INTAKE

Under experimental conditions the accurate measurement of individual intake is highly desirable in order to reduce the economic resources necessary for statistical validity and to explain individual anomalies. Where animals are penned singly and hand fed, the measurement of both the quantity and quality of feed intake is a comparatively straight forward task. However, with the increasing trend towards loose housing of dairy cows, it is clearly desirable to examine individual indices of performance under such conditions. One method, frequently used in grazing studies, employs equation (1) to obtain an indirect measure of individual consumption, although McDonald (1968) has reviewed the numerous difficulties involved in applying this to free ranging ruminants.

$$\text{Herbage Intake} = \text{Weight of faeces voided} \times \frac{100}{100 - \%\ \text{digestibility of herbage eaten}} \quad \text{--(1)}$$

The weight of faeces voided may be measured directly with collection bags or estimated indirectly by the use of indigestible external tracers such as chromium sesquioxide. Corresponding internal tracers, which are natural forage constituents such as nitrogen and plant chromogens, may be used simultaneously in the determination of in vivo digestibility, although recent developments of in vitro digestibility procedures have made this latter technique equally reliable.

An alternative but direct method of measuring individual feed intake in loose housing is also discussed.

A. DETERMINATION OF FORAGE DIGESTIBILITY

1. Determination of 'In Vivo' Digestibility

Traditionally, digestibility trials have been carried out upon stall-fed animals where the measurement of the relative variables is simplified. However, the scope of this review is directed more towards the determination of digestibility under loose housing. Since the literature on this aspect is extremely restricted it is necessary to draw a corollary between this and studies at pasture which have been more extensive.

It would be possible, as in the case of Jackson et al. (1962) to apply the digestibility value determined in a stall feeding trial for a particular forage, to cows in loose housing. This method however is subject to two limitations:-

(a) The digestibility of the forage fed to cows in stalls may differ from the digestibility of the forage selected by loose housed cows.

(b) Different environments may induce different individual performances. It is therefore desirable to have a measurement of digestibility 'in situ'. To this purpose two methods have been developed:-

(i) The ratio technique, the application of which requires a naturally occurring indigestible indicator and the determination of the indicator in both the forage and faeces.

(ii) The faecal index technique, in which the indicator does not necessarily need to be indigestible and is measured only in the faeces. This relies on observed relations in pen fed animals between the digestibility of forage and the faecal concentration of indicators such as nitrogen or plant pigments.

(a) The Ratio Technique

If a chemical constituent is present in forage and passes undigested into the faeces, digestibility may be estimated directly from the concentration of this constituent in a plucked sample of forage and in the resulting faeces, assuming a 100 per cent recovery in the faeces (Raymond, 1954). This may be expressed by the equation (2) of Kane et al. (1953b).

$$\text{Apparent digestibility} = 100 - 100\,\frac{\text{Percentage Indicator in feed}}{\text{Percentage Indicator in faeces}} \quad ---(2)$$

Lignin: Early work was first directed towards using lignin as such a chemical constituent capable of being employed as an 'internal indicator' or 'plant tracer'. Forbes and Garrigus (1948), Richards and Reid (1952) and Kane et al. (1950) found digestion coefficients very closely related to those determined by total collection when using lignin in hand feeding trials. However, the reports were conflicting regarding the indigestibility of this substance. Despite the accurate digestibility determinations, both Forbes and Garrigus (1948) and Richards and Reid (1952) found lignin faecal recoveries greater than 100 per cent. Further work by Kane et al. (1953a) found lignin to be an unreliable digestibility predictor when they only obtained a lignin faecal recovery of 95.7 per cent.

Since lignin is not a chemical entity of definite composition the possibilities of different metabolism in first and second growth grass, and of chemical changes within the bovine intestinal tract have been discussed. (Kane et al., 1953a).

Methoxyl: Since methoxyl is contained in lignin, but is a more clearly defined chemical compound and is more easily measured than lignin, attempts have been made to use the concentration of methoxyl groups in forage and faeces as an index of digestibility (Richards and Reid, 1952). Its accuracy in the ratio technique was slightly greater than lignin. However, in view of the report by Ely et al., (1951) where only 70 per cent of the methoxyl content of the lignin in the ration was recovered in the faecal lignin, its use has been restricted.

Nitrogen: Nitrogen and plant chromogens are the most widely recognised plant indicators, but the problem of obtaining an accurate sample of 'forage consumed' has limited the use of the ratio technique in grazing studies, unless a rumen fistula can be used.

Forbes (1950) developed an elaborate relationship with steers, using indigestible protein (percentage nitrogen x 6.25) as an internal indicator. This gave satisfactory determinations of dry matter digestibility compared with that calculated from total collections. Under stall feeding conditions in America, Kane et al. (1953b) working with cows and Holter and Reid (1959) with steers and wethers also found that indigestible protein provided a remarkably accurate estimate of the dry matter digestibility. The latter authors concluded that the true digestibility of protein was relatively constant regardless of the concentration of crude protein in forages. However Greenhalgh and Corbett (1960) have reported that the proportions of undigested food nitrogen and metabolic faecal nitrogen (M.F.N.) may vary with different protein levels. Since/

Since these authors have also noted that digestibility does not vary consistently with the nitrogen level in the herbage the basic concept of the ratio technique may be questioned. It is apparent that the indigestible protein in the faeces will include a source of nitrogen (M.F.N.) which is not present in the forage and may vary with the level of feed intake. The significance of this variability may be more pronounced in conditions such as loose housing where intake is less easily controlled.

<u>Chromogens</u>: Reid et al., (1952) extracted the chromogens from forage and faeces with 85 per cent acetone and then estimated their concentration spectrophotometrically at a wavelength of 406 mμ., their point of maximum light absorbtion. The relative concentrations were then applied in equation (2) to calculate digestibility. Brisson et al., (1954) using this technique with dried grass found excellent agreement in one trial with wethers, but with steers an adjustment of the wavelength was necessary to avoid the result being significantly different from those calculated by total collection. Working with cows, Kane et al., (1951), (1953a), (1953b) obtained results very closely related to those of total collection techniques, but in the last experiment they reported chromogen recoveries averaging 129 per cent. They could offer no explanation for the effectiveness of the formula developed by Reid et al., (1952) which was based upon the complete indigestibility of these pigments. It is possible however, that chemical degradations occurring during digestion may have interfered with the analysis (Irvin et al., 1953). Reid (1962) also reports that erroneous results may be caused by changes in pigments during ensiling, or by incomplete extraction of the pigments from mature forage.

Kane and Jacobson (1954) have improved the accurecy of the ratio technique by the addition of oxalic acid to the acetone extracts of feed and faeces. This has the advantage of degrading the chromogen indicator to pheophytin, as in the digestion process, thus making the feed and faeces comparable. Pheophytins are most accurately measured at their light absorbtion maximum of 415 mμ.

(b) The Faecal Index Technique

Since this method relies on observed relations between the faecal concentration of an indicator and the digestibility of a forage it is not dependent on a sample of 'forage consumed'. This criterion has been responsible for the almost total adoption of this technique for determining digestibility at grass.

Nitrogen: Early studies by Lancaster (1954) in New Zealand, feeding cut herbage varying from 58 - 84 per cent organic matter digestibility to dry cows determined the regression shown in Table I relating the feed to faeces ratio (Y) - which is simply the reciprocal of the indigestibility ratio - to the nitrogen concentration of the faeces (X).

Meanwhile in Britain, an alternative method was proposed by Raymond et al., (1954) where he related the percentage of organic matter digested (Y^1) to the percentage of nitrogen in the faeces (X), also over a similarly wide digestibility range of 55 - 80 per cent. This regression together with subsequent studies based on these methods are shown in Table I.

Theoretically the technique is dependent on the excretion of nitrogen in the faeces being proportional to the dry matter intake and hence the digestibility of forage dry matter. However, it would appear to be influenced by individual environmental conditions so that various research workers have found different regressions applicable to their environment. Table I indicates the range of digestibilities that would be predicted by these authors assuming an arbitrary faecal nitrogen concentration of 3 per cent.

TABLE 1

Organic Matter Digestibility Prediction at 3 per cent Faecal Nitrogen

Reference	Regression	Trial Animals	Percentage Organic Matter Digestibility	Analysis
Lancaster (1954)	$Y = 0.97x + 1.02$	Dry Cows	74.6	Percentage nitrogen in organic matter of dried faeces
Kennedy & Lancaster (1957)	$Y = 0.74x + 1.83$	Dry Cows	75.3	
Langlands (1967)	$Y = 0.401x + 2.562$	Wethers	73.4	
Raymond et al. (1954)	$Y^1 = 7.946x + 44.85$	Wethers	68.7	Percentage nitrogen in organic matter of undried faeces
Kennedy & Lancaster (1957)	$Y = 0.80x + 1.47$	Dry Cows	74.2	
Greenhalgh & Corbett (1960)	$Y^1 = 11x + 39.4$	Steers	72.4	
Minson & Kemp (1961)	$Y^1 = 7.25x + 49.2$	Wethers	71.0	
Greenhalgh & Runcie (1962)	$Y^1 = 5.83x + 56.5$	Lactating Cows	74.0	
Langlands et al. (1963)	$Y^1 = 8.1x + 46.9$	Steers, cows	71.2	
Lambourne & Reardon (1963b)	$Y = 2.04 - 0.24x + 0.186x^2$	Wethers	65.5	

The results in Table I have been divided according to the analytical methods used, since it is possible that drying the faeces would tend to lead to lower faecal nitrogen values due to losses of volatile nitrogen (Raymond et al., 1954). The 3 per cent faecal nitrogen in the dried faeces would thus be representative of a slightly higher nitrogen level with the associated higher digestibility.

Unfortunately many of the relationships in Table I have rather large errors of prediction which vary from ± 2.0 to ± 3.7 digestibility units. As pointed out by Raymond et al., (1959) an overestimate of digestibility by 1 - 1.5 units may result in an overestimate of digestible organic matter intake by 5 - 10 per cent, once errors associated with faecal output measurement have been included.

One particular error in certain of the values depicted in Table I would appear to be the use of a single regression equation to cover a wide range of feeds, animals and environments. Raymond et al., (1954) noted a curvilinearity in the relationship of organic matter digestibility to percentage nitrogen in the faeces at the ends of the wide range of digestibilities he studied, so that linear predictions over this range were slightly inaccurate. Even within the same herbage species, Greenhalgh and Corbett (1960), Minson and Kemp (1961), Langlands et al., (1963) and Lambourne and Reardon (1963) have all shown that there may be considerable differences between the relationship of herbage digestibility to faecal nitrogen content at different times of the year. This discontinuity in faecal index relationships is due to an increased herbage nitrogen concentration for a given level of digestibility in later growth stages and to a slower rate of decline in the digestibility of summer growth (Greenhalgh et al., 1960). The same authors also reported that the addition of nitrogen fertiliser resulted in significantly different regression coefficients during a Spring trial.

Errors arising through the use of different animals have also been examined. Hardison et al., (1954) and Greenhalgh et al., (1960) have found that intra species differences are small, although Charlet-Lery (1969) quotes an experiment where 36 per cent of the total variation in the digestion coefficients of organic matter were due to individual variation. This can be reduced by using a minimum of three or preferably four animals. Langlands et al., (1963) also found significant differences between individuals of a species, but the means of three values for steers and cows were similar. This is in contrast to Corbett (1960) who found that at a given value for faecal nitrogen, organic matter digestibility predicted for cows was about 2.5 units lower than that predicted for steers. However these results are also comparing a total collection technique, which was used with the steers, against an indirect measurement of faecal output in the cows by the use of chromic oxide.

The range of values in Table I provides a certain measure of environmental differences which would appear to necessitate the derivation of a regression for a particular circumstance. It is perhaps pertinent that all the studies on wethers in Table I predict lower digestibility values than those involving cows alone.

Chromogen: Faecal index predictions with plant chromogens have provided reliable estimates of digestibility (Reid et al., 1952; Kane and Jacobson, 1954). However, the studies of Kane et al., (1953b) and Kennedy and Lancaster (1957) have shown that Reid's equation does not have universal application, varying with the potency of the chromogen unit in the particular environment it is being used.

Chlorophyll is degraded to pheophytins during digestion so that the addition of oxalic acid (Kane and Jacobson, 1954) has little role to play when only faecal samples are being analysed. However, the studies have shown that the absorbtion peak of these pigments is close to 415 mμ and could be more accurately measured at this level than at 406 mμ as suggested by Reid et al., (1952).

Greenhalgh and Corbett (1960) found that the correlation between nitrogen and chromogen concentration in the forage was $r = +0.96$. It is not surprising therefore that these authors reported similar seasonal trends to nitrogen, demanding the use of regressions restricted to first or later growths. Indeed, the effect appeared to be slightly greater with chromogens since there was no buffering effect such as with nitrogen, where metabolic faecal nitrogen excretion varied according to the quantity of undigested food nitrogen. Although restricting the regressions seasonally increased the accuracy over general regressions like those of Raymond et al., (1954), the estimation of digestibility from faecal chromogen concentration would appear to be no more precise than nitrogen in each comparison (Raymond et al., 1954; Kennedy and Lancaster, 1957; Greenhalgh and Corbett, 1960). Since chromogen determinations are more difficult than nitrogen Kjeldahl determinations and chromogen faecal recoveries are often high and variable (Kane et al., 1953b; Greenhalgh and Corbett, 1960), the use of faecal nitrogen has generally been preferred.

Methoxyl, Sulphur, Phosphorus and Crude Fibre: Only limited success has been achieved with these substances. Anthony and Reid (1958) found that the herbage dry matter digestibility and faecal methoxyl content of steers were closely correlated (r = -0.74) over a range of digestibility from 50 - 75 per cent. However the recovery in the faeces was only 63.5 per cent and it was suggested that it could only be used as an approximate guide where digestibilities differed markedly. Similarly Barrow and Lambourne (1962) working with Merino wethers found that the sulphur and phosphorus contents of faeces were correlated with digestibility, although they were inferior to nitrogen as indicators. The use of crude fibre has also been proposed (Raymond et al., 1954), but again would not appear to confer any benefits over nitrogen.

2. Determination of 'In Vitro' Digestibility

While limited correlations have been found between in vivo herbage digestibility and the contents of individual chemical components such as crude protein, crude fibre or lignin, these relationships tend to be rather unreliable. However with the development of oesophageal and rumen fistula, increasing attention is being focussed upon in vitro rumen fermentation techniques, in which feeding stuffs are digested by preparations of micro-organisms or of enzymes which are similar in function to those present in the digestive tract of the ruminant.

Reviews by Shelton and Reid (1960) and Reid (1962) have observed a considerable divergence in the relationships between in vivo digestibilities and the various in vitro measurements. However in 1960, Tilley et al., noted that a large proportion of the protein digestion occurred after leaving the rumen and thus was not accounted for when only using rumen micro-organisms. While no precise attempt was made to simulate digestion in vivo, the imposition of a second digestion stage involving acid-pepsin reduced the standard error of estimate considerably from approximately ± 4 to ± 2. Further work with this technique by Tilley and Terry (1963), involving 130 samples of grass and 18 samples of clover and lucerne, established the regression equation (3) relating the <u>in vivo</u> (Y) and <u>in vitro</u> dry matter digestibility (X).

$$Y = 0.99x - 1.01 \ (\pm 2.31) \qquad r = 0.97 \text{ ---(3)}$$

A similar correlation of 0.97 was achieved by Alexander and McGowan (1961) using thirteen herbage samples already analysed by Tilley.

In applying the two stage digestion technique to conserved forages necessary for winter feeding, Alexander (1969) has described modifications to the procedure used by Tilley et al., (1960) which have been designed to increase the accuracy of prediction and the speed of throughput. Working with 18 grasses and 25 hays, Alexander and McGowan (1966) expressed the <u>in vivo/in vitro</u> relationship of the organic matter digestibilities by the regression equation (4) which has a correlation coefficient of 0.96.

$$Y = 0.97x + 5.03 \text{ ---(4)}$$

where Y = organic matter digestibility in vivo

X = " " " in vitro

The relative standard deviation of $\pm$ 2.33 associated with this equation is greater than that of an earlier report on dried grasses alone (Armstrong et al., 1964a), however this trial included data from six different centres. On a more limited scale, with three hays of varying quality and three artificially dried grasses, Alexander (1966) obtained a highly significant correlation ($r = 0.998$ $p = 0.001$) for the <u>in vivo/in vitro</u> digestibility relationship.

Work with silage has been less satisfactory. Simkins and Baumgardt (1963), Raymond and Terry (1966) and Alexander (1969) all obtained poor correlation coefficients when working with silage dry matters. Raymond and Terry (1966) proposed that errors were introduced by chemical changes and loss of volatile constituents during the heat drying of silage prior to analysis. Accordingly, Alexander and McGowan (1969) developed a homogeniser capable of preparing a fresh silage suspension with 4 per cent dry matter, which could subsequently be analysed without any drying being involved. In one trial they obtained a highly significant ($P < .001$) correlation between *in vivo* and *in vitro* digestibility determinations ($r = 0.86$) with 12 different silages. However the predictive accuracy of the regression equations were significantly improved for all the fresh silages analysed when percentage dry matter was included with *in vitro* digestibility in a bivariate regression.

B. DETERMINATION OF FAECAL OUTPUT

In accordance with equation (1), the weight of faeces voided, together with the forage digestibility will provide an indirect measure of the feed intake. For stall fed animals the most straight forward method of measuring faecal output is by the use of harnesses and collection bags. However under grazing systems, or loose housing, Reid (1962) has stated that this equipment may influence behaviour, cause the animal considerable distress, and increase the energy expenditure. This has led to the development of marker techniques whereby the regular dosage of an animal with known quantities of a completely indigestible external tracer enables a calculation to be made of the total quantity of faeces from the concentration of this tracer in the faeces. The inherent assumption is that the marker, and the component of the digesta being measured, move at the same speed through the gut. McDonald (1962) however, stresses that one of the functions of the rumen and reticulum is to control the passage of digesta into the omasum and abomasum, resulting in fluids and minute particles moving out of the rumen at very different rates from large food particles. This phenomenon not only introduces problems of simulation, but is responsible for diurnal fluctuations in the faecal concentration of external tracers, which may prevent grab samples from the rectum being truly representative of the marker concentration in the total faeces.

Raymond and Minson (1955) in reviewing the literature have reported the use of a large number of external indicators including silica, ferric oxide, barium sulphate, monastral blue, titanium oxide, polyethylene glycol, radioactive tracers, anthraquinone violet dye and chromium sesquioxide. However, the discussion will be limited mainly to chromium sesquioxide (Cr_2O_3) in view of its widespread use, particularly in grazing studies.

Faecal Recovery: One basic prerequisite of an external tracer such as chromium sesquioxide is that it should provide a 100 per cent recovery in the faeces, or at least a constant recovery which can then be allowed for in subsequent calculations. In order to express these absolute recovery values a number of studies have used total collections to supplement their grab samples. The results are shown in Table 2.

TABLE 2

Mean percentage recovery of chromium sesquioxide in the faeces as measured by total collections

Mean % Recovery G_2O_3	Collection Period (days)	Animals Used	Reference
99.9	54	3 cows	Kane et. al. (1952)
100.7	40	3 cows	Lancaster et al. (1953)
100.7	11	6 steers	Hardison & Reid (1953)
97.5	7	4 cows	Smith & Reid (1955)
85.4	3	4 steers	Brisson et al. (1957)
97.2	5	6 cows	Corbett et al. (1958a)
99.6	4	4 cows	Putnam et al. (1958)
97.4	91	6 cows	Stevenson (1962)
96.1	3	3 steers	Langlands et al. (1963)
95.4	6	11 cows	Curran et al. (1967)

These results are general averages which apply to different environments and different trial conditions, and as such are not strictly comparable. However in certain trials very low recoveries have been reported. The low recoveries reported by Brisson et al., (1957) were due to faecal loss, but Curran et al., (1967) has found differences between methods of administration. When given in capsules, only 89.8 per cent of the chromium sesquioxide was recovered in the faeces, compared to 100.9 per cent with administration in a cubed feed. Capsules however have generally been preferred to avoid any wastage in feeding. (Smith and Reid, 1955).

It is apparent that in many of the trials there have been small losses of chromium sesquioxide which may have been due to (a) regurgitation (b) absorbtion of soluble chromate (c) retention in the bovine tract (d) loss of faeces (e) losses in grinding faecal samples (f) and analytical losses. In particular, a grinding loss of 2.66 per cent reported by Stevenson (1962) may be fairly common.

The duration of the collection period is important since Lancaster et al., (1953) has found a variation of 90 - 119 per cent in five day collection periods. Stevenson (1962) noted that level of intake or faecal output, had no effect on chromium sesquioxide recoveries, but she also reported an inter-week variation. Before commencement of the collection period Charlet-Lery (1969) recommended an adaption period of 10 - 12 days followed by a preliminary period of 10 days after the chromium sesquioxide has been introduced.

Diurnal Fluctuations: In contrast to the absolute recovery, which refers to the weight of marker recovered, expressed as a percentage of the weight of marker administered, a number of authors have expressed a range of recoveries for sampling at different times through the day. These have been termed 'relative recoveries' by Curran et al., (1967) and refer to the concentration of the marker in a given sample of faeces expressed as a percentage of the daily mean concentration in the faeces. Although the use of the term 'recovery' may lead to confusion, its purpose has been to demonstrate the range of diurnal variation which can be responsible for sampling errors when using grab samples.

Putnam et al., (1958) found chromium sesquioxide relative recoveries varying from 85 - 124 per cent when cows were fed indoors. In the field however, intake is not so easily controlled and the fluctuations tend to be greater. Smith and Reid (1955) reported a variation from 65 - 141 per cent with cows, although an even greater difference of 50 - 180 per cent was obtained with steers at pasture (Hardison and Reid, 1953). As shown by fig. 1 the fluctuations tend to be in an opposite direction to those determined with house feeding.

It can also be seen in fig. 1 that the extreme intraday variability precludes random sampling. With dairy cows however, practical limitations restrict the choice of sampling times. Conveniently, accurate estimates of faecal output in cows have been obtained by bulking grab samples of faeces taken at 6.00am and 4.00pm. (Kane et al., 1953a; Hardison and Reid, 1953; Lancaster et al., 1953). Using these sampling times Smith and Reid (1955) found a close correlation ($r = 0.983$) between estimated and measured outputs of dry matter. Raymond and Minson (1955) however were unable to establish a constant diurnal pattern, and suggested that fresh faeces be sampled direct from the grazing sward. Further work (Minson et al., 1960) enabled the faeces of six different bullocks to be identified by the use of different coloured polystyrene particles.

Factors influencing the diurnal variation pattern have been studied by several workers. The time of daily administration of chromic oxide would appear to have an important influence (Balch et al., 1957, Putnam et al., 1958). This is demonstrated by a comparison of figs. 1 and 2 where indoor comparisons have been standardised according to this factor.

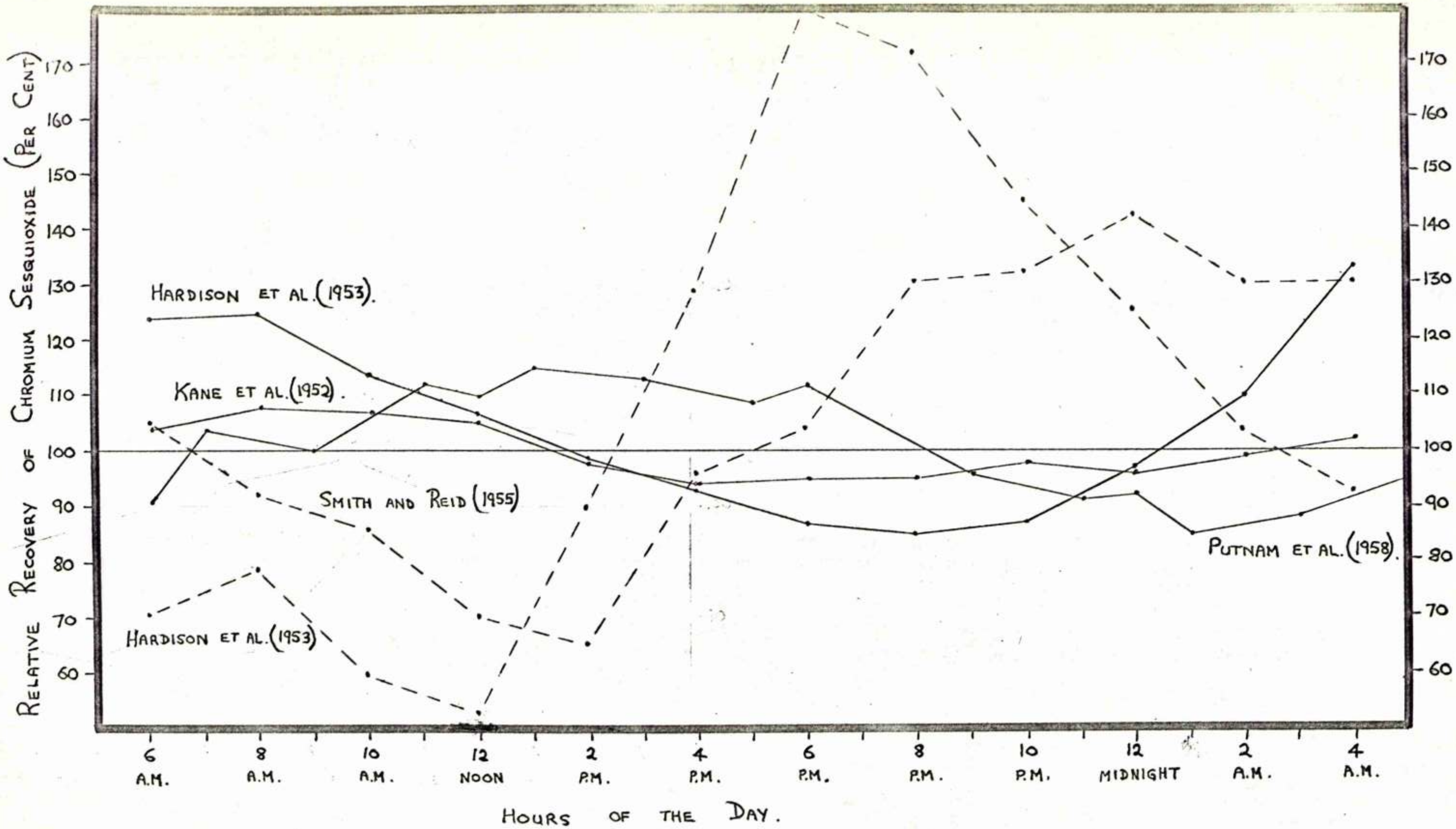


FIG. I Relative Chromium Sesquioxide recovery at different hours of the day for cattle when grazing (dotted line) and when house fed (continuous line).

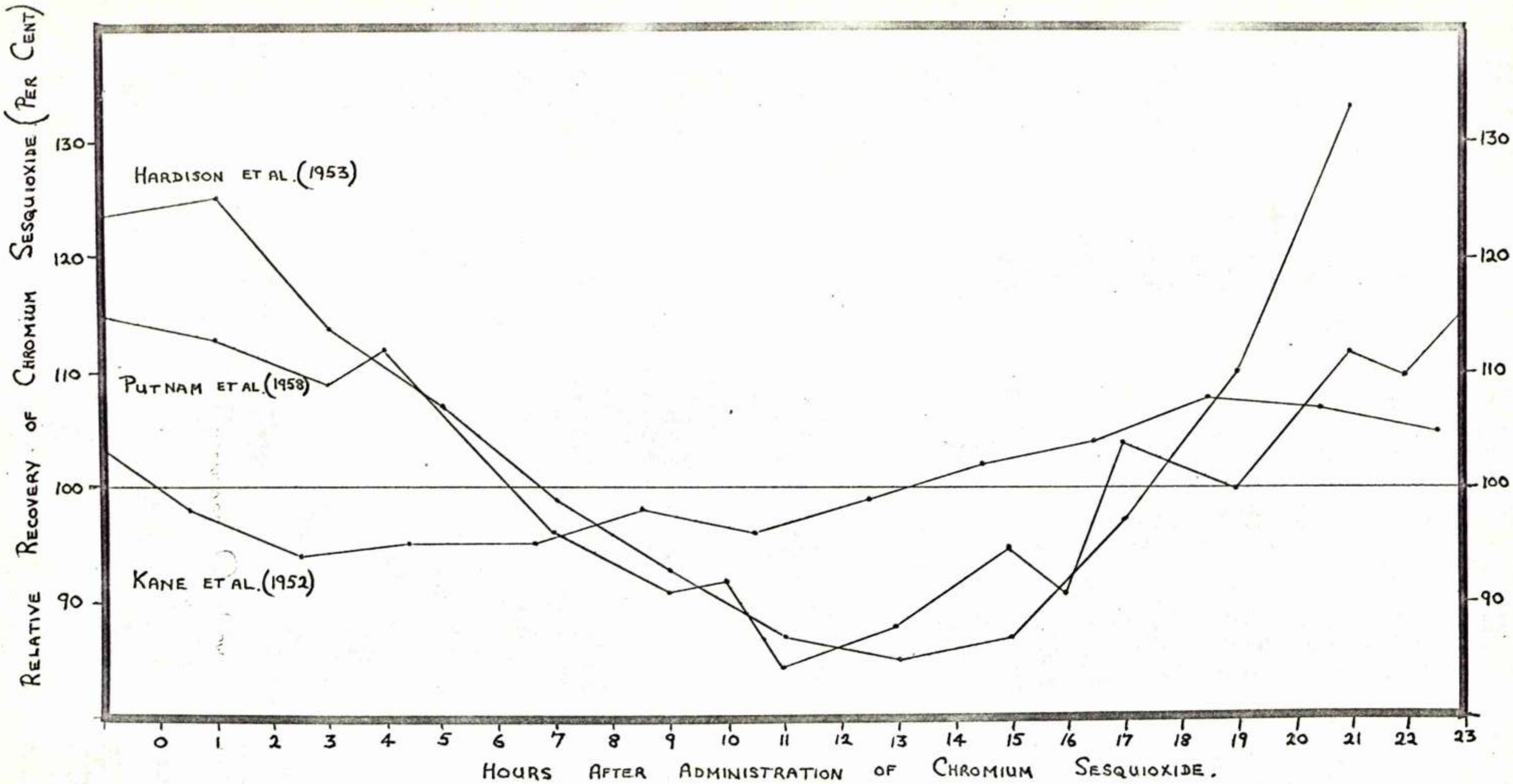


FIG. 2 Relative hourly chromium sesquioxide recovery in house fed trials when standardised according to time of administration.

It was suggested by Putnam et al., (1958) that in the first 30 to 60 minutes after entering the rumen, a large proportion of the chromic oxide from capsules passed into the omasum without becoming evenly mixed with digesta. It is therefore desirable that administration should be followed by a period of maximum intake which, according to the behaviour studies of M.A.F.F. (1967), would coincide conveniently with the time of milking.

In contrast to Mahaffey et al., (1954), Brisson et al., (1957) found a more even distribution when they divided 20 g. chromic oxide into six doses daily. However more refined techniques have been introduced which are less laborious. Pigden and Brisson (1957) developed a sustained release pellet by coating a chromic oxide capsule with plaster of paris, while Corbett et al., (1958b) achieved a similar effect by impregnating paper with chromic oxide. In a comparison of the two, Corbett et al., (1958b) noted that the plaster provided a more uniform release than the paper, but the latter had the advantage of containing 1 per cent aluminium sulphate which attracted oxide particles, and so was perhaps more representative of the passage of dry matter through the bovine tract. Even with this paper however, Langlands et al., (1963) noted a significant difference between estimated faecal output from chromic oxide and actual faecal output.

C. THE DIRECT MEASUREMENT OF INDIVIDUAL FEED INTAKE IN LOOSE HOUSING

Broadbent (1967a) has developed an individual feeding device which is capable of restricting individual animals to their own allocation of food while exposed to the influences of group housing. Each device is dependent upon an electronic unit which may only be activated by one particular animal, and Broadbent (1967b) reported that up to twelve different frequencies had been used within a group. Since the technique is still being developed, and is the subject for the experimental work of this dissertation, the potential of the method is unknown. However if loose housing behaviour and feed intake are normal, as found by Broadbent (1967a), the method offers a more accurate approach to measuring forage intake than by the use of internal and external indicators.

It is perhaps not directly comparable with indicator methods on two accounts however.

(1) A principal disadvantage is that the technique is dependent on trough feeding, so may only simulate 'easy feeding' and not the commonly practised, self feeding system.

(2) Alternatively the technique offers the considerable advantage of being able to compare different forage feeding regimes within the same loose housing environment.

D. CONCLUSIONS

Digestibility indicator methods are reliant upon an accurate knowledge of 'forage consumed'. In view of the selectivity observed in grazing animals (Hardison et al., 1954; Weir et al., 1959) it is probable that a certain degree of individual food selection will be practised by loose housed cows, the extent depending upon managerial circumstances. Where digestibility is estimated by the ratio or the *in vitro* technique the use of an oesophageal or rumen fistula can provide a much more accurate sample of forage consumed that would otherwise be obtainable (Tayler and Deriaz (1963)). However this procedure has large economic and labour demands.

The necessity for a knowledge of 'forage consumed' in the faecal index technique may not be immediately apparent. However Lambourne and Reardon (1962) found a distribution of nitrogen and chromogen in herbage, where the immature stem and leaf sheath gave faeces with lower values of these two constituents than from the leaf alone, although their digestibilities were similar. Since animals will select the leaf before the stem (Raymond, 1966) a general regression of forage digestibility on faecal nitrogen or chromogen, based upon whole cut herbage, would predict a much higher digestibility for this material at any given nitrogen concentration (Fig. 3). Raymond et al., (1959) found that a given concentration of nitrogen in the faeces may be associated with a slightly lower digestibility of 1 - 2 units in the grazing animal than in its stall fed counterpart, while Langlands (1967) obtained a difference of approximately 6 units. In addition to selection, these errors could be caused by a higher level of feed intake while grazing (Raymond et al., 1959), and a consequently reduced digestive efficiency (Blaxter,

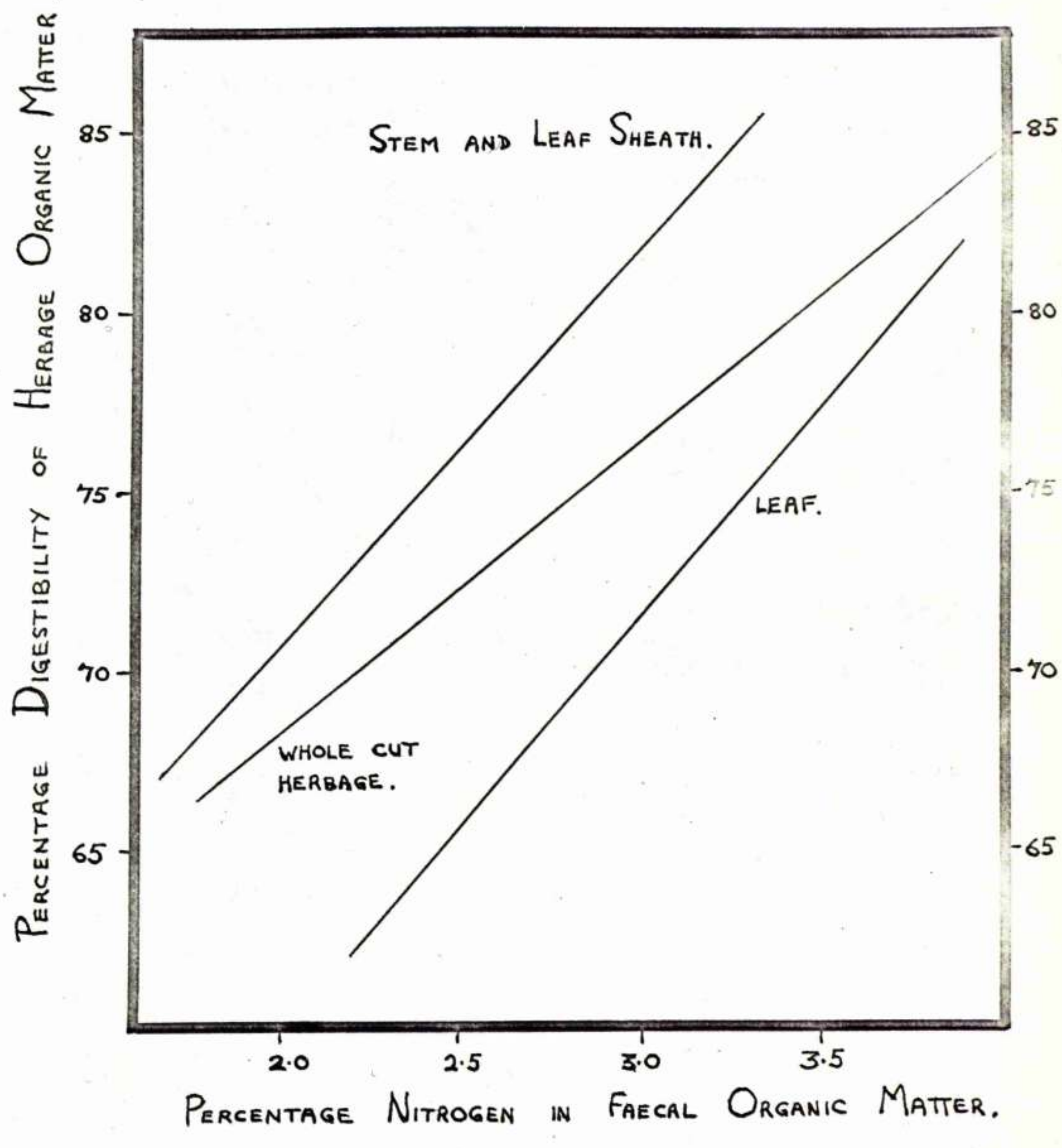


FIG. 3 Relationships between percentage digestibility of herbage organic matter and percentage nitrogen in faecal organic matter, for whole cut herbage and for leaf rich and stem rich fractions separated from these herbages.

Lambourne and Reardon (1962). Nature 196 961.

1967) which may also be characteristic of loose housed feeding. The application of values determined under stall feeding conditions, such as with the use of a separate digestion trial or the faecal index method, may therefore be questioned when applied to loose housing, although selection will undoubtedly have a smaller influence than at pasture.

Such application errors may also be extended to the _in vitro_ procedures, where sheep are generally preferred to cows as a source of inoculum in view of their smaller feed requirements and easier handling. To maintain standardisation between batches, these animals are generally fed at maintenance levels and on a uniform ration such as hay. The errors involved in applying digestibility values determined in this way to cows feeding on silage at levels above maintenance are unknown, particularly since _in vivo/in vitro_ relationships are generally based upon _in vivo_ data with sheep fed at maintenance. Nevertheless, Raymond and Terry (1966) have stated that the digestion efficiencies of sheep and cattle are similar.

Another possible source of error involved with the use of indicators is associated with the absolute faecal recovery. Internal indicators are particularly variable, but with chromium sesquioxide there appears to be a relatively consistent under recovery (Table 2) leading to an upward bias of faecal output. When used in conjunction with an internal indicator such as nitrogen or chromogen though, both Lambourne and Reardon (1963) and Langlands et al., (1963) concluded that the bias in faecal output would tent to compensate to some extent any bias in the estimate of digestibility. However, since the recovery of chromium sesquioxide is relatively consistent between individuals in a trial Greenhalgh (1969) suggests that individual intakes can be calculated simply in inverse proportion to faecal chromium sesquioxide concentration, provided the total food intake of the group is known. Although this avoids the necessity of digestibility indicators, no account is taken of any differences in individual selection.

It is apparent that the many variables associated with indicator studies have limited the usefulness of indirect estimates of feed intake in loose housing and so restricted the experimental work on this subject. The use of individual electronic feeders in loose housing may provide an opportunity to extend this field of study.

S E C T I O N II

THE INFLUENCE OF VOLUNTARY INTAKE IN THE FEEDING OF HAY OR SILAGE TO DAIRY COWS

At present, low cost feeding of the dairy cow is dependent upon a large proportion of nutrients being provided in the form of roughage. With cows of high genetic potential an increased nutrient intake is not only associated with an increase in milk production but also an increased efficiency of conversion (Blaxter, 1967). It is therefore pertinent to study the factors affecting the voluntary intake of nutrients, particularly in roughage, in order that optimum economic resources can be utilised to achieve maximum efficiency.

A. FACTORS AFFECTING VOLUNTARY INTAKE

1. Physical Limitations

Fatigue: Voisin (1955) proposed that a cessation of eating may be brought about by jaw fatigue and that intake of a particular food may be governed by the degree of mastication necessary. In a detailed study however, Duckworth and Shirlaw (1958a) found no relationship between the number of chews cudding and the weights of either the wet or dry matter consumed. Nevertheless, there was a negative correlation between the number of bites of eating and the weight of grass wet matter consumed, the rate of eating also declining towards the end of a meal. The influence of fatigue was later shown to have a very small effect by Campling and Balch (1961). Using a rumen fistula they collected all the hay swallowed during the first three hours of a meal and found that this extended the period of eating from 3 - 4 to 6.5 - 8 hours and increased intake by 77 per cent. Since the cows did not eat as much dry matter as had been removed through the fistula it is possible that some satiation of appetite had occurred.

Gut Distension and Rate of Passage: Since ruminants have been evolved to utilize bulky fodders the limitations of physical size have often been regarded as a determining factor regulating appetite. Campling and Balch (1961) reported that when bladders full of water were substituted for digesta the mean voluntary intake of hay fell by 0.54 lb. for every 10 lb. water in the bladders. Further experiments (Freer and Campling, 1963) found that cows would cease eating roughage in the form of hay or dried grass when the reticulo-rumen contained about 250 lb. digesta (35 lb. dry matter). Blaxter, Wainman and Wilson (1961) also noted that sheep ate to a constant gut fill with hays of varying quality.

In contrast to these experiments Campling et al., (1961) reported that immediately after a meal the dry weight of digesta in the reticulo-rumen of cows offered ad lib. hay was 35 per cent greater than with straw, but only 6 per cent greater before the next meal. Although the intra-ruminal infusion of 150 g. urea increased straw intakes by 39 per cent (Campling et al., 1962) approximately equal amounts of digesta dry matter were still found in the reticulo-rumens of cows offered straw ad lib. with or without urea twenty-four hours after feeding began. These authors therefore hypothesised that intakes of hay and straw were regulated in relation to the respective rates of dissappearance of the digesta derived from each diet in such a way that there was a constant amount of food residue (19 lb. dry matter) in the reticulo-rumen immediately before feeding. Later work (Freer and Campling, 1963) suggested that this theory did not apply to high quality roughages, such as dried grass, where the daily rate of dissappearance of digesta from the reticulo rumen was greater than 18 lb. dry matter. In a comparison of hay and silage Campling,(1966b) found that the amount of digesta in the reticulo rumen immediately after a meal ad lib. was greater with hay than silage, although silage residues tended to remain in the gut longer by virtue of a slower rate of passage.

The 10 - 15 per cent individual variation in voluntary intake (Campling, 1966a) may perhaps be partly explained by differences in physical ability. Balch and Campling (1962) in a comprehensive review presented evidence of a positive relationship between the weight of the empty reticulo-rumen and the voluntary intake of cows, while Campling et al., (1961) noted a positive relationship in four cows between digestive efficiency - measured by the retention time of food residues - and the voluntary intake of hay.

Pregnancy: The effect of pregnancy acting as a further limitation to gut distension might be expected. Indeed Graham and Williams (1962) observed that in pregnant ewes the amount of digesta in the alimentary tract decreased by 150 g. per kilogram increase in concepta when fed on a constant diet. Little work has been done on directly comparing the voluntary intake of pregnant and non pregnant cows. Campling (1966c) during preliminary observations with monozygotic twin heifers noted that in five of six pairs the voluntary intake of hay was depressed by pregnancy.

2. Physiological Regulations

Evidence that the amount of digesta in the reticulo rumen and its rate of disappearance were not the sole factors governing appetite was provided by Freer and Campling (1963). When three cows were offered a concentrate mixture ad lib. the amounts of digesta in the reticulo-rumen did not approach the amounts of either hay or dried grass before or after eating.

The existence of a central nervous regulatory mechanism in ruminants with some control over appetite is known. Balch and Campling (1962) have reviewed experiments concerned with the electrical stimulation of the hypothalamus, cerebral cortex and medulla oblongata which have induced feeding behaviour. Little is known however of the governing factors.

Thermostatic theory: Blaxter (1967) has reviewed the theory that eating is a response to a fall in heat production and that the cessation of eating is a response to a rise in heat production governed by the hypothalamus. However, he points out that poor quality roughages are associated with a lower voluntary intake than high quality rations despite the increased heat production with the latter.

Chemostatic theory: Montgomery and Baumgardt (1965) and McCullough (1969) have both suggested that with diets high in nutritive value, food intake may be regulated to keep energy intake constant. Intravenous infusions of glucose have not affected voluntary intake (Holder, 1963) and it has been postulated by Balch and Campling (1962) that the concentration of metabolites, such as acetic acid, may have a more pronounced effect. Sodium acetate, acetic and propionic acid when infused intravenously into cattle depressed voluntary intake (Dowden and Jacobson, 1960), and in cows on a ration of hay, infusion of acetic acid into the reticulo-rumen had the largest depressant effect of the volatile fatty acids (Montgomery et al., 1963).

Other substances, present in silage, have also been shown to have an inhibitory effect on voluntary intake. Thomas et al., (1961) found that the intake of both silage and hay was reduced when the effluent liquid from a silo, large quantities of lactic acid or lactic plus other silage acids, urea or other ammonium salts were placed directly in the rumen. Hillman et al., (1958) demonstrated that adjusting the pH of silage to that of hay did not affect voluntary intake. Experiments with histamine have been inconclusive (Okamoto et al., 1964).

Lipostatic theory: Kennedy (1961) proposed that animals adjusted their intake to maintain constant body fat stores. This was supported by Hutton (1963), who observed that stage of lactation and degree of fatness were both related to voluntary intake. By itself however, it does not explain the consistently higher digestible organic matter intakes of cows fed on a ration of dried grass compared to concentrates. (Freer and Campling, 1963).

Hormones: Balch and Campling (1962) have reported a number of experiments involving the administration of exogenous thyroxine, but they have not always been accompanied by an increase in voluntary intake. Limitations of these studies have been induced by the frequent use of bulky fodders which may physically restrict intake and by the influence that hormones may have on energy requirements per se. It is not known whether the increased voluntary intake observed during lactation (Hutton, 1963; Campling, 1966c) is in accord with the lipostatic theory, or of hormonal origin. Similarly the increased appetite observed when the frequency of feeding is increased (Balch and Campling, 1962; Campling, 1966b) may be associated with a hormonal effect.

3. Forage Preparation

It has frequently been reported (Larsen, 1960; Moore et al., 1960; Brown et al., 1963; Murdoch and Rook, 1963; Campling, 1966b; Jones, 1967) that cows consume more dry matter in the form of hay rather than silage, although no satisfactory explanation of the difference has yet been provided.

Putnam and Loosli (1959), Blaxter et al., (1961), and Campling (1966a) have demonstrated that voluntary intake was directly related to the dry matter digestibility of a food up to 70 per cent, and inversely related to the mean retention time of food residues in the digestive tract. Although higher digestibilities are generally associated with shorter retention times, the opposite may occur (McCullough, 1969). Where digestibility of the diet is greater than 70 per cent the association between voluntary intake and digestibility is often poor (Hutton, 1963; Murdoch, 1967). In fact, when McCullough (1969) working with steers, increased the dry matter digestibility of the ration by varying the concentrate:hay ratio he found that above 80 per cent concentrates or 70.3 per cent dry matter digestibility, voluntary intake and apparent digestibility were negatively related.

To standardise digestibilities, comparisons of silage and hay have been made from similar herbage cut at the same stage of maturity, but silage dry matter intakes are still generally lower (Campling, 1966b; Brown et al., 1963). The water contained in silage is probably not directly a governing factor (Moore et al., 1960; Hillman et al., 1958), although within limits the drier the silage the more of it will be consumed (Moore et al., 1960; Duckworth and Shirlaw, 1958b) and prewilting herbage is an effective method of increasing silage intake (Murdoch, 1960).

It has not been established to what extent the perceptive faculties are involved, but Balch and Campling (1962) have reviewed some experiments on taste, smell and palatibility. It would appear that these senses play a larger part in the initiation of eating rather than in the determination of the amount eaten, and are most important when there is a choice of foods. Nevertheless, the inhibitory effect of certain silage acids has already been reviewed in the discussion of the chemostatic theory.

The physical form of the ration may also have an important effect on voluntary intake. Grinding or chopping roughages results in a smaller particle size which may increase its rate of passage through the digestive tract. Murdoch (1965) found that chopping silage into pieces about 1 - 2 inches long before feeding, led to marked increases in the quantity of silage eaten, although chopping hay in a similar manner gave no increase in voluntary intake. On the other hand, Duckworth and Shirlaw (1958b) observed that chopping silage significantly reduced the daily dry matter intake. However, this trial had a crossover design with experimental periods of only seven days. Campling and Freer (1966) reported that the mean voluntary intake of long and ground dried grass were similar although the voluntary intake of ground pelleted straw was 26 per cent greater than of long straw. Since the digestibility of the roughage was reduced by grinding there would appear to be little benefit in reducing particle size when high quality roughages are on offer unless a better fermentation is achieved. (Watson and Nash, 1960).

4. Concentrate Substitution

Since concentrates, balanced for milk production, are frequently fed to lactating cows, it is necessary to establish their influence upon roughage intake. With restricted amounts of concentrates, total dry matter intake generally increases although the intake of roughage often declines (Campling, 1964), the extent depending upon the quality of the roughage (Blaxter et al., 1961). The more digestible the roughage the greater the depression of roughage intake.

This was explained by Campling, Freer and Balch (1962), who suggested that the addition of a protein rich concentrate to low quality roughages increased the cellulolytic activity of the rumen microflora and accelerated the rate of disappearance of the digesta, subsequently increasing intake. In contrast, the addition of carbohydrate supplements to high quality roughage may slow down cellulolytic activity and reduce roughage intake (Campling, 1966a). Campling and Murdoch (1966) suggested that the addition of up to 12 lb. concentrates per day to a forage diet had only a small effect on the intake of forage but that larger amounts of concentrates, up to 20 lb., reduced the intake of dry matter by 0.2 to 0.4 lb/lb. of concentrate given, the reduction being more marked with high quality roughages.

At high levels of concentrates, McCullough (1969) found that the inclusion of hay in the diet increased the dry matter intake of steers between the weights of 318 - 363 kg. With younger animals, the inclusion of hay depressed the daily dry matter intake. Putnam and Loosli (1959) observed that dry matter intakes increased as the proportion of concentrates was raised from 20 to 60 per cent of the ration.

B. THE INFLUENCE OF HAY AND SILAGE ON MILK PRODUCTION

Watson and Nash (1960) in reviewing the limited comparisons made in Britain at this time, concluded that hay and silage produced milk yields compatible with their nutrient content and digestibility when combined with concentrates as a feed for dairy cows. Since the limitations of forage nutrient value demand that roughage is supplemented with concentrates when feeding high yielding dairy cows according to production, very few comparisons have been made with hay or silage as the sole nutrient source. In such a comparison however, Brown et al., (1963) found that cows on an all silage diet consumed 25.8 lb. dry matter per day and produced 27.6 lb. 4 per cent fat corrected milk, as opposed to consuming 37.7 lb. dry matter per day and producing 29.4 lb. 4 per cent fat corrected milk on an all hay ration. Thus when compared on the basis of 4 per cent fat corrected milk produced per lb. of dry matter consumed, the efficiency of dry matter utilisation was considerably higher for the all silage group. This is in agreement with the work of Murdoch and Rook (1963) at the National Institute for Research in Dairying.

Where limited concentrates have been fed, results from trials in America (Huffman, 1958), the Netherlands (Larsen, 1960) and Britain (Murdoch, 1962), have shown that where silage is cut from a grass crop at an earlier stage of physiological development than hay, and fed at the same dry matter intake, a higher milk yield is obtained from a ration based on silage than with one based on hay. The association of forage digestibility, stage of maturity and milk yield is thus well known. (Watson and Nash, 1960).

When, however, silage is compared with equal quantities of hay dry matter from similar herbage cut at the same stage of maturity, little or no difference in milk yield has been obtained in some trials (Murdoch, 1962; Murdoch and Rook, 1963) while in others silage has given a higher milk yield (Murdoch, 1959a; Brown et al., 1963). Since Murdoch has only used three or four week experimental periods as opposed to thirteen weeks by Brown et al., there may have been insufficient time to establish any trend.

The increased use of ad lib. roughage feeding in the United Kingdom merits consideration of its effect on milk production. It has already been mentioned that in general, more dry matter is eaten in the form of hay than silage under these conditions, and in fact, the higher dry matter intakes have often been associated with increased milk yields (Moore et al., 1960; Murdoch and Rook, 1963), although this is not invariably so (Brown et al, 1963; Jones, 1967). Influences due to environment and heredity may partly bring about such discrepancies, but the trend, although not always significant, has been towards an increased milk production with the higher dry matter intake. Jones (1967) points out that high intakes of roughage dry matter must be accompanied by savings in concentrates to avoid a 'luxury consumption' whereby the additional nutrients are utilised for increasing body weight rather than milk yield.

Furthermore, the higher dry matter intakes achieved by feeding hay would not appear to confer any benefits on the persistency of lactation. Both Moore et al., (1960) and Larson (1960) noted no significant differences between the decline of milk yield on either hay or silage rations, although Brown et al., (1963) found that over a 90 day trial cows on silage were more persistent in milk production (91.6%) than cows receiving hay (86.7%) (P 0.05).

The role of concentrates in milk production is important and may confuse the interpretation of different trials. It has been noted that supplementation with concentrates generally increases the total dry matter intake, although it reduces the dry matter intake of either hay or silage (Campling, 1964). Murdoch and Rook (1963) compared three levels of concentrate feeding of 0, 2 and 4 lb. per gallon with either ad lib. silage or barn dried hay. With both roughages, milk production increased with the concentrate level, although the superiority of the hay was reduced at the upper concentrate level. Similarly Brown et al., (1963) obtained a greater milk production response from feeding 2.5 lb. grain per gallon of milk produced, to cows consuming silage than to cows consuming hay. This increased response may tend to counteract any advantage that hay obtains by virtue of a higher dry matter intake, and would be in accordance with the review of American literature by Huffman (1958) who reported that differences between hay and silage were often ruled out where grain was also fed. Further evidence to this theory was provided by Campling and Murdoch (1966), who found that concentrates depressed the dry matter intake of hay more than that of silage at similar concentrate levels.

The inevitable exception was provided by Nordfeldt (1966) in Sweden, who found that as the proportion of concentrates in the ration increased from 30 - 60 per cent, milk production increased from 15.7 to 17.4 kg. fat corrected milk /cow /day with cows receiving hay, but only from 15.1 to 15.5 kg. fat corrected milk /cow /day with cows on silage.

C. THE INFLUENCE OF HAY AND SILAGE ON THE COMPOSITION OF MILK

Watson and Nash (1960) in an extensive review, concluded that in general no conservation product specifically affected the fat content of milk, although in certain cases the solids-not-fat content of milk dropped below the legal minimum of 8.5 per cent, particularly with high silage rations.

In experiments where hay and silage were fed on an equal dry matter basis, Murdoch (1959a), Murdoch (1962), Murdock and Rook (1963) and Nordfeldt (1966) have all reported a slight decrease in the percentage solids-not-fat (S.N.F.) with silage, but in no case was this drop of experimental significance. In comparing two levels of dry matter intakes of 16.0 and 8.0 lb/day with both hay and silage, and a mean concentrate intake of 14.0 lb/day, Murdoch (1962) found a slight decrease in the percentage S.N.F. and a slight increase in the percentage fat at the lower level with both hay and silage so that total solids did not differ markedly.

Where hay was cut from herbage at a later stage of maturity than silage and offered ad lib., Murdoch (1962) observed an increase in both percentage fat and percentage S.N.F., such that cows on hay produced milk of 12.96 per cent total solids, compared to 12.68 per cent total solids from cows on silage. In a similar trial, Larsen (1960) found significant differences.

Murdoch and Rook (1963) conducted a series of trials using hay and silage from similar herbage cut at the same stage of maturity. Where ad lib. roughage was provided as the sole feed, the consumption of 32 lb. dry matter in the form of barn dried hay produced milk with 8.70 per cent S.N.F., while cows on silage only consumed 20 lb. dry matter and produced milk of 8.50 per cent S.N.F. This difference in the solids-

-not-fat content was significant ($P<0.01$) although the percentage fat was similar under both regimes. Furthermore, when a concentrate treatment of 4 lb. per gallon of milk produced was superimposed upon this trial, the percentage S.N.F. increased significantly ($P<0.05$) with hay and silage although the percentage fat was again unaltered. In this trial the total solids for concentrate levels of 0, 2 and 4 lb/gallon were 11.09, 11.81 and 11.88 per cent for silage and 12.16, 12.15 and 12.64 per cent for barn dried hay. In similar trials involving ad lib. roughage feeding, Jones (1967) found no difference in the percentage total solids from silage or hay based rations.

D. CONCLUSIONS

The control of voluntary intake would appear to be largely dependent on the type or quality of food being assimilated. Campling, Freer, and Balch (1962) showed that with low quality roughage, intake was regulated in relation to the rate of disappearance of digesta from the reticulo-rumen and that either the addition of concentrates or chopping the roughage could markedly improve the dry matter intake. (Campling and Freer, 1966). Higher dry matter intakes are usually accompanied by an increased, although limited, milk production (Murdoch and Rook, 1963).

Where comparatively high quality roughages are being fed, intake is apparently limited by the capacity of the reticulo-rumen at a meal and the subsequent rate of disappearance of digesta from this organ. (Freer and Campling, 1963). Silage has a slower rate of passage through the digestive tract than hay (Campling, 1966b), and is usually associated with lower dry matter intakes. Nevertheless, Brown et al., (1963) found that even under these circumstances silage could support a similar milk production to hay made from the same field at a similar stage of maturity, albeit with the loss of a certain amount of body weight.

The introduction of concentrates in complement with high quality roughage tends to reduce the difference in dry matter intake between hay and silage (Campling and Murdoch, 1966), but will increase the total dry matter intake as the proportion of concentrates in the ration rises to at least 60 per cent. (Putnam and Loosli, 1959). In terms of nutrient intake per lb. of fat corrected milk produced, there will be a decline of efficiency at the higher concentrate levels.

In the comparison of the effect of hay and silage on milk quality, there would appear to be few consistent trends. In general, the percentage fat was unaffected by the type of roughage, but did show a decline as the proportion of grain in the ration increased. (Putnam and Loosli, 1959). The percentage S.N.F. on the other hand, was lowered where dry matter intakes of silage were much less than hay (Murdoch and Rook, 1963), but increased significantly with concentrate supplementation.

In economic terms, Jones (1967) calculated that the cost per acre of producing barn dried hay was greater than clamp or tower silage, although the cost per lb. of dry matter available for feeding was similar. Unless the higher dry matter intakes achieved with hay are utilised to reduce concentrate costs, cows may be allowed a luxury consumption which will result in a lower margin over feed costs.

SECTION III

THE BEHAVIOUR OF DAIRY COWS IN A LOOSE HOUSING ENVIRONMENT

With the change of management practices towards an increased population density and a reduced labour requirement per cow, the whole concept of social interactions assumes a new intensity. Deviations from optimum conditions result in physiological and behavioural stress adaptations which may perhaps be at the expense of the cow's production output. Under loose-housing regimes in particular, behavioural studies over twenty-four hour periods can be of considerable value in guiding the husbandryman towards an optimal productive efficiency. This section is therefore devoted both to a review of physical and social behavioural patterns under loose housing.

A. PHYSICAL BEHAVIOUR PATTERNS

1. Feeding Behaviour

Farmers are becoming increasingly aware of the important economic contribution that can be made by high quality roughages in the ration. It is therefore common practice to find loose housing systems adapted to provide continuous access to such feed, with concentrates being fed during milking to supply the additional requirements. Although self-feeding silage lends itself to ease of labour, it is uncommon to find farms providing this as the only roughage (Small, 1966), and hay is a frequent supplement. Loose housing behaviour studies have therefore largely been confined to situations of this type, although M.A.F.F. (1967) has reported twenty-four hour studies on six farms, during March, which were at the time using silage as the only roughage.

Time spent eating: The results of the several studies reported in Appendix 1 reveal that on average, feeding occupies 10 - 30 per cent of the total time under loose housing. A similar range of time may be spent loitering around the feed area and collecting yards. Schmisseur et al., (1966) found that approximately one third of this time at the feed bunks was spent ruminating, during which they only took an occasional mouthful of feed. The difficulties of distinguishing between feeding and ruminating involve a certain degree of subjective interpretation which may obviously lead to variation between recorders. However, such a large difference as 10 - 30 per cent encompasses not only differences due to breed, type, age, climate, layout and managerial factors, but also an individual day to day variation. Thus, although the time spent feeding is basically governed by physiological needs, the results of single 24 hour studies such as reported by M.A.F.F. (1967) and Small (1966), are open to question.

Nevertheless, from the limited studies available, the ranges shown in Table 3 might permit some tentative conclusions.

TABLE 3

Approximate ranges of average eating times under different managerial regimes (Extracted from Appendix 1)

SYSTEM	% EATING TIME
Cubicles	11 - 21% (5)
Straw Bedding	12 - 26% (14)
Silage Only	11 - 21% (9)
Hay Only	21 - 23% (2)
Silage + Hay	16 - 26% (10)

(figs. in brackets indicate the number of references)

Fuller (1928), comparing the eating habits of cows in loose boxes with animals in byre stanchions, when free access to hay was allowed, reported that the latter spent only 12.8 per cent of their time feeding as opposed to 24.8 per cent in the loose boxes. Under loose housing however, although Schmisseur et al., (1966) found that cows definitely preferred to use straw bedded areas as opposed to cubicles, the figures in Table 3 would suggest that neither regime by itself has a significant effect on feeding time. On the other hand, the type of roughage would appear to exert some influence, in that the feeding of hay apparently extends the overall eating time.

Rate of eating: Harshbarger (1949) observed that silage was eaten at 1.75 - 2.75 minutes per lb. and hay at 7 - 16 minutes per lb. Furthermore, the rate of eating was highest for Holsteins and lowest for Jerseys, with other breeds intermediate. By contrast, Porter (1953) obtained figures of 3.2 minutes per lb. and 3.0 minutes per lb. for silage and hay respectively. Walker-Love (1954) found rates approximately comparable with Harshbarger. Hay alone was eaten at 14.9 minutes per lb., but when both hay and silage were offered the respective rates of consumption were 9.7 minutes per lb. and 3.9 minutes per lb. With the free choice of hay or silage, although three times more dry matter was eaten as silage, the rate of eating per lb. dry matter was essentially similar for both. More recent work by Walker-Love and Laird (1964) found that when cows were eating 66 lb. self-feed silage and 8 lb. barn dried hay, the time for eating one lb. dry matter of hay was higher than for a similar weight of silage. The variations in the rate of ingestion may be partly due to differences in both the quantity and quality of forage consumed.

Feeding Cycles: Schmisseur et al., (1966) reported that under loose housing, group action was the single most important factor in the cow's social behaviour. This phenomenon of allelomimetic behaviour, reported in detail by Hafez (1962), results in peak periods of any one particular activity, and so limits the usefulness of average figures.

Webb et al., (1963) and Jackson et al., (1962) found that loose-housed cows fed on average eighteen times each 24 hours in a self feed silage system. Gelling et al., (1958) noted a maximum of seventeen times, where silage was continuously available for only 21 hours each day, and hay was fed in the byre during milking. Webb et al., (1963) further reported that the cows visited the feeding area more frequently during the night, but spent less time at each feed (5 - 15 minutes as opposed to at least 20 minutes). Seventy-four per cent of the total time spent at the feeders was between 6.00am. and 6.00pm.

The major peaks of feeding activity occur after each milking. Where numbers are restricted, such as at a self-feed silage face, there will be a continuing exchange of cows for about the first three hours after the morning milking (M.A.F.F., 1967), gradually declining towards the afternoon. This trend is repeated subsequent to the next milking, although the intensity of light may play an important part in determining the duration of this period. Webb et al., (1963) observed that eating activity usually terminated about thirty minutes after darkness. When darkness occurred at 6.00pm. cows would leave and return around midnight to feed again; but if darkness was at 8.00pm. cows would remain until 8.30pm. and not come back to feed later that night. The peak of eating around midnight was also found by M.A.F.F. (1967) and Small (1966), followed by a period of very little activity lasting until about 30 minutes before the morning milking.

Where hay is fed at times other than milking, the normal feeding patterns will be disrupted. It can however be used to reduce the crowding at the silage face during peak periods.

2. Drinking Behaviour

Water intake may be influenced by many factors including breed, age, dry matter intake, ambient temperature, protein and salt content of ration, pregnancy and lactation (Hafez, 1962).

On plotting the number of animals drinking in each hour, Small (1966) found that there were peaks of water intake after each milking. In this case none of the cows drank any water after 2.00am., a finding fairly similar to that reported by Hafez, (1962). M.A.F.F. (1967) observed that on average 0.44 per cent of time was spent drinking, but distinct peak periods were not so obvious. There were very few occasions when more than one cow wished to drink at the same time, suggesting that large drinking troughs are unnecessary. The same authors recommended one drinking bowl per 30 cows.

3. Resting Behaviour

Appendix 1 shows that, in general, cows spent 30 - 50 per cent of their time lying down. These figures are subject to seasonal, breed and individual variations. Sixty-five - eighty per cent of the total rumination time occurs while cows are lying down (Hafez, 1962), but the desirability or otherwise of a long resting period is unknown. Balch (1955) concluded that sternal recumbency was an attitudinal prerequisite for the proper functioning of the reticulo-rumen, and that this posture prevented the loss of consciousness associated with sleep.

Schmisseur et al., (1966) and M.A.F.F. (1967) observed that cows will rest for extended periods of time, generally between 1 to 4 hours. Beyond this time they will exhibit an inclination to move rather than continue lying down. As with feeding patterns, cows tend to exhibit strong allelomimetic resting behaviour. Immediately after milking, on those farms where the number feeding at any one time is restricted, cows show the inclination either to feed or to rest. Consequently there is a continuing exchange of cows between those two activities. However, although cows only rest for approximately 40 per cent of the time there is not sufficient exchange to prevent a build up of cows in the bedded area subsequent to the midnight feeding peak. Both M.A.F.F. (1967) and Walker-Love and Laird (1964) found this peak to be approximately 92 per cent of the total herd so that the saving in either bedding space or cubicles is minimal if natural behaviour patterns are to be followed.

With regard to choice, Schmisseur et al., (1966) noted that cows preferred loose-housing on straw as opposed to cubicles. Within the cubicles certain animals showed significant preferences to occupy certain areas or even particular cubicles. Walker-Love and Laird (1964) found that cows preferred the area nearest the door. In both cases however, there was minimal conflict for these particular regions.

4. Loitering Behaviour

Little is known about the significance of this particular activity and its value to milk production. It is however closely associated with defaecation patterns. Although defaecation may occur while the cow is walking or lying down it more commonly happens while standing. Hafez, (1962) notes that cows deposit their excreta haphazardly with respect of location and make little or no effort to avoid walking through or lying in soiled areas. It is recognised, however, that certain animals may lie down in yards near hay hecks where spillage has occurred. For the economical use of bedding and the maintenance of a clean herd it is highly desirable to reduce loitering in the bedded area. While layout and work routines can have obvious effects on the degree of trampling, the introduction of cubicles has been a major improvement towards cleaner cows. (Crowl and Albright, 1965). With straw yards however, advantage can be taken of behaviour patterns to minimise soiling. Lewis and Johnson (1954) observed that loitering in the bedded area increased markedly just before milking and remained at a relatively high level from 9.00pm. to 7.00am., declining thereafter. Bedding the herd in the evening therefore saved considerably in litter usage since the area remained relatively untrampled through to the next morning and did not require further bedding then.

It is recognised that cows in the incidence of storms (Lewis and Johnson, 1954) or of oestrus (Clough et al., 1968) will increase their loitering time in the bedded area.

5. Individual Behaviour

Several experiments have attempted to explain the individual variation as a function of age or yield. The results in Table 4 were presented by M.A.F.F. (1967), but it should be emphasised that they apply only to individual animals at one particular time and on one particular farm.

TABLE 4

A Comparison of Herd and Individual Cows
Percentage of Behaviour Pattern

M.A.F.F. (1967) Agricultural Land Service. Tech. Rep. 13.

	Herd Average	Oldest Cow	Youngest Cow	Highest Yielder	Lowest Yielder
Lying	43.12	49.75	34.91	47.63	41.81
Feeding (Silage)	15.24	13.23	15.34	20.10	16.93
Loitering - bedded area	19.12	15.34	28.03	13.74	17.46
Loitering - feed & exercise area	14.76	19.57	11.12	14.30	16.93
Parlour and Yards	7.76	2.11	10.60	4.23	6.87

The oldest cow lay down for the longest time and fed the least, which is in agreement with the work of Walker-Love and Laird (1964). The youngest cow although spending a similar amount of time in the bedded area, lay down for a much shorter period. This may well have been influenced by social behaviour patterns particularly in view of the long parlour and yard time indicative of low social rank. (Guhl and Atkeson, 1959).

The pattern according to yield is less well established. Webb et al., (1963) found no relation between the number of visits to the feeders and yield, although the lowest yielder did eat for the least amount of time.

Contrary to the pattern of Table 4, Gelling et al., (1958) found no correlation between length of time eating at the silo and age, lactation, stage of lactation, milk yield or teeth.

B. SOCIAL BEHAVIOUR PATTERNS

Although this is conveniently discussed as a separate entity, it is apparent that it is very closely linked with physical behaviour patterns. Under loose housing conditions the role of social interactions assumes much greater importance.

1. Social Dominance

Woodbury (1941) was the first to report the presence of dominance orders among cows. A more detailed study was carried out by Schein and Fohrman (1955), in which the various agonistic interactions to determine the dominance-subordination relationship of two animals were fully described and discussed. From the work of Beilharz and Mylrea (1963a), it would appear that these relationships are established on the initial meeting and will remain for as long as they are in the same herd. Once the relationship is firmly established a stable social order is set up whereby a subordinate animal will usually retreat from the dominant in the presence of any threat. This has the advantage of reducing social strife, which as Schein et al., (1955) showed, may result in as much as a 5 per cent average decline in milk yield.

The decline in production commonly associated with the oestrus period may be partly caused by such social strife. From the onset of oestrus the cow becomes hyper-reactive and will temporarily ignore relative social hierarchy positions to approach both dominant and subordinate herdmates. Schein and Fohrman (1955) report that even after being repeatedly threatened or chased by a more dominant animal, such a cow will often continue her efforts to mount the aggressor.

This early work of Schein and Fohrman (1955), in Beltsville, appeared to have established that dominance orders were of the straight line type where one animal won all its contests and another lost them all, with a gradation between the two. However in this report all the fights between individual animals were not recorded, so that if cow A dominated B, and B dominated C, then A was assumed to dominate C if this was not contested. In fact, the presence of 'bunting circles', whereby C may dominate A, has been reported by Beilharz and Mylrea (1963a) revealing the danger of the former assumption. Nevertheless, McPhee et al., (1964) working with steers also noted a linear social order.

Guhl and Atkeson (1959) based their dominance order on the number of cows one animal was superior over, rather than the relationship between individual animals. Beilharz and Mylrea (1963a) preferred to express social position by a dominance value. This was the number of animals one cow dominated as a fraction of all its encounters, transformed into angles.

The presence of a dominance order among cows has important implications to management. The accessibility of feed influences the degree of competition, the space available affects the extent of mobility during interactions, while density and herd size determine how frequently any two cows may meet. The interaction between space and social organisation is perhaps most apparent at the feed trough or silo face. If such space is in short supply, subordinate animals are continually forced away and are therefore unable to obtain adequate intake (Schein and Fohrman, 1955). Small (1966) noted that such animals often fed in the early hours of the morning when there was minimal competition.

M.A.F.F. (1967) found that over eight farms the average width of silo face required by Friesians at maximum usage varied from 22.5 - 30.5 inches per cow, averaging 26.7 inches per cow. Using this as a minimum, and the commonly allotted 9 inches of silo face per cow (Hodges and O'Connor, 1960) a maximum of one third of the herd may feed together at the face. M.A.F.F. (1967) did not observe any stress at this restriction.

Factors Contributing to Dominance: Woodbury (1941) first reported that 'hook order' was largely determined by the size, shape and effectiveness of horns, whereas in dehorned cows 'bunt order' was largely determined by an animal's strength and tenacity in pushing. Schein and Fohrman (1955) obtained significant correlations of $r = 0.93$ ($P<0.01$), $r = 0.87$ ($P<0.01$) and $r = 0.25$ ($P<0.05$) for rank x age, weight and milk production respectively. It was not possible to determine whether age and weight were causally or coincidentally related to rank. Guhl and Atkeson (1959) also found highly significant correlations between rank, body weight and seniority (number of months in the herd), but again could not separate individual effects. They observed that Ayrshires and Holsteins dominated more cows than Jerseys, but that there were no predominant trends between Holsteins and Ayrshires in this particular herd.

McPhee et al., (1964) working with steers also found breed differences in aggressiveness and social dominance. Although high social ranking animals had priority at the feed trough, there was no relationship between social rank and growth, suggesting that husbandry conditions were adequate. In this study wither height was significantly ($P<0.01$) related to social rank, after the effects of other variables had been removed. No significant correlation was obtained between social rank and weight or girth circumference.

Beilharz and Mylrea (1963a) found that chest girth gave a better indication of the dominance value with dairy heifers than wither height. They postulated that this may have been a reflection of change in weight as a result of social position, rather than a cause of social position.

Other workers (McBride, 1958; Tulloh, 1961b) have discussed the influence of temperament or aggressiveness upon social rank. Tulloh (1961b) found that docile cattle grew better than those which were nervous and aggressive. Beilharz and Mylrea (1963a) noted that many docile heifers had a higher dominance value than those of more aggressive temperament. It is apparent that the difficulties of defining the concept of temperament have led to many problems in this field of study.

Within dairy herds it would appear that the effects of age, seniority and physical size are closely inter-related in establishing the social hierarchy, and that consideration of these facts in grouping cows could aid social facilitation.

2. Leadership

This is a phenomenon which appears to be quite distinct from the dominance-subordination relationships previously discussed. Kilgour and Scott (1959) found a very low correlation between herd rankings, based on the average leadership score, and the dominance rankings. No one particular individual could be established as a leader under all herd movements. There appeared to be a trend for top leader cows to come from the middle dominance group, while middle leadership cows were from the top third dominant cows, and rear cows were of low dominance status. Further work by Beilharz and Mylrea (1963b) obtained similar results.

An explanation on the basis of territorial yard behaviour was offered by Beilharz and Mylrea (1963a). They found that heifers with high dominance values reacted to men more than did heifers with lower dominance values, who seemed to be more concerned with avoiding superior heifers. Dominant heifers therefore remained in the centre of the yard. It was also observed that individual animals tended to remain in particular parts of the yard so that the highly significant ($P<0.001$) weighing order obtained by Tulloh (1961a) would not be surprising if this explanation were a valid one.

Contrary to the above workers Guhl and Atkeson (1959) obtained a significant and positive rank correlation of 0.52 between rank in the bunt order, and rank in the order of entry to the milking barn. This was obtained over five different herds, and may indicate that social status has a more positive influence in the response of cows to routine procedures.

C. CONCLUSIONS

In recent years a great deal of attention has been focussed on animal behaviour studies with the realisation that the selection of the optimum environment will allow an animal to express its full genetic potential. In nutritional trials with group housed animals the reported feed intakes often differ widely, and it is apparent from Appendix 1 that 24 hour observation periods may well provide reasons for the underlying effects. The use of statistics such as the percentage time spent daily in a particular activity may be criticised by virtue of the day to day individual variation,and the fact that an 'ideal' behaviour pattern has not been established. However,the importance of determining allelomimetic behaviour patterns and peak periods has been clearly shown (M.A.F.F., 1967).

Within a loose housing environment the influence of social facilitation on productive ability may be reflected in poor management or experimental error. Furthermore,the introduction of new techniques may induce stress behaviour. This stress may take the form of a 'displacement activity' whereby there is an increase in social conflict (Hafez, 1962), and as shown by Schein, Hyde and Fohrman (1955) may bring about a 5 per cent average decline in milk yield. It is important therefore that nutritional trials under these conditions are accompanied by systematic observations on behaviour which may provide some indication of environmental influences.

EXPERIMENTAL PROCEDURE AND RESULTS

S E C T I O N I

ELECTRONIC FEEDERS AND THEIR INFLUENCE ON DAIRY COW BEHAVIOUR PATTERNS

Nutritional trials in loose housing are generally dependent on different treatments being compared in separate pens, thus introducing a possible variation due to social dominance relationships (McBride, 1959). In poultry (McBride, 1958) and in dairy cows (Schein and Fohrman, 1955), dominance orders have been shown to be related to productivity, so that an individual cow may vary in production according to the presence or absence of certain dominant animals within a pen. The use of equipment to provide a direct measurement of individual intakes within a group of animals, provides a means of comparing different nutritional treatments within the same pen. Satisfactory results have been obtained with bullocks (Broadbent, 1967a) in the use of electronic feeders, and a design has been suggested for dairy cows (Broadbent, 1967b).

This experiment was conducted to make a critical assessment of electronic feeders used by dairy cows. Different roughage feeding regimes were compared in a loose housing environment and observations were made of cow behaviour patterns.

A. EXPERIMENTAL

Animals: Four Ayrshire and four British Friesian cows were each randomly assigned to an electronic feeder approximately two weeks before calving. They were introduced in two groups; four on the 29th November, 1968 and the remaining four on the 10th December, 1968, all remaining on trial until the 23rd April, 1969. Approximately twenty-four hours before calving the cows were removed from the unit to a loose box and returned usually three days later.

All the cows came directly off pasture and were in reasonable condition and health. Their previous records are shown in Table 5. During the 1967-68 winter, all the cows had been kept in a self-feed silage/cubicle loose housing system where a limited quantity of barn dried hay was also on offer.

<u>Rations</u>: Barn dried hay and wilted silage were offered <u>ad lib</u>. in a precalving period varying from 8 to 21 days. This was supplemented with 4 to 6 lb. concentrates per cow per day. In the following two week post calving period cows were gradually restricted to either hay or silage, with concentrates being fed at 4 lb. per gallon of milk produced above 1.5 gallons. The allocation of treatments is shown in Table 5. When cows were required to change their roughage ration, this was done over a two week period.

The nutritional trial and feed composition are given in Section II of this experimental work.

<u>Housing</u>: The cows were housed in a low cost wooden cladded cubicle house with a central concrete slatted passage. This house contained 22 cubicles with concrete bed dimensions of 3 feet 7.5 inches by 6 feet 8 inches and two different types of cubicle division as shown in Fig. 4.

Cows were allowed free access from the cubicle house to a concrete yard of 297 square feet but were restricted to feeding from a particular position in the tombstone barrier by the individual feeders. The yard and feeders were totally covered by an asbestos lean-to which sloped from a height of 12 feet at the back, to 6 feet 8 inches above the feeding passage.

Water was provided from a drinking bowl, and the yard and cubicles

TABLE 5

Division, Lactation records and physical size of experimental animals

Expt. No. and Breed	PREVIOUS LACTATION RECORDS (1967/68)						PHYSICAL SIZE			HEALTH RECORD	Expt. Treatment Period I/II
	Lactation	Total Yield (lb.)	305 Day Yield (lb.)	Milk Fat (%)	Length of Lactation (days)	Length of Dry Period (days)	Weight (lb.)	Shoulder Height (ins.)	Girth (ins.)		
1F	3rd	10,393	9,990	4.03	334	92	1212	53.0	76.5	-	H/H
6F	4th	8,588	-	3.64	243	106	1227	52.75	80.5	-	S/S
2F	1st	11,550	9,450	3.40	402	45	1075	49.5	75.25	-	S/H
5F	7th	9,009	-	3.47	277	97	1437	53.0	85.0	Mastitis 1966/7 Bad quarter	H/S
3A	2nd	9,376	-	4.06	303	69	1037	49.5	73.75	-	H/H
10A	2nd	9,677	8,986	4.22	353	37	970	49.5	73.0	-	S/S
4A	3rd	9,062	-	3.68	282	49	1231	52.0	77.75	Mastitis 1966/8	H/S
7A	2nd	8,024	-	3.98	270	57	917	48.75	70.5	Mastitis 1967	S/H

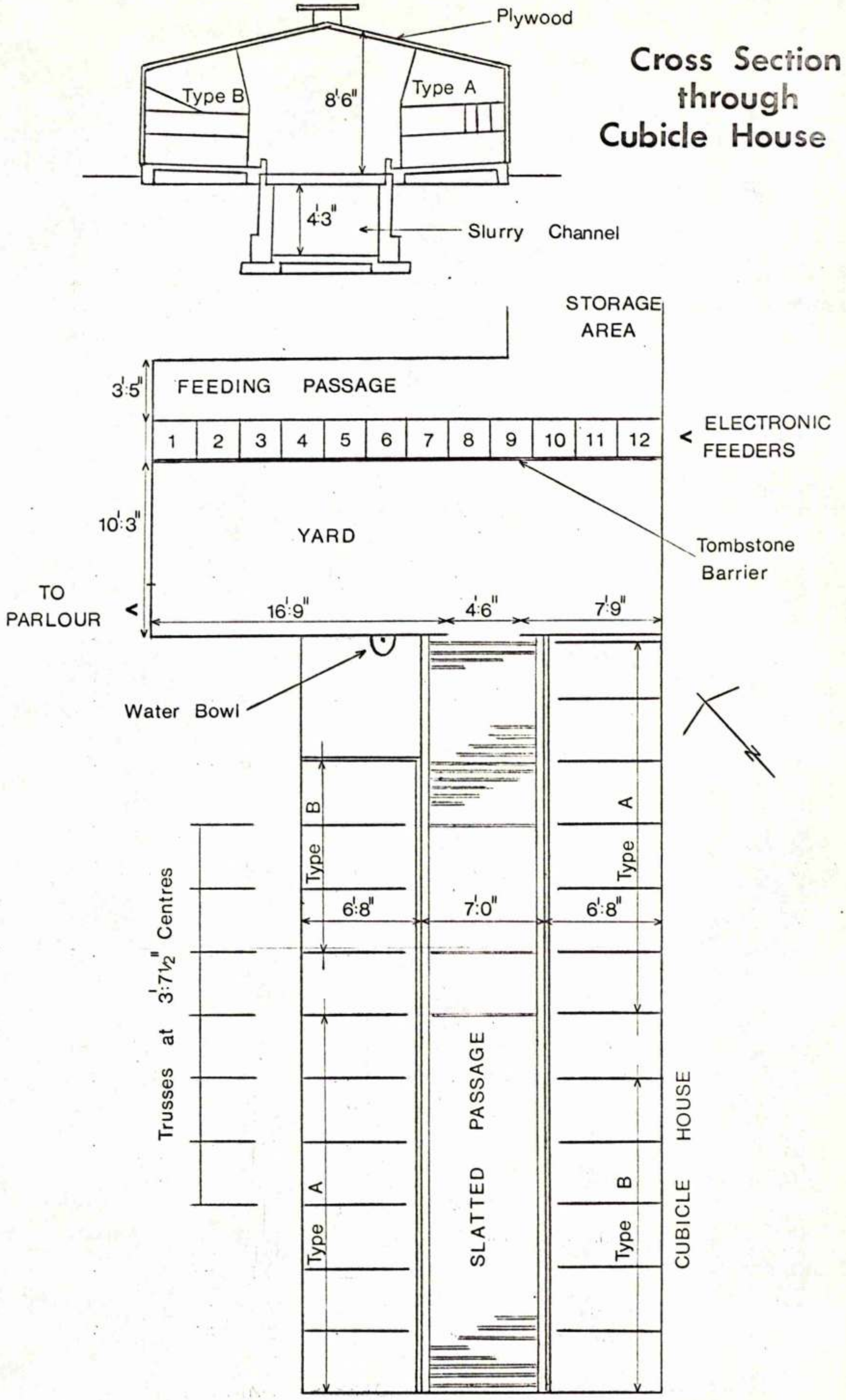


FIG. 4 Scale Diagram of Experimental Layout (1 inch = 8 feet)

were illuminated at night.

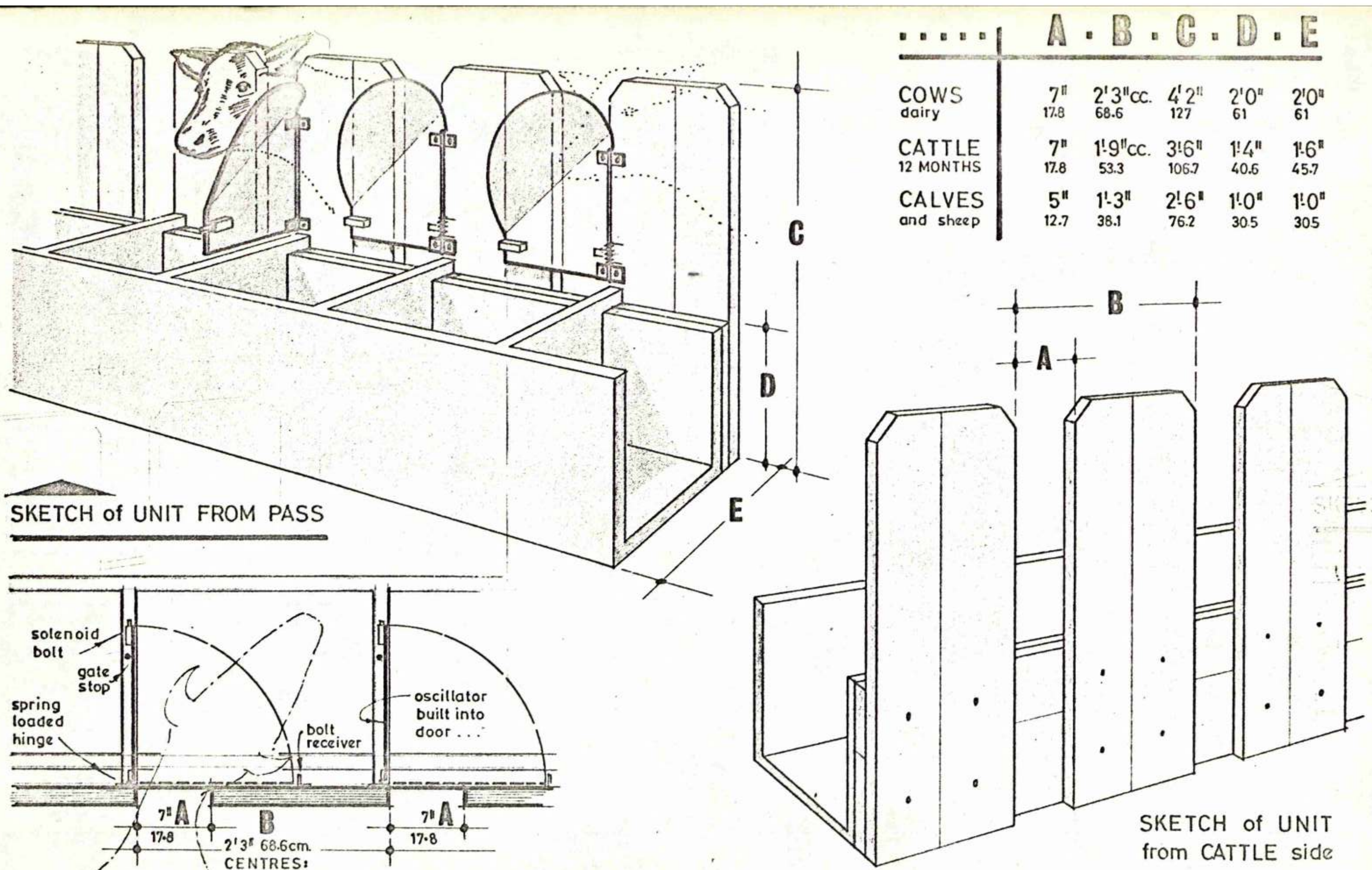
Electronic Feeders: The wooden tombstone barrier and feed box as developed by Broadbent (1967b) were used in the first instance, and are shown in Fig. 5. The electronic equipment was manufactured by Renfrew Electronics Limited.

Each cow was restricted to feeding from a particular position in the tombstone barrier by a fibre glass door (Plate A) which contained an oscillator unit and electro-lock. The oscillator unit was attached to a removable panel on the back of the door and is shown in Plate B. Each oscillator was tuned to a particular frequency so that access to a feed box could only be achieved by the cow carrying a coil tuned to that frequency. This tuned but inert coil known as the 'neck key' was carried on a nylon neck chain collar. It was surrounded by foam rubber and encased in a pear-shaped fibre glass cover approximately 3 inches in diameter by 2 inches thick, weighing 7 ounces.

Each oscillator unit was supplied by a 12 volt D.C. power circuit which was in continuous operation. When the cow carrying the appropriate 'neck key' approached the door, a current was induced in a secondary circuit of the oscillator. This was amplified by a relay coil and passed to the solenoid. The armature of the solenoid acted as a bolt and was withdrawn from the receiver or latch by this induced current. The door could then be pushed open. A circuit diagram of the unit is shown in Fig. 6.

Bale counters attached to each door were used as a means of determining the frequency of usage.

Management Practices: The cows were milked twice daily in an 8/16



	A	B	C	D	E
COWS dairy	7" 17.8	2'3"cc. 68.6	4'2" 127	2'0" 61	2'0" 61
CATTLE 12 MONTHS	7" 17.8	1'9"cc. 53.3	3'6" 106.7	1'4" 40.6	1'6" 45.7
CALVES and sheep	5" 12.7	1'3" 38.1	2'6" 76.2	1'0" 30.5	1'0" 30.5

FIG: 5 INDIVIDUAL FEEDING DEVICE FOR LIVESTOCK

The SCOTTISH FARM BUILDINGS INVESTIGATION UNIT ... CRAIBSTONE .. ABERDEEN. . . . . .

P. 12 OCTOBER 67

PLATE A: View of electronic feeders from yard

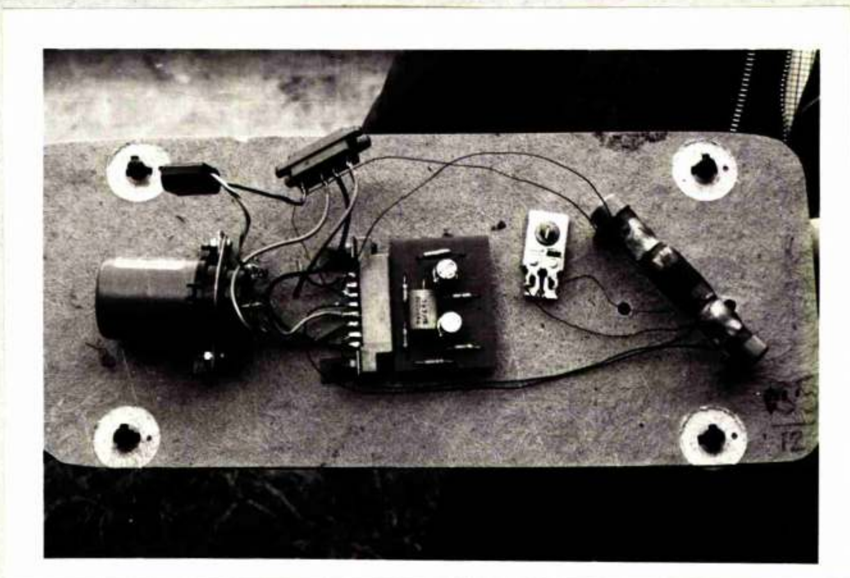


PLATE B: Individual oscillator unit for electronic feeder

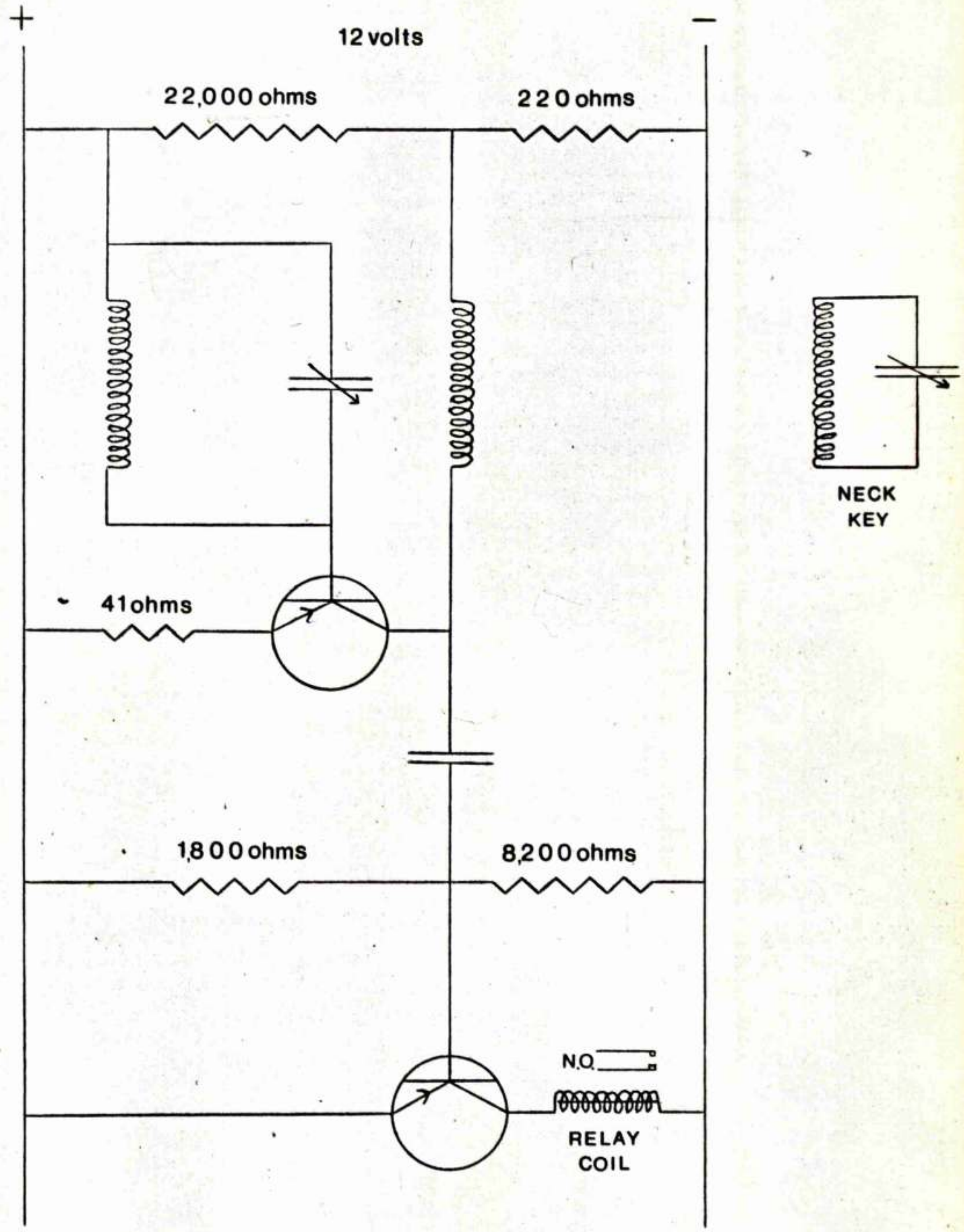


FIG. 6 Diagram of the electronic feeder circuit

herringbone parlour at 5.45am. and 3.45pm., receiving concentrates at this time. The yard and slats were scraped and silage was cut from an indoor clamp silo at 8.00am. each morning.

The previous days' refusals and the daily allowance of silage and hay were weighed out at 10.30am. This allowance was fed in four feeds at 11.00am., 4.00pm., 9.00pm. and 6.00am., door counters also being read at this time.

Training: The cows were trained in two sets of four, the second set being introduced 11 days after the first. The initial training for the first four cows involved 24 hours free access to either hay or silage at any part of the tombstone barrier, since they were unused to this type of feeder. With the second batch however, this was successfully reduced to 1 hour when the first four were restricted to the cubicle house.

After this initial introduction, the feeder doors were closed and each cow was coaxed to a feed box with the aid of concentrates. When an animal entered its allocated position, the door was quietly opened to assist entry. The length of each neck chain was adjusted to achieve maximum efficiency of operation of the electro-lock. Soon after the cow had entered her feeding position, she was gently pushed back, the door allowed to close, and the operation repeated until each cow could successfully use her own feeder. If a cow entered a wrong feeding position during the training period and tried to force open the door, she was made to retreat.

Records: Feeder usage, breakdowns and adaptations to the equipment were recorded over a total period of 146 days. Three 24 hour observation studies were made on the 27th February, 20th March and the 3rd April, 1969. These consisted of a continuous watch on the feeders and on social behaviour, together with 15 minute recordings of cow positions within the house. Cows were identified by marker so that all observations were made from outside the cubicles and yard.

B. RESULTS

The results are reported under four sub-sections:

1. Design of Feed Box

There were several limitations in the design of the feed box and tombstone barrier.

(1) The capacity of the feed box (7.3 cubic feet) was occasionally insufficient to maintain *ad lib.* conditions, particularly with hay. In addition, the two foot width of the box (measurement E in Fig. 5.), did not prevent cows dropping roughage into the feeding passage. This latter fault was counteracted with four boards, 16 inches high, each extending the length of three feed boxes (6 feet 9 inches). It was hinged at the top of the feed box on the passage side and maintained at an angle of 30 degrees from the vertical by chain supports as shown in Plate C.

(2) The feeding space in the tombstone barrier proved to be critical. Three of the Friesian cows had difficulty in feeding through the 7 inch gap in the tombstone barrier. When extended to 8 inches, the height of the fibre glass doors had to be raised by 2 inches to prevent other cows reaching over the angle of these doors into the feed boxes.

(3) The 2 feet 3 inch length of the feed box (measurement B in Fig. 5) was not sufficient to prevent certain cows reaching across into the edge of the neighbouring box. This was prevented by two horizontal 1.5 inch metal bars situated 3.5 inches and 7 inches above the top of the feed box as shown in Plate D.

(4) It was necessary to erect a bar above the top of each door as shown in Plates C and D, to prevent cows leaning over the top of their

PLATE C: View of electronic feeders from feeding passage

PLATE D: Modifications to the design of the feed box door while it was open and pulling roughage from their neighbour's mouth.

2. Electronic Feeder Faults

The total breakdowns have been divided into electrical and mechanical faults as shown in Tables 6 and 7 respectively. There was a total of 171 breakdowns over the 146 days, corresponding to 1 fault per 6.5 cow days. Thirty-four per cent of all the faults occurred in the first month of the trial.

The main problems fell into two categories:-

(1) Humidity: Initial experience noted that varying degrees of humidity could change the frequency of oscillation and result in the electro-lock being activated, even in the absence of an animal key. This necessitated the removal of the units from January 21st - 24th to allow wax impregnation of the oscillators and neck keys which subsequently reduced the incidence of this fault.

(2) Shock resistance of components: This was the major problem in this trial and affected several components.

(a) Neck key - Although only one key was broken open, the continual shocks were often sufficient to damage the internal wires adjacent to the soldered joints and prevent the key from operating the electro-lock.

(b) Oscillator and relay coil - Vibrations initiated by the closing of the spring-loaded doors were often sufficient to shake the oscillators or relay coil from their sockets. This was temporarily remedied with the aid of elastic bands. In some cases these vibrations also broke soldered contacts inside the relay coil.

TABLE 6

Electrical faults incurred over the total period of 146 days

FAULTY COMPONENT	PERIOD OF TRIAL						
	Nov. 29- Dec. 31	Jan. 1 - 31	Feb. 1 - 28	March 1 - 31	April 1 - 22	TOTAL Number	%
Animal key malfunction	8	5	4	3	2	22	32.4
Humidity shorting circuit	7	10	2	1	0	20	29.4
Relay coil broken	7	3	1	4	0	15	22.1
Oscillator malfunction	3	0	0	2	0	5	7.4
Circuit contact broken	0	0	1	1	1	3	4.4
Circuit fuse blown	3	0	0	0	0	3	4.4
TOTALS	28	18	8	11	3	68	100.1

TABLE 7

Mechanical faults incurred over the total period of 146 days

FAULTY COMPONENT	PERIOD OF TRIAL						
	Nov. 29- Dec. 31	Jan. 1 - 31	Feb. 1 - 28	March 1 - 31	April 1 - 23	TOTAL Number	%
Hinges bent, door open	4	8	15	7	11	45	43.7
Armature bent/broken	4	4	1	4	1	14	13.6
Neck chain broken	0	1	3	3	4	11	10.7
Armature extension broken	5	3	0	1	1	10	9.7
Oscillator out of socket	9	0	1	0	0	10	9.7
Relay coil out of socket	4	0	0	1	0	5	4.9
Bolt receiver bent open	3	3	0	0	0	6	5.8
Door forced off tombstone	1	0	0	0	1	2	1.9
TOTALS	30	19	20	16	18	103	100.0

(c) Solenoid armature - When cows attempted to enter different feeding positions, the force they exerted upon the door was often sufficient to bend the stem of the armature and prevent it operating. Subsequent forcings, often by the correct user of the feeder, were sufficient to completely damage this armature.

(d) Hinges - Despite the substitution of bolts for the original screws, the pressure exerted by cows leaning over the top of the doors was sufficient to distort the hinges, and as shown in Table 7 was the most frequent problem. This distortion, particularly of the top hinge, resulted in misaligning the door so that after being opened by the correct cow, it would fail to close properly. Access was then available to any cow.

(e) Doors - By the completion of the trial, four of the eight fibre glass doors in use had chips missing from the face. Six gates had extensive surface cracks.

(f) Bolt receiver - This was composed of a plate with a horizontal slot for receiving the bolt. When under pressure from a cow this plate tended to spring out and allow entry. Extensions to the armature to provide a firmer hold proved unreliable, and the receiver had to be supported by a solid wooden block.

(g) Neck chains - These were generally satisfactory although an easier method of adjusting the length was desirable. Most broken chains resulted from being caught on a faulty parlour design.

3. Cow Behaviour and Feeder Usage

Training: Training the cows to actually operate the feeders took two operators approximately two hours with both batches, but each cow increased her proficiency in operating the units with individual actions developed over the following few days. Even when fully trained however, the cows persisted in approaching other feeders and attempting to gain entry. This behaviour was perhaps encouraged by the separate feeding of hay and silage, but was still prevalent when hay and silage were on free offer to all the cows. The more aggressive cows could apply considerable pressure to different doors by forcing their head down over the top, and levering their front feet off the ground. By using this technique, one cow was estimated to be able to reach six inches down into a feed box. However, only three of the eight cows (numbers 1, 3 and 6) were observed to obtain roughage in this way. It would appear from Table 5 that shoulder height was not the sole criterion.

Physical Behaviour Patterns: The behaviour of each cow was classified as shown in Table 8. The mean values were derived from the percentages shown in Appendix III.

Cows on hay ate longer and lay down for less time than cows on silage. Friesian cows ate longer but also lay down for longer periods than Ayrshires. Although total loitering time was similar for both breeds, Ayrshires spent the majority of this time in the cubicle passage, while Friesians loitered for longer periods in the yard. Since three of the four older cows were Friesians their behaviour pattern was very similar to the breed.

The behaviour was influenced by two cows in season in the first study and one in the second. Table 9 provides a comparison of these

TABLE 8

Mean of three 24 hour observation studies comparing the influence of ration, breed and age

Percentage time spent

Activity	Mean (24)	Hay (11)	Silage (10)	Hay/Silage (3)	Ayrshires (12)	Friesians (12)	2nd & 3rd Lactation (12)	4th or older Lactation (12)
Eating	19.2	21.5	16.8	19.1	17.4	21.1	20.0	18.5
Loitering - yard	11.1	12.1	10.2	10.1	8.6	13.5	9.4	12.8
Standing - cubicle	2.8	2.9	2.1	4.5	4.3	1.2	2.8	2.8
- 2 feet in cubicle	3.1	2.9	3.5	2.4	4.5	1.7	4.8	1.5
- passage	13.5	13.4	15.3	7.6	18.3	8.6	17.1	9.8
Lying	46.9	43.8	48.7	52.4	43.4	50.4	42.5	51.2
Milking	3.5	3.4	3.4	3.8	3.5	3.5	3.5	3.5

(The figures in brackets indicate the number of cows included in these mean values) cows with three cows which they were observed to influence and with the remainder of the cows observed during the three studies.

TABLE 9

A comparison of the mean behaviour patterns of cows in heat with those cows they influenced and with the remainder of the herd

Percentage of time spent in each activity

Activity	Cows in heat (3)	Affected cows (3)	Herd norm (18)
Eating	13.9	16.3	20.6
Loitering - yard	11.5	13.9	10.5
Standing - cubicle	1.7	4.9	2.6
- 2 feet	4.9	2.1	3.0
- passage	29.5	11.8	11.1
Lying	34.7	47.2	48.9
Milking	3.8	3.8	3.3

(Figures in brackets indicate the number of cows included in the mean value)

The most noticeable effects of being in heat was the restlessness which induced a much higher loitering time in the passage, with a considerably reduced lying and eating time. This was partially reflected in the cows which they disturbed. In particular, the increased cubicle standing time was caused by the frequent approaches of cows in heat. It is notable that the mean values for all the cows in a particular activity were very similar in the first two studies and different from the third study (Appendix III) where no cows were observed to be in heat.

Eating times recorded for hay and silage were 11.1 and 3.2 minutes per pound respectively, although the eating time per pound of dry matter intake was similar for both, being 13.1 and 12.7 minutes respectively. The pattern of eating appeared to be influenced by allelomimetic behaviour. Figure 7 indicates the mean distribution of all the cows eating at any particular hour of the day. Feeding behaviour was very similar for all three studies and appeared to be stimulated by the offering of fresh roughage.

As shown in Table 10 there was a considerable range in the number of times each cow used her feeder. The differences in usage between silage and hay treatments with cow numbers 5 and 7 were largely due to the attentions of cow number 6 which was on an all silage ration. This cow continually forced them to leave their feeders in her attempts to obtain hay. Table 11 shows the percentage of the total daily feeder usage over different periods of the day for each cow.

Despite the large differences in total usage, it can be seen from Table 11 that allelomimetic behaviour patterns resulted in individuals having a similar percentage of total feeder activity during different periods of the day. It was noticeable that feeder activity generally decreased throughout the day, although there was a revival after the morning milking.

Table 12 provides a comparison of actual observed feeding from Fig. 7, and the percentage of total feeder usage over similar periods of time. During the night, cows were able to eat for longer periods undisturbed. The large amount of feeder activity in the morning was not accompanied by a similar percentage of eating time, due largely to the increased number of social interactions over this period.

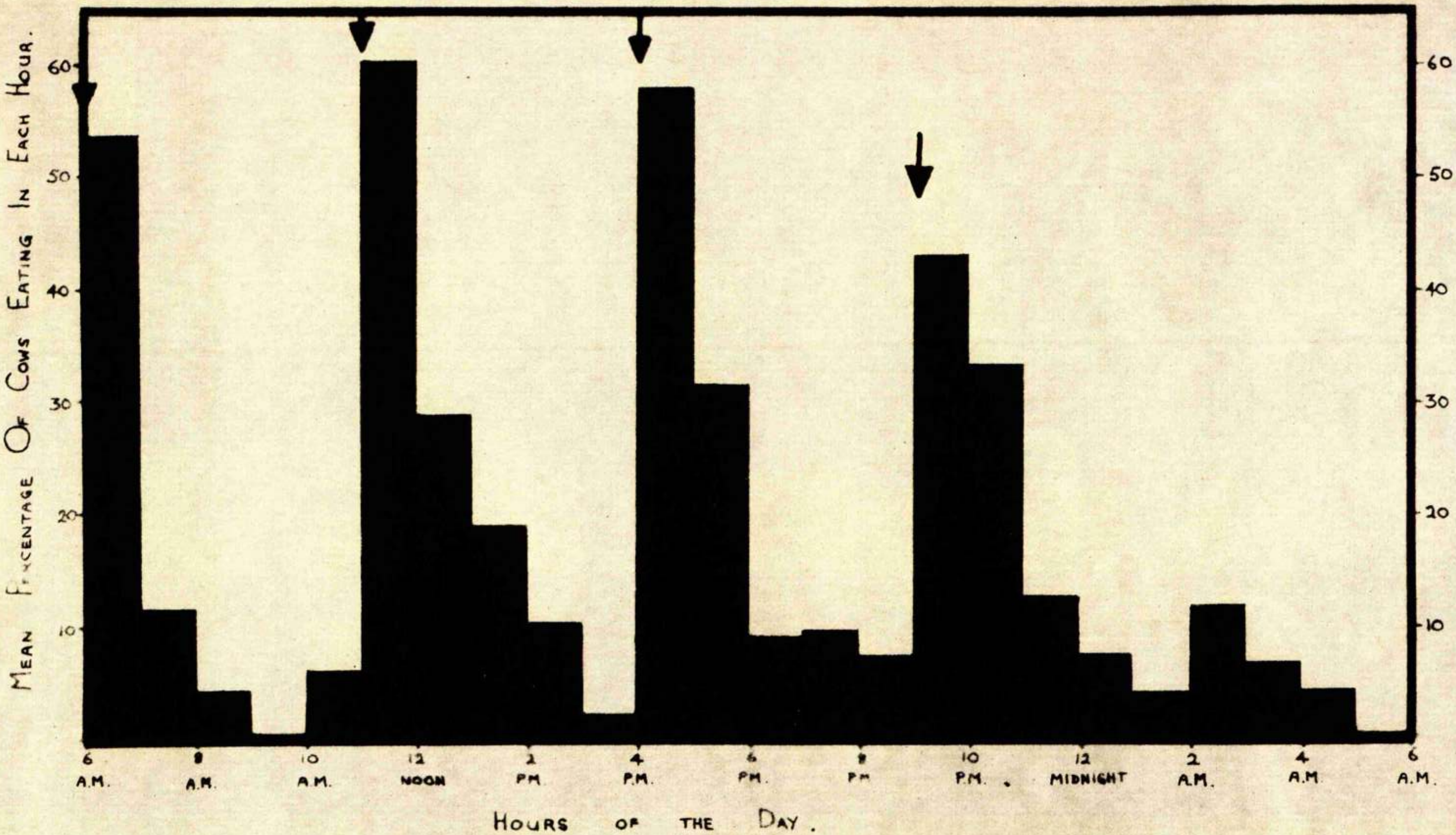


FIG. 7 Histogram of mean percentage of cows eating in each hour. (Arrows indicate when fresh food was offered).

TABLE 10

Mean daily usage of electronic feeders

Mean daily number of times feeder doors were opened

	COW NUMBERS							
Treatment	1	2	3	4	5	6	7	10
SILAGE	-	38.7	-	21.9	44.1	31.0	64.3	34.7
HAY	16.0	31.1	33.1	23.5	58.4	-	79.3	-
SILAGE/HAY	-	40.7	-	22.9	52.1	-	79.5	-
OVERALL MEAN	16.0	34.8	33.1	22.5	52.4	31.0	72.9	34.7
RANGE	6 - 29	17 - 55	14 - 64	9 - 39	27 - 108	14 - 68	38 - 104	15 - 57

TABLE 11

Mean percentage of the total daily feeder usage over different periods of 24 hours

Mean percentage of total times feeder doors were opened

	COW NUMBERS							
Period of time	1	2	3	4	5	6	7	10
11.00am. - 4.00pm.	33.8	34.2	34.7	32.0	30.5	35.2	33.5	31.4
4.00pm. - 9.00pm.	22.4	27.0	26.9	29.3	25.0	28.3	26.3	32.9
9.00pm. - 6.00am.	21.3	20.4	19.1	20.9	22.9	18.1	21.4	20.7
6.00am. - 11.00am.	22.5	18.4	19.3	17.8	21.6	18.4	18.8	15.0

TABLE 12

A comparison of mean percentage of total eating time and mean percentage of total feeder usage over similar periods within 24 hours

Period of time	Percentage of total eating time	Percentage of total feeder usage
11.00am. - 4.00pm.	27.9	33.2
4.00pm. - 9.00pm.	26.6	27.3
9.00pm. - 6.00am.	28.9	20.6
6.00am. - 11.00am.	16.6	18.9

Social Behaviour: The mean daily numbers of social contests recorded over the final two 24 hour observation periods are shown in Table 13. Social dominance values were clearly marked at the top and lower end of the scale, but there was an indication of a 'bunting circle' within the middle dominance cows, e.g., cow number 3 was dominant over cow number 2 and this cow was dominant over cow number 4, despite the fact that cow number 4 was dominant over cow number 3.

The total number of contests, which averaged 165 in 24 hours, provides a measure of the mean aggression in the herd. This was undoubtedly elevated by cow number 10 being in heat during the second observation. Although not the most dominant cow, number 6 was involved in 50 per cent of all the contests, and was observed to be aggressive over the whole trial period. This was associated with her allocation to an all silage ration and was reflected by an increased number of contests with cow number 7 when this latter cow was changed over to a hay ration. Similarly, cows numbers 1 and 3 were often trying to obtain silage from feeder number 10 by forcing this latter cow out. Table 14

TABLE 13

Social Dominance Relationships within the Experimental Cows
Mean Interactions in 24 hours

Each dot represents a single contest between two animals. Losses are read vertically and wins horizontally, e.g. Number 2 lost three times to Number 1, but beat number 4 twice. The dots have been arranged to have as few as possible on the left of the diagonal in accordance with the theory of a straight line dominance order. Dots on the left are indicative of bunting circles.

WINS	LOSSES								Contests
	Heron 1	Gael 6	Duchess 5	Justice 3	Kirsty 2	Heroine 4	Janina 10	Jovial 7	Won
Heron 1	1	••••••	••••	••••	•••	••	•••••••	••••	30
Gael 6		6	•••••••••	••••	•••••	•••	••••••••••	•••	78
Duchess 5			5	••••	•	••	••	••	11
Justice 3				3	•••••		••••••••	••••	17
Kirsty 2			•		2	••	••	••	7
Heroine 4				•		4	••••••••••••••••	••	19
Janina 10							10	•••	3
Jovial 7								7	0
Contests Lost	0	6	14	13	14	9	45	64	165

lists the number of attempts to feed from alternative feed boxes other than allocated during the second and third observation periods.

TABLE 14

The mean number of individual cow attempts to enter feeders other than allocated in a 24 hour period

Cow No.	Observation Study 2	Observation Study 3	Mean
1	11	57	34.0
6	43	8	25.5
3	9	18	13.5
7	4	1	2.5
10	2	1	1.5
5	1	0	0.5
2	0	1	0.5
4	0	0	0

The most dominant cows tended to be the most unsettled. It was apparent that cow preferences could change rapidly, since individuals were quite content for certain periods of the trial and particularly aggressive in attempting to gain access to different feeders at other periods. This can be seen from the figures for cows numbers 1 and 6 in Table 14. These attempts naturally gave rise to an increase in social conflict.

4. Performance and Health of Cows

Figs. 8 and 9 show a comparison of the lactation curve obtained

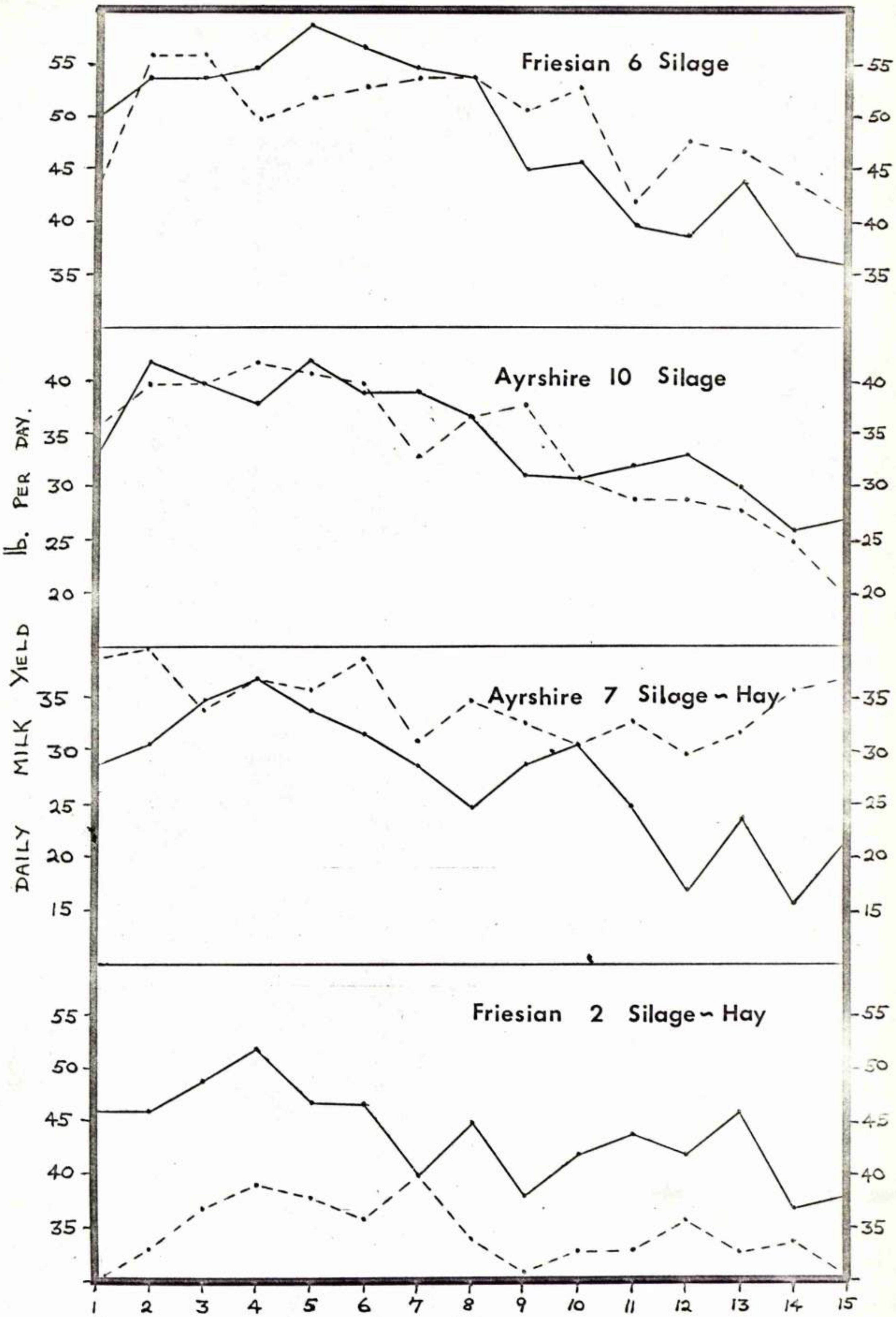


FIG. 8 Individual Cow Comparisons of Previous (dotted line) and Present Lactations (continuous line).

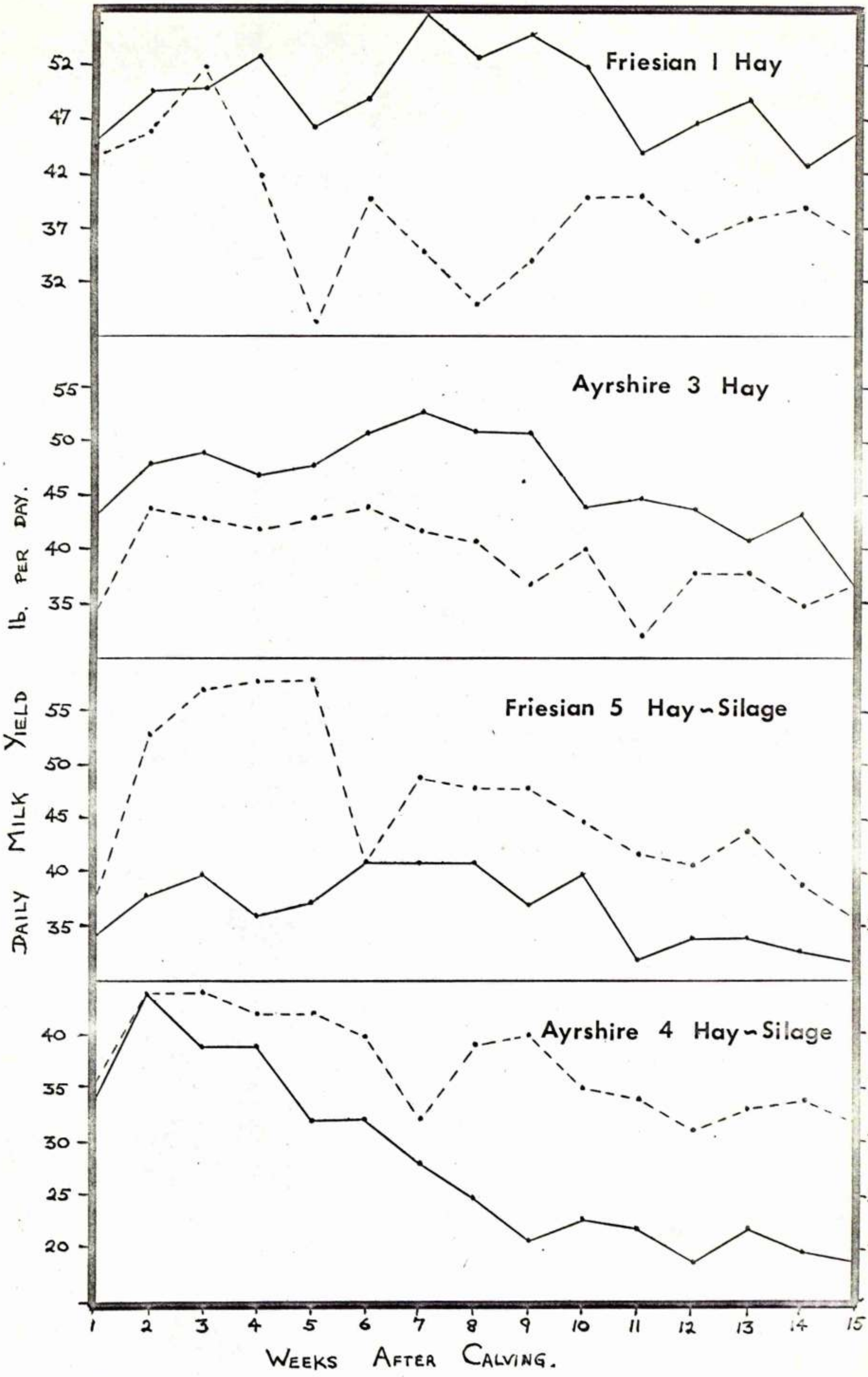


FIG. 9 Individual Cow Comparisons of Previous (dotted line) and Present Lactations (continuous line).

while feeding from the electronic feeders, with that obtained in the previous year while feeding on self-feed silage and a limited quantity of barn dried hay in a cubicle housed 110 cow dairy herd. No consistent trend was apparent. Cow numbers 4, 5 and 7 produced less milk than in their previous lactation, while cow numbers 1, 2 and 3 produced more. The yields for cow numbers 6 and 10 were very similar in both years. Details of nutrient intake are provided in Section II of this experimental work.

With regard to health, four cows showed an incidence of mastitis. Over the trial, cow numbers 4, 7, 6 and 10 were given 10, 6, 2 and 1 tube of penicillin respectively. A Californian Mastitis Test on the 24th March 1969 revealed that cow numbers 4 and 7 showed an incidence of mastitis in all four quarters and that cow numbers 6 and 10 were slightly infected in two quarters.

Cow numbers 1 and 6 developed slight shoulder sores from rubbing on the tombstone barrier as they attempted to gain access to different feed boxes.

C. DISCUSSION

Experience of this trial would suggest that the use of electronic feeders for individual feeding in loose housing is a technique which shows potential. However, there were certain limitations in the equipment used in this study.

Firstly, with certain cows, it was necessary to modify the design of the tombstone barrier developed by Broadbent (1967b). If however the gap in the tombstone barrier was to be universally extended to 8 inches, it would appear to be necessary to raise the level of the fibre glass doors by a slightly greater margin than 2 inches. This would reduce the purchase that the larger cows could apply, while still allowing the smaller cows to put their head over the angle of the door. It is appreciated that this would involve a similar extension to the foot of the door to maintain the distance between this and the feed box at two inches.

Since the capacity of the feed box was rather limited, it is suggested that the internal width of the box could be extended by 8 inches. This would increase the volume by 42 per cent and facilitate the maintenance of ad lib. conditions with bulky materials such as hay.

The electronic feeders manufactured by Renfrew Electronics Limited differed from the prototype of Broadbent (1967b) in certain of the materials used. The substituted components appeared to have a relatively low shock resistance and were unsuitable for use with the dairy cows in this trial. On the basis of this experiment, it is proposed that several alterations could be made to the existing mechanism:-

(1) The use of a larger bolt capable of withstanding greater pressure.

(2) The use of a solid bolt receiver that would not spring open under pressure.

(3) Substitution of the existing relay coil for a coil more suited to receiving shocks such as the glass enclosed Reed relay coil.

(4) A firmer, more resilient protection for the coil and capacitor inside the 'neck key'.

(5) The use of stronger hinges to prevent the door from being misaligned.

It is possible that the oscillator unit could be removed from the door to the back of the tombstone barrier. This would have the double advantage of removing the shock component and of allowing a larger solenoid to be installed which would be capable of withdrawing a solidly mounted bolt.

With regard to the effect on cow performance it should be established whether (a) behaviour and cow performance are similar to conventional loose housing, or (b) whether individual feeding within a group confers a commercial advantage or even disadvantage. In terms of physical behaviour patterns, the mean distribution of activities compared similarly with the previous loose housing studies of Walker-Love and Laird (1964) and Wood (1968) at the West of Scotland College of Agriculture (Table 15). The higher percentage time observed standing in the passage during this trial was presumably due to the larger proportion of available loitering area that this passage composed in relation to the yard.

Feeding cycles differed from those of self-feeding reported by M.A.F.F. (1967) and Small (1966) in that eating activity was largely influenced by the offering of fresh feed four times per day. In addition, it was noted that cows opened their feeder doors an average of 37 times

TABLE 15

A comparison of the mean behaviour distribution of cubicle housed cows being either self-fed or individually-fed

	SELF FEED SILAGE + 8 lb. BARN DRIED HAY/HEAD		AD LIB. HAY or SILAGE
	Walker-Love and Laird (1964)	Wood (1968)	Electronic Feeders (1969)
Eating - Hay	6.0	5.5	19.2
- Silage	13.3	10.1	
Lying	48.4	43.6	46.9
Standing - Cubicle	3.8	1.8	2.8
- 2 feet	3.4	2.2	3.1
- Passage	4.9	4.9	13.5
Loitering and Milking	20.2	31.9	14.6

in 24 hours. This is twice the number of times feeding recorded by Webb et al., (1963) and Jackson et al., (1962), although it is probable that their results took no account of cows which backed out and returned almost immediately to feed. It is notable that the times recorded for eating hay and silage were relatively similar to those of Harshbarger (1949) and Walker-Love (1954). However, the difficulties of recording exact eating time under self feeding conditions have already been stressed.

No comparisons of herd aggression could be made, but the mean number of approximately 7 social contests per hour appeared to be fairly high for a group of eight cows. This may have been stimulated by the feeding of different rations within the same environment, but the fact that 34 per cent of the total breakdowns occurred in the first month of the trial may also have induced 'bad habits' leading to increased subsequent aggression. Once a cow had gained entry into another feed box by force, she was reluctant to desist in pushing less dominant cows away from their feeder and attempting to force their doors open. Furthermore, increased aggression was perhaps exhibited as a 'displacement activity' if a feeder failed to operate correctly.

During the trial it was observed that the number of daily attempts to force other doors open varied quite widely for an individual at different periods, a high degree of restlessness being associated with a low intake. It is possible that sudden changes of taste reported by Nevens (1927) and Campling (1966b) may have influenced this behaviour.

In terms of milk production there was no clear trend as to the effects of individual feeders in relation to the previous years lactation. However this study was confused by the incidence of mastitis in 50 per cent of the cows and by the limited number of cows in the trial.

Further experiments will be necessary to assess whether cow performance in loose housing is significantly affected by individual feeding of this type.

EXPERIMENTAL PROCEDURE AND RESULTS

S E C T I O N II

A COMPARISON OF HAY AND SILAGE WITH CONCENTRATE SUPPLEMENTATION FOR MILK PRODUCTION IN LOOSE HOUSING

From the review of literature in this dissertation it is apparent that several factors may influence appetite control. It is desirable that these factors are established and integrated with a knowledge of animal production so that they may be utilised to achieve optimum economic efficiency under the prevailing circumstances. A knowledge of individual performance in group housing enables intake and production factors to be clearly established.

Within the limitations imposed by the numerous breakdowns and subsequent developments of the electronic feeders already described in the initial part of this experimental work, a comparison was made of the individual *ad lib.* feeding of either barn-dried hay or wilted silage from a covered pit, in association with concentrates.

A. EXPERIMENTAL

The experimental equipment, housing and management practices have already been described in Section I of this experimental work.

Design

Two groups of four cows were fed either *ad lib.* hay or silage from individual electronic feeders, in a trial commencing two weeks after calving and consisting of two separate periods of 8 weeks and 4 weeks. The trial involved a comparison of cows at an identical stage of lactation, so that the actual date of each week of the trial varied by as much as three weeks between individual cows. At the end of the 8 week period, half the cows were subjected to a change of treatment, the changeover period lasting two weeks, while the other half were maintained on continuous treatments. The design of this trial is shown in Table 16.

TABLE 16

Experimental Design

Treatment	Introduction 2 weeks	Period I 8 weeks	Changeover 2 weeks	Period II 4 weeks
A	Hay/Silage	Hay	Hay	Hay
B	Hay/Silage	Hay	Hay/Silage	Silage
C	Hay/Silage	Silage	Silage	Silage
D	Hay/Silage	Silage	Silage/Hay	Hay

Cows were allocated by assigning one Ayrshire and one Friesian to each treatment. Breed pairs, similar in previous milk yield, milk quality and age if possible, were assigned to hay or silage groups at random. The previous milk records and treatment allocations are shown in Table 5.

Statistical Methods

The results in this section were each analysed by a conventional analysis of variance to determine the influence of ration, breed, period and the four interactions. Where applicable, a covariance analysis was also used to determine the effect of Period I treatments on Period II treatments. The following abbreviations have been used throughout the text:-

d.f. = Degrees of freedom

S.S. = Sum of squares

M.S. = Mean square

F = Variance ratio

S.E. = Standard error

N.S. = Not significant at probability (P) less than 5 per cent.

* = P 0.05

** = P 0.01

*** = P 0.001

Nutritional Treatments

Roughage: Daily silage dry matter determinations were made from representative hand samples, taken after the silage had been thoroughly mixed. The samples were stored in a refrigerator and every two weeks individual composites, weighted according to intake, were analysed for organic matter digestibility by the technique of Alexander and McGowan (1969). Individual hay bales for each week were cored with the apparatus suggested by Alexander, McGowan and Stewart (1969). These weekly samples were analysed by a similar technique to that used with the silage. The mean of the analyses determined in each period of the trial are shown in Table 17.

The silage and hay were prepared from different herbages harvested at separate stages of maturity. The silage was cut with a rotary mower on the 3rd June, 1968 from a ley sown out in 1965 with a mixture of 22 lb. meadow fescue, 6 lb. timothy and 2 lb. S100 white clover. After wilting for approximately 24 hours, it was lifted with a forage harvester and ensiled in a concrete walled, totally covered pit; molasses was added at the rate of 2 gallons per ton of herbage. During the 1968 season prior to cutting, the herbage had received a dressing of 448 lb. per acre of compound fertiliser - containing 23 per cent nitrogen (N), 11 per cent phosphate (P_2O5) and 11 per cent potassium (K_2O) - and an application of 3,000 gallons of slurry per acre.

The hay used in this trial was obtained from a variety of fields containing mainly perennial ryegrass/white clover mixtures that had received similar compound fertiliser treatments to the ensiled herbage. Cutting dates varied from the 14th June, 1968 to the 3rd August, 1968 and were generally followed by two days of swath treatment with tedders and turners, before baling at approximately 30 per cent moisture. This

TABLE 17

Mean Analysis of Roughages

Period	Roughage	Dry Matter (%)	As Percentage of fresh matter			As Percentage of dry matter		
			Crude Protein	Digestible Crude Protein	Starch Equivalent	Digestibility of organic matter	Organic Matter	Digestible Organic Matter
I	Silage	25.3	4.07	2.72	11.6	73.2	88.2	64.6
	Hay	86.2	9.46	5.44	41.6	65.9	92.8	61.2
II	Silage	25.4	4.23	2.86	11.7	73.1	88.9	65.0
	Hay	84.8	9.77	5.79	41.9	65.3	93.5	61.4

hay was then dried in 50 ton batches by a fan unit with a capacity of 30,000 cubic feet per minute against a 2.5 inch water guage.

The quantity of roughage offered four times per day was such that the uneaten food amounted to approximately 10 per cent of the quantity available.

Concentrates: Representative daily concentrate samples were compiled in a composite and analysed every two weeks for crude protein, by the Kjeldahl method. The constituents of the concentrate and the mean analysis are shown in Table 18.

TABLE 18

Composition of Concentrate Mixture

Weight (cwt.)	Constituent	Percentage of Mixture
7	Milled Barley	25.0
2	Bruised Barley	7.1
5	Bruised Oats	17.9
3	Maize Meal	10.7
2.5	Biscuit Meal	8.9
1	Rus Meal	3.6
5	Beans	17.9
1.25	Soya Bean Meal	4.5
0.5	White Fish Meal	1.8
27.25		
+ 25 lb.	Salt	2.6
7 lb.	Vitamin supplement supplying 4 million and 1 million international units per ton of Vitamins A and D_3 respectively	
50 lb.	High phosphorus mineral supplement	

Mean Analysis of Concentrate Mixture

Crude Protein	14.15%
Digestible Crude Protein	11.9%
Starch Equivalent	69.8%
Dry Matter	86.5%

This concentrate was home mixed and offered in a bruised form at 4 lb. per gallon of milk produced above 1.5 gallons, on the scale shown in Table 19.

TABLE 19

Concentrate Feeding Rate

Milk Yield (lb/day)	Concentrate (lb/day)
15.0 - 19.5	2
20.0 - 24.5	4
25.0 - 29.5	6
30.0 - 34.5	8
35.0 - 39.5	10
40.0 - 44.5	12
45.0 - 49.5	14
50.0 - 54.5	16
55.0 - 59.5	18

Concentrate allowance was adjusted weekly on the basis of the previous two days milk production. During the trial, concentrates were fed in the parlour at each milking, from a head rail hopper.

Records

In addition to the feed sampling, the following records were also compiled:-

Liveweight: The cows were weighed at 10.00am. on three successive days at the beginning of Period I and at the end of Period II. They were also weighed on two consecutive days at the start and finish of the changeover period.

Roughage Intake: All roughages offered were weighed, and each morning, refusals were weighed and discarded.

Concentrate Intake: The concentrate allowance was weighed out, any refusals being reweighed after milking.

Milk Yields: These were recorded twice daily at approximately 5.45am. and 3.45pm.

Milk Quality: Individual cow weekly composite evening/morning milk samples were analysed for percentage butterfat by the Gerber method (British Standards, 1955), for total solids and percentage lactose by the British Standard (1963) methods and for percentage protein by an adaptation of the technique suggested by Dolby (1961).

Climate: A thermohygrograph continuously recorded humidity and temperature within the cubicle house from the 19th January 1969 to the 23rd April 1969.

The experimental records are shown in Appendix III

B. RESULTS

In both periods the individual daily roughage intake tended to be rather variable as a direct result of feeder breakdowns. All the electronic feeders were observed to be in perfect working order on only 26 of 119 days actually on trial, so that exact measurements of individual intake could only have been guaranteed by constant invigilation, which was not feasible. This fact should be taken into account when considering these results.

1. Dry Matter Intake

The mean daily dry matter intakes of roughage and concentrates are given in Table 20. Analyses of variance were calculated to determine the influence of ration, breed, period and the four interactions, on each component of the mean daily dry matter intake. The full analysis of variance table for roughage daily dry matter intake is shown in Table (i) of Appendix II, while a summary of the analyses of variance for daily concentrate and total dry matter intake is provided in Table (iii) of Appendix II.

In each period the amount of roughage dry matter consumed by the cows when silage was offered was less than that consumed when hay was offered, although the difference was not statistically significant. In terms of total dry matter intake however, the difference between those cows receiving hay and concentrates, and those receiving silage and concentrates, was almost statistically significant at the $P = 0.05$ level. Although the Friesian cows consumed more dry matter (P 0.05) in the form of concentrates than the Ayrshire cows, they did not have a significantly greater total dry matter intake than the Ayrshires. It is notable that

TABLE 20

Mean Daily Dry Matter Intakes

Treatment	SILAGE (lb. D.M./day)			HAY (lb. D.M./day)		
Component	Silage	Concentrate	Total	Hay	Concentrate	Total
Period I Mean	18.0	10.8	28.8	20.7	10.2	30.9
S.E. of Mean	± 1.37	± 0.90	± 1.04	± 1.37	± 0.90	± 1.04
Period II Mean	20.0	6.8	26.8	21.7	9.0	30.7
S.E. of Mean	± 1.22	± 1.42	± 1.53	± 1.22	± 1.42	± 1.53

there was a trend towards a larger roughage intake in Period II than in Period I corresponding to a lower concentrate intake during Period II than during Period I.

Broster and Curnow (1964) stated that carryover effects are a distinct possibility in changeover experiments that involve different treatments in the first few weeks after calving. Covariance analysis was therefore applied to the Period II results to reduce errors associated with the influence of Period I treatments on Period II treatments. An example of the analysis of covariance for roughage dry matter intake is shown in Table (ii) of Appendix II. The adjustment of the Period II values reduced the error mean square from 6.9 to 4.3 with the analysis of roughage dry matter intake, but did not show any statistical treatment difference with roughage, concentrate or total dry matter intake.

Since the dry matter intake of the cows receiving silage was calculated using the silage percentage dry matter, any correlation between the two variables would have been 'spurious' (Snedecor, 1956). However, the correlations for individual cows, between the percentage dry matter and the daily fresh weight intake of silage, are shown in Table 21

With the exception of one cow, in the first period, fresh weight intake decreased with an increase in the percentage dry matter of the silage. This cow was often attempting to obtain hay, and was responsible for a large number of feeder breakdowns, particularly during Period I.

When these results were analysed within and between concentrate levels, the correlation coefficients between percentage dry matter and daily fresh weight intake of silage, shown in Table 22, were obtained.

The limited number of degrees of freedom between concentrate levels prevent any statistically significant results. It was of interest however, that between concentrate levels the fresh weight intake of

TABLE 21

Correlation Coefficients (r) for individual cows, between percentage silage dry matter and fresh weight intake of silage (lb.), on a daily basis

	CONTINUOUS TREATMENT						CHANGEOVER TREATMENT					
	Friesian			Ayrshire			Friesian			Ayrshire		
	r	d.f.	Sig.	r	d.f.	Sig.	r	d.f.	Sig.	r	d.f.	Sig.
Period I	+ 0.13	54	N.S.	- 0.06	54	N.S.	- 0.06	54	N.S.	- 0.25	54	*
Period II	- 0.34	26	*	-0.15	26	N.S.	-0.70	26	***	0.18	26	N.S.

TABLE 22

Correlation Coefficients for individual cows, between percentage silage dry matter and daily fresh weight intake of silage (lb.), within the between concentrate levels

Period	Concentrate	CONTINUOUS TREATMENT						CHANGEOVER TREATMENT					
		Friesian			Ayrshire			Friesian			Ayrshire		
		r	d.f.	Sig.	r	d.f.	Sig.	r	d.f.	Sig.	r	d.f.	Sig.
I	Between levels	+ 0.64	3	N.S.	+ 0.48	2	N.S.	+ 0.34	2	N.S.	- 0.49	5	N.S.
	Within levels	+ 0.09	50	N.S.	- 0.07	51	N.S.	- 0.13	51	N.S.	- 0.16	48	N.S.
II	Between levels	- 0.99	1	N.S.									
	Within levels	- 0.07	24	N.S.	- 0.15	26	N.S.	- 0.70	26	***	- 0.18	25	N.S.

three of the cows increased as the percentage dry matter of the silage increased, contrary to the results obtained within concentrate levels.

No correlation was found with hay or silage, between liveweight and either mean daily roughage or mean daily total dry matter intake.

2. Roughage Digestible Organic Matter Intake

It was shown in Table 17 that the mean digestible organic matter was approximately 3.5 per cent higher in the silage than in the hay dry matter. Table 23 provides a comparison of the digestible organic matter intakes of the cows on these respective roughages.

TABLE 23

Mean Digestible Organic Matter Intake of Silage and Hay (lb./day)

	Treatment		S.E. of Mean
	Silage	Hay	
Period I	11.6	12.7	± 0.88
Period II	13.0	13.2	± 0.83

A summary of the analysis of variance is given in Table (iii) of Appendix II. There were no statistical differences between the treatments even with covariance analysis. In accordance with the dry matter intake, the cows tended to have a higher digestible organic matter intake of both roughages in Period II than in Period I.

3. Milk Production

The mean daily milk yield and daily body weight change are shown in Table 24. A summary of the analyses of variance is given in Table (iv) of Appendix II.

The Friesian cows produced more milk ($P<0.05$) than the Ayrshire cows in this trial, while the difference between Period I and Period II mean levels of milk production approached statistical significance at the $P = 0.05$ level.

TABLE 24

Mean Daily Milk Yield and Corresponding Daily Body Weight Change

Treatment	MILK YIELD lb/day		BODY WEIGHT CHANGE lb/day	
	Period I	Period II	Period I	Period II
SILAGE	41.8	29.6	− 0.76	+ 0.24
HAY	43.0	37.2	+ 0.20	0.00
S.E. of Mean	± 4.28	± 4.27	± 0.27	± 0.25

During the second Period, cows on a hay-based ration produced a mean of 7.6 lb. more milk per day than cows on a silage-based ration. The analysis of covariance to adjust the milk yields in Period II for the effects of Period I treatments is shown in Table 25. This analysis shows that the apparently large treatment effect in Period II was associated with a very high interaction sum of squares. Adjustment for Period I effects reduced this interaction sum of squares from 207.1 to 14.8, indicating that the allocation of the cows in the changeover design was largely responsible for the apparent treatment effect in Period II. The majority of the higher producing cows were inadvertantly allocated to hay rations during this second period.

TABLE 25

Analysis of Covariance for Milk Yield (lb/day)

x = Period I yield   y = Period II yield

Source	D.F.	SSx	SPxy	SSy	Adj.SSy	D.F.	M.S.	F
Breed	1	215.28	227.73	240.90	-	-	-	-
Treatments	3	291.87	300.51	343.93	-	-	-	-
Period I treatment	1	2.76	7.81	22.11	-	-	-	-
Period II treatment	1	34.86	63.25	114.76	47.28	1	47.28	1.70 N.S.
I and II treatment interactions	1	254.25	229.45	207.06	14.77	1	14.77	0.53 N.S.
Error	3	60.88	21.55	63.13	55.50	2	27.75	-
Total	7	568.03	549.79	647.96	-	-	-	-
Period II + error	4	95.74	84.80	177.89	102.78	-	-	-
Interaction + error	4	315.13	251.00	270.19	70.27	-	-	-

Cows on silage lost more weight than cows on hay in Period I, and gained more weight than cows on hay in Period II, as shown in Table 24. This interaction was statistically significant ($P<0.05$). Relatively large mean squares for breed and period (Table iv, Appendix II) indicated that higher levels of milk production were either associated with greater body weight losses or lower liveweight gains.

<u>Persistency of Lactation</u>: The average weekly milk yield decline during Period I is shown in Fig. 10. The analysis of covariance, assuming a linear rate of decline, is shown in Table 26. There were insufficient results to project the weekly milk decline during Period II.

The linear rate of milk yield decline was not significantly different between cows on silage or on hay, but there was a statistically significant difference ($P<0.05$) between the mean values for each line. Although the linear regression coefficients were significant for silage ($P<0.001$) and for hay ($P<0.01$), it was apparent that a curvilinear trend was present. In fact, a curvilinear regression analysis improved the accuracy of the regression with silage ($P<0.05$) but not significantly with hay, and was used in Fig. 10. The common regression analysis is shown in Table 27.

The significant deviation ($P<0.05$) from the common curvilinear regression indicates that the rate of decline of milk yield was more rapid with cows on silage than on hay, and that this difference was statistically significant.

The logarithms of individual mean weekly milk yield were regressed against the weeks of the trial to estimate the percentage decline in milk yield for each cow during Period I. These results are shown in Table 28.

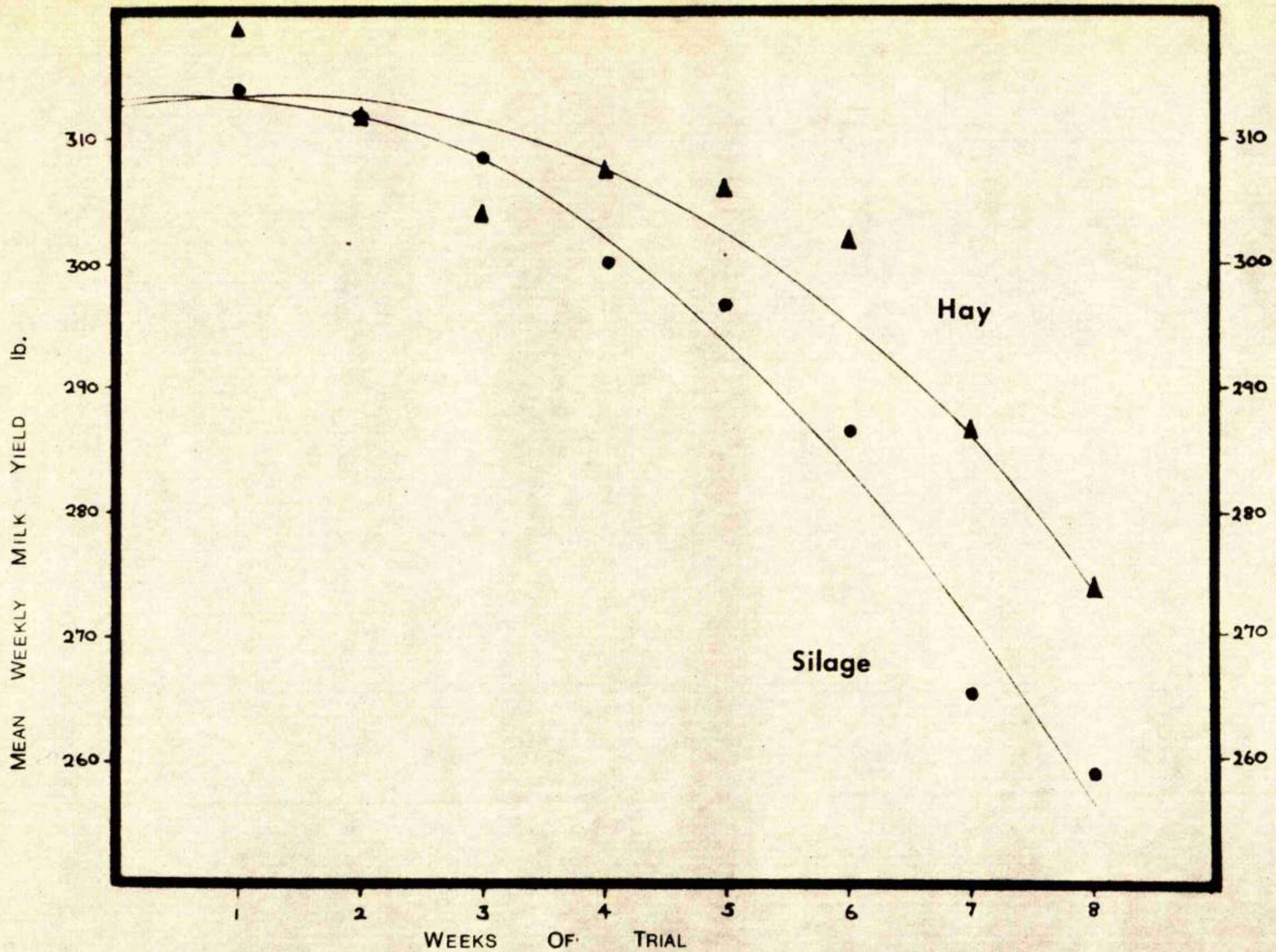


FIG. 10 Curvilinear regression indicating the rate of decline of milk yield on hay or silage.

TABLE 26

Analysis of Covariance for Decline in Milk Yield during Period I (lb/week)

x = Weeks of trial   y = Average weekly milk yield

						Deviations from Regression		
Source	D.F.	SSx	SPxy	SSy	Reg. Coef.	D.F.	Adj.SSy	M.S.
Silage	7	42.0	-343.1	3,066.2	-8.17***	6	263.4	43.9
Hay	7	42.0	-225.4	1,469.2	-5.37**	6	259.6	43.3
Within						12	523.0	43.6
Reg. Coef.						1	164.9	164.9
Common	14	84.0	-568.5	4,535.4	-6.77	13	687.9	52.9
Adj. Means						1	272.2	272.2
Total	15	84.0	-568.5	4,807.6		14	960.1	

Difference between Regression Coefficients $F_{1, 12} = \frac{164.9}{43.6} = 3.78$ N.S.

Difference in elevation $F_{1, 13} = \frac{272.2}{52.9} = 5.15$ *

TABLE 27

Linear and Curvilinear Common Regressions of Analysis for Milk Yield Decline (lb/week)

Period I

Source	D.F.	S.S.	M.S.	F
Common Linear Regression	1	3847.5	3847.5	183.2 ***
Difference between treatment	(1)	(164.9)	(164.9)	
Linear regression coefficients				
Common Curvilinear Regression	1	306.5	306.5	14.6 **
Deviation from Common	2	171.3	85.6	4.08 *
Error	10	210.1	21.0	
Total	14	4535.4		

TABLE 28

Weekly Percentage Decline in Milk Yield for Individual Cows During Period I

Treatment	FRIESIANS		AYRSHIRES	
SILAGE	- 2.05	- 3.51	- 3.06	- 2.79
HAY	+ 0.39	- 0.83	- 0.16	- 8.91

The analysis of variance is given in Table (v) of Appendix II.

There were no statistically significant differences between breed, treatment or the interaction, but this was largely due to the very rapid decline in milk yield by one of the Ayrshire cows on the hay treatment. This was caused by the incidence of mastitis. When the results were analysed without the value from this cow, the regression coefficient was reduced from - 5.37 (Table 26) to -0.09. The curve in Fig. 10 for those cows on the hay treatment would have tended to have risen slightly and then fallen, so that the mean decline in milk yield over the trial period would have been very small. By inspection of this curve, the rate of milk yield decline would have been clearly different for cows on silage and on hay.

4. Milk Composition

The percentage butterfat and percentage solids-not-fat (S.N.F.) were weighted according to milk yield and are shown in Table 29.

The slight discrepancies between the figures presented for total solids and the addition of percentage fat and percentage S.N.F. are due to rounding. A summary of the analyses of variance is given in Table (vi) of Appendix II.

There were no statistically significant effects of ration, breed or period upon the percentage fat, S.N.F., or total solids. By weighting the percentage composition according to milk yield, the difference between breeds was effectively reduced. Cows on hay produced milk of higher percentage S.N.F. in both periods of the trial, but the percentage butterfat and the percentage total solids were higher with cows on silage than on hay in Period I, yet lower in Period II. These effects approached statistical significance at the $P = 0.05$ level. Covariance analysis, to adjust the values in Period II for the effects of Period I, was applied to each component in Table 29, but did not show any statistical differences between treatments. The relatively high interaction sum of squares in the analysis of the percentage butterfat indicated that cows tended to be individualistic, and that the allocation

TABLE 29

Mean Percentage Composition of Milk (weighted according to yield)

Treatment	FAT (%)		S.N.F. (%)		TOTAL SOLIDS (%)	
	Period I	Period II	Period I	Period II	Period I	Period II
SILAGE	3.94	3.78	8.36	8.31	12.31	12.10
HAY	3.61	3.83	8.41	8.52	12.02	12.35
S.E. of Mean	± 0.15	± 0.10	± 0.08	± 0.06	± 0.18	± 0.08

of the changeover treatments was a large factor in producing the interactions of period and ration.

The mean weighted protein and lactose concentrations of the milk were also determined and are set out in Table 30.

TABLE 30

The Mean Percentage Lactose and Protein in Milk (weighted according to yield)

Treatment	LACTOSE (%)		PROTEIN (%)	
	Period I	Period II	Period I	Period II
SILAGE	4.66	4.46	2.95	3.16
HAY	4.62	4.69	3.03	3.17
S.E. of Mean	± 0.15	± 0.09	± 0.08	± 0.08

A summary of the analyses of variance is shown in Table (vi) of Appendix II.

A low percentage lactose was indicative of mastitic infection. Since three of the Ayrshire cows were treated for mastitis, a lower percentage lactose than in the milk from the Friesian cows was expected. This difference was not statistically significant however. A covariance analysis, to adjust the Period II values for Period I, again showed a high interaction sum of squares associated with the changeover of the experimental animals.

As with the percentage lactose, there were no statistically significant effects of ration, breed or period on the percentage protein in the milk. However, the higher protein percentage during the second period was almost significantly greater ($P = 0.05$) than in Period I. An analysis of covariance similar to that calculated for percentage lactose, did not show any significant treatment differences. With all the cows, the percentage milk protein was rather low, particularly during Period I, indicating that the energy supply may have been limiting especially at the higher levels of milk production. This hypothesis was supported by the trend towards a lower percentage protein in the milk from the Friesian cows than from the Ayrshire cows.

5. Relationship between Production Requirements and Feed Intake

Table 31 provides a comparison between the intake of starch equivalent and digestible crude protein, and an estimate of their corresponding values necessary to maintain body weight and achieve the mean level of milk production attained in each period of the trial. This estimate was based upon a 10 per cent increase of the standards given by Evans (1960) and an increased allowance per gallon at higher production levels as suggested by Blaxter (1967).

With the cows on silage-based rations the starch equivalent appeared to be the limiting factor, while the digestible crude protein was more critical with the cows on hay-based rations. The calculations support the observations of the low percentage protein in the milk, since there appeared to be a varying degree of undernutrition in 87.5 per cent of the cases, although this was not substantiated by a loss of liveweight in each situation.

TABLE 31

The Relationship between mean daily intake of starch equivalent and digestible crude protein, and the corresponding estimated mean daily requirements

Ration and Period	Cow Particulars			Mean Daily Intake		Estimated Mean Daily Requirements		Apparent difference (Intake - Requirements)	
	Number and Breed	Milk Yield lb/day	Live-Weight lb.	S.E. lb.	D.C.P. lb.	S.E. lb.	D.C.P. lb.	S.E. lb.	D.C.P. lb.
Period I	6F	53.8	1233	19.0	3.64	23.6	3.70	- 0.5	+ 0.61
Silage	2F	45.5	1054	19.2	3.85	20.8	3.32	- 1.6	+ 0.53
	10A	36.9	987	16.2	3.40	17.0	2.76	- 0.8	+ 0.64
	7A	31.0	896	14.2	2.96	14.7	2.35	- 0.5	+ 0.61
Hay	1F	52.4	1225	18.1	2.74	23.6	3.70	- 5.5	- 0.96
	5F	38.6	1453	18.6	2.73	20.5	3.20	- 1.9	- 0.47
	3A	49.0	1031	19.7	2.97	22.7	3.62	- 3.0	- 0.65
	4A	31.9	1238	16.8	2.41	16.4	2.50	+ 0.4	- 0.09

(cont'd overleaf)

TABLE 31 (Cont'd)

Ration and Period	Cow Particulars			Mean Daily Intake		Estimated Mean Daily Requirements		Apparent Differences (Intake - Requirements)	
	Number and Breed	Milk Yield lb/day	Live-Weight lb.	S.E. lb.	D.C.P. lb.	S.E. lb.	D.C.P. lb.	S.E. lb.	D.C.P. lb.
Period II	6F	36.5	1221	15.7	3.23	18.2	2.80	- 2.5	+ 0.43
Silage	5F	32.8	1422	16.4	3.52	17.5	2.65	- 1.1	+ 0.77
	10A	29.5	952	16.0	3.50	15.0	2.37	+ 1.0	+ 1.13
	4A	19.5	1224	11.6	2.68	13.3	1.87	- 1.7	+ 0.81
Hay	1F	46.2	1199	18.8	2.92	21.6	3.47	- 2.8	- 0.55
	2F	39.9	1094	19.0	2.87	19.0	3.05	0.0	- 0.18
	3A	41.6	1042	19.1	2.96	18.9	3.02	+ 0.2	- 0.06
	7A	20.9	938	14.6	2.14	11.9	1.77	+ 2.7	+ 0.37

C. DISCUSSION

It should be emphasised that this trial was based upon a comparison of two high quality roughages cut from separate swards at different stages of maturity. Since the digestibility of the organic matter of the silage was approximately 7.5 per cent higher than the hay, a true comparison would not be valid. Furthermore, although the use of individual electronic feeders permitted a comparison of the two roughages within an identical loose housing environment, the technique was not sufficiently reliable to guarantee an accurate measurement of individual intake. However, in view of the limited individual nutritional studies in group housing, and of the high coefficient of individual animal variation, the results have been presented for comparison with more conventional experiments.

The observation that cows consumed more dry matter in the form of hay than silage, was in general agreement with the results of other workers (Campling, 1966b; Murdoch and Rook, 1963; Jones, 1967). However, since the virtually significant difference ($P = 0.05$) in total dry matter intake was only achieved as a result of a slightly greater concentrate administration to the hay group of cows during Period II, it is possible that either the lower digestibility (Campling, 1966a), or the feeding of concentrates in addition to the roughage (Campling and Murdoch, 1966), may have suppressed the difference between the two. It was of interest that during the changeover period, cows changing from hay to silage lost a mean of 28.5 lb. while cows changing from silage to hay gained a mean of 50.8lb. This may support the contention of Campling (1966b) that silage residues tend to remain longer in the alimentary tract than hay residues, but it also emphasises the large variations in gut fill that can occur.

Within the silage treatments there was generally a decline in fresh weight intake as the dry matter percentage of the silage increased over the range of 19.3 to 31.3 per cent, in accordance with Moore et al., (1960) and Duckworth and Shirlaw (1958b). The tendency for roughage intake to increase as the concentrate level was reduced, may have contributed towards the positive, although not statistically significant, correlations between percentage dry matter and fresh weight intake at different concentrate levels in three of the four cows which had at least two degrees of freedom for this component.

Despite the higher total dry matter intakes, the milk yield of the cows on hay was not significantly greater than those on silage. This is in agreement with the findings of Larsen (1960) and Murdoch (1962) using roughages of different digestibilities. The apparently large difference in milk yield in the second period was shown to be associated with the experimental allocation of the cows.

The Friesian cows in this trial produced more milk ($P<0.05$) than the Ayrshire cows. Although they also received a larger amount of concentrates ($P<0.05$), there were indications that this higher milk production was sustained on a larger deficit from their estimated requirements than the Ayrshires, albeit with a greater loss of body weight. Since one Ayrshire developed mastitis and two others showed slight symptoms, this comparison should not be taken as generally representative of the breed.

In contrast to the results of Brown et al. (1963) it was found that the persistency of lactation was poorer with the cows on silage than on hay ($P<0.05$), despite the very rapid decline (8.91% per week) by one cow on the hay treatment. The removal of this value showed a very consistent advantage in milk yield decline for the cows on hay.

No significant effect of ration, breed or period was observed upon the milk composition during this trial. However, there was a trend towards a lower percentage solids-not-fat with the cows on silage, as reported by Murdoch and Rook, (1963) when higher dry matter intakes of hay were compared with silage. The analysis of covariance for butterfat in particular, showed that cows tended to be individualistic with changeover treatments producing relatively large interaction effects.

It was observed, that despite the stage of lactation, the percentage milk protein was relatively low, particularly during Period I. As the concentrate mixture only supplied 2.8 lb. starch equivalent per gallon of milk, an energy limitation at higher milk yields might be expected, since roughage intake decreased with increasing concentrate levels. Despite the high quality roughages, approximate calculations revealed an estimated mean deficit of 1.5 and 1.2 lb. starch equivalent per day with silage and hay treatments respectively. Cows on silage consumed an estimated surplus of 0.61 lb. digestible crude protein per day on average, while the estimated deficit was 0.32 lb. per day with cows on hay. Since the calculated deficits for each cow were not always supported by a loss of liveweight, several contributory factors may have been involved:-

(a) The requirements may have been overestimated.

(b) The apparent change in liveweight may have been largely due to differences in gut fill.

(c) The efficiency of conversion to milk may have varied widely.

(d) Cows may have forced open feeders other than allocated and consumed more roughage than was accounted for, although a deficit was apparent for most cows.

GENERAL CONCLUSIONS

The potential for individual feeding techniques, to be used in nutritional research with group housed animals, is apparent. Within this dissertation, attention has been drawn to the inadequacies of indirect methods of determining individual feed intake with dairy cows. While the use of electronic feeders in this trial did not provide an accurate alternative, it is believed that the developments suggested by this study would considerably improve the reliability of the unit.

The limitations, imposed by the use of only eight cows, prevent a critical assessment of cow performance under the system. However, certain general features were notable. It was observed that physical behaviour patterns appeared to be very similar to those reported in previous loose housing studies, despite a relatively large number of social interactions. The level of roughage intake in this trial averaged 18.7 lb. dry matter per cow per day on silage treatments, and 21.0 lb. dry matter per cow per day on hay treatments. These corresponded to 1.71 and 1.78 lb. per 100 lb. liveweight respectively, although there was no correlation between liveweight and roughage intake. The values represent a lower roughage intake than was reported in stall-fed trials, by Brown et al., (1963) on a similar level of concentrate feeding, and by Campling (1966b) where hay and silage were fed alone. However, the intake of silage dry matter was almost identical to that found by Jackson et al., (1962) under loose housing and self feeding conditions, and to Murdoch (1960) and Moore et al., (1960) when stall-fed. It is recognised that the many variables controlling intake tend to invalidate such comparisons between experiments, but it is of note that the values obtained in this study do not appear to differ markedly from the reports of other trials comparing hay and silage. It is probable that the indicated nutritional limitation of the ration was associated with the early stage of lactation of the cows used in this trial. With regard to milk production, the results of this study would suggest that individual feeding in group housing was probably not directly responsible for the fluctuations observed between the lactation in this trial, and that of the previous year.

The separate feeding of hay and silage within the same environment was designed to provide a critical test of the reliability of these feeders. It is interesting however, that the advantage of comparing rations with cows in a similar social structure, may have been outweighed by the disadvantage of the stress that this form of 'teasing' induced. The large number of social conflicts were undoubtedly associated with this factor.

In conclusion, this study would suggest that cow performance was very similar to reports from other nutritional trials, and that an improvement in the reliability of individual electronic feeders would produce a very valuable research tool for experiments with group housed cows. The cost, maintenance and management of the electronic feeders used in this trial would not have permitted a commercial application for individual roughage feeding of loose housed dairy cows. However, with the development of improved electronic units this possibility should be considered, particularly for the administration of concentrates outside the parlour.

SUMMARY

Eight electronic feeders were used for the direct measurement of individual feed intake in loose housing with four British Friesian and four Ayrshire cows. A comparison was made between *ad lib.* barn dried hay and wilted silage, cut at different stages of maturity. Concentrates were fed at 4 lb. per gallon of milk produced above 1.5 gallons.

After an introductory period to the tombstone barrier, training the cows to actually operate the feeders took two persons approximately two hours with both batches of four cows. Throughout the trial, cows persisted in attempting to feed from feed boxes other than allocated; a feature which was largely responsible for 171 feeder breakdowns over a 146 day period. Adaptations were made to the design, and suggestions have been given to improve the shock resistance of the components in the unit.

Behavioural observations over 24 hour periods showed that the patterns of activity were very similar to previous loose housing studies, although a mean of 7 social conflicts per hour was recorded. Mean daily roughage dry matter intakes were 18.7 lb. and 21.0 lb., and mean daily total dry matter intakes were 28.1 ln. and 30.8 lb., for silage and hay respectively. The difference between the total dry matter intakes was almost statistically significant at the $P = 0.05$ level. Correlations for individual cows showed that daily fresh weight intake of silage generally declined as the dry matter percentage increased over the range of 19.3 to 31.3 per cent.

The mean daily milk yield was 37.7 lb. and 41.1 lb. from cows on silage and hay respectively. During the first period, which was eight weeks, the weekly decline in milk yield was more rapid with the cows on silage than on hay ($P<0.05$). In comparison to their previous

years' lactation when they were loose housed and self fed in groups of about 60 cows, there was no clear trend towards an environmental effect on milk production.

There were no statistical differences in milk composition when weighted according to yield. However, differences between nutrient intake and the estimated requirements confirmed that a low percentage milk protein may have indicated a slight nutritional limitation, probably associated with the stage of lactation.

The results are discussed in relation to the future experimental use of electronic feeders as a means of determining individual feed intake in loose-housed dairy cows.

LITERATURE CITED

ALEXANDER R.H. (1966). Establecimiento De Un Sistema De Digestibilidad In Vitro En El Laboratorio.
Metodos In Vitro Para Determinar El Valor Nutritive De Los Forrajes Memorias Del Simposio Realizado En La Estanquela, Uruguay.

ALEXANDER R.H. (1969). The establishment of a laboratory procedure for the 'in vitro' determination of digestibility. West of Scot. Agric. Coll. Research Bulletin No. 42. January.

ALEXANDER R.H. and McGOWAN, Mary (1961). A Filtration Procedure for the In Vitro Determination of Digestibility of Herbage. J. Brit. Grassld. Soc. 16 (4) 275.

ALEXANDER R.H. and McGOWAN, Mary (1966). The Routine Determination of In Vitro Digestibility or Organic Matter in Forages - An Investigation of the Problems Associated with Continuous Large-Scale Operation. J. Brit. Grassld. Soc. 21 (2) 140.

ALEXANDER R.H. and McGOWAN, Mary (1969). The assessment of the Nutritive Value of silage by determination of in vitro digestibility on homogenates prepared from fresh undried silage. J. Brit. Grassld. Soc. (In press).

ALEXANDER R.H., McGOWAN, Mary and STEWART D. (1969). A Manually Operated Tool for Sampling Hay Bales in Stacks. J. Brit. Grassld. Soc. (In press).

ANTHONY W.B. and REID J.T. (1958). Methoxyl as an indicator of the nutritive value of forage. J. Dairy Sci. 41 1715.

ARMSTRONG D.G., ALEXANDER R.H. and McGOWAN, Mary (1964a). The use of in vitro digestibilities of dried grasses for the prediction of their energy values for ruminants. Proc. Nutr. Soc. 23 XXVI.

BALCH C.C. (1955). Sleep in Ruminants. Nature (Lond.) 175 940.

BALCH C.C. and CAMPLING R.C. (1962). Regulation of voluntary food intake in ruminants. Nutr. Abstr. Rev. 32 669.

BALCH C.C., REID J.T. and STROUD J.W. (1957). Factors influencing the rate of excretion of administered chromium sesquioxide by steers. Brit. J. Nutr. 11 184.

BÁRCZY G. and CZAKÓ J. (1962). Behaviour Studies on Cows in tie-up stalls and loose housing. D. Sci. Abs. 24 Abs. 2194, p.381.

BARROW N.J. and LAMBOURNE L.J. (1962). Partition of Excreted N, Sulphur and Phosphorus between the faeces and urine of sheep being fed pasture. Aust. J. Agric. Res. 13 461.

BEILHARZ R.G. and MYLREA P.J. (1963a). Social position and behaviour of Dairy Heifers in Yards. Anim. Behav. 11 522.

BEILHARZ R.G. and MYLREA P.J. (1963)(b). Social position and movement orders of Dairy Heifers. Anim. Behav. 11 529.

BLAXTER K.L. (1967). The Energy Metabolism of Ruminants. Pub. Hutchinson, Scientific and Technical, London.

BLAXTER K.L., WAINMAN F.W. and WILSON R.S. (1961). The regulation of food intake by sheep. Anim. Prod. 3 51.

BRISSON G.J., ANGUS W.J. and SYLVESTRE P.E. (1954). Plant pigments as internal indicators of digestibility of pasture herbage. Canad. J. Agr. Sci. 34 528.

BRISSON G.J., PIGDEN W.J. and SYLVESTRE P.E. (1957). Effect of frequency of administration of chromic oxide on its faecal excretion pattern. Canad. J. Animal Sci. 37 90.

BRITISH STANDARDS INSTITUTION (1955). Methods for the Chemical Analysis of Liquid Milk and Cream. British Standard 696.

BRITISH STANDARDS INSTITUTION (1963). Methods for the Chemical Analysis of Liquid Milk and Cream. British Standard 1741.

BROADBENT P.J. (1967)a. Individual feeding device for livestock. Proc. 45th meeting of the Brit. Soc. Anim. Prod. 20-22 March. Harrogate. No. 11.

BROADBENT P.J. (1967b). Individual feeding device for livestock. Scottish Farm Buildings Investigation Unit 12 p. 7.

BROSTER W.H. and CURNOW R.N. (1964). A note on the use of the analysis of covariance to reduce standard errors in experiments on milk production. J. Agric. Sci. 63 91.

BROWN L.D., HILLMAN D., LASSITER C.A. and HUFFMAN C.F. (1963). Grass silage vs. Hay for lactating dairy cows. J. Dairy Sci. 46 (5) 407.

CAMPLING R.C. (1964). Factors affecting the voluntary intake of grass. J. Br. Grassld. Soc. 19 110.

CAMPLING R.C. (1966a). The control of voluntary intake of food in cattle. Outlook on Agric. 5 (2) 74.

CAMPLING R.C. (1966)b). The intake of hay and silage by cows. J. Br. Grassld. Soc. 21 (1) 41.

CAMPLING R.C. (1966c). A preliminary study of the effect of pregnancy and of lactation on the voluntary intake of food by cows. Brit. J. Nutr. 20 25.

CAMPLING R.C. and BALCH C.C. (1961). Factors affecting the voluntary intake of food by cows I Preliminary observations on the effect on the voluntary intake of hay, of changes in the amount of the reticulo-ruminal contents. Brit. J. Nutr. 15 523.

CAMPLING R.C. and FREER M. (1966). Factors affecting the voluntary intake of food by cows. 8. Experiments with ground, pelleted roughages. Br. J. Nutr. 20 229.

CAMPLING R.C., FREER M. and BALCH C.C. (1961). Factors affecting the voluntary intake of food by cows. 2. The relationship between the voluntary intake of roughages, the amount of digesta in the reticulo-rumen and the rate of disappearance of digesta from the alimentary tract. Brit. J. Nutr. 15 531.

CAMPLING R.C., FREER M. and BALCH C.C. (1962). Factors affecting the voluntary intake of food by cows. 3. The effect of urea on the voluntary intake of oat straw. Brit. J. Nutr. 16 115.

CAMPLING R.C. and MURDOCH J.C. (1966). The effect of concentrates on the voluntary intake of roughages by cows. J. Dairy Res. 33 1.

CHARLET-LERY G. (1969). Methods for Determination of Digestibility Coefficients of Feeds for Ruminants. Report No. 1. from the Study Commission of the E.A.A.P. on Animal Nutrition.

CLOUGH P., SHAW E. and THOMAS T.P. (1968). Cow Behaviour Studies. Proc. 47th Meeting of the British Soc. Anim. Prod., 25-27th March, Harrogate.

CORBETT J.L. (1960). Faecal-index techniques for estimating herbage consumption by grazing animals. Proc. Int. Grassld. Congr. VIII, Reading, p.438.

CORBETT, J.L., GREENHALGH J.F.D., GWYNN P.E. and WALKER D. (1958)(a). Excretion of chromium sesquioxide and polyethylene-glycol by dairy cows. Br. J. Nutr. 12 266.

CORBETT J.L., GREENHALGH J.F.D. and MacDONALD A.P. (1958)(b). Paper as a carrier of Chromium Sesquioxide. Nature, Lond., 182 1014.

CROWL B.W. and ALBRIGHT J.L. (1965). Free stalls work in Indiana. Hoard's Dairyman, 110 (13) 776.

CURRAN M.K., LEAVER J.D. and WESTON E.W. (1967). A note on the use of chromic oxide incorporated in a feed to estimate faecal output in ruminants. Anim. Prod. 9 (4) 561.

DOLBY R.M. (1961). Dye-binding methods for the estimation of protein in milk. J. Dairy Res. 28 43.

DOWDEN D.R. and JACOBSON D.R. (1960). Inhibition of Appetite in Dairy Cattle by Certain intermediate Metabolites. Nature, Lond., 188 148.

DUCKWORTH J.E. and SHIRLAW D.W. (1958a). The value of animal behaviour records in pasture evaluation studies. Anim. Behav. 6 139.

DUCKWORTH J.E. and SHIRLAW D.W. (1958b). A study of factors affecting feed intake and the eating behaviour of cattle. Anim. Behav. 6 147.

ELY R.E., JACOBSON W.C. and KANE E.A. (1951). Metabolism of lignin in orchard grass hay cut at various stages of maturity. J. Dairy Sci. 34 492.

EVANS R.E. (1960). Rations for livestock. Ministry of Agriculture, Fisheries and Food Tech. Bull. 48. 15th ed. London:H.M.S.O.

FEDERATION OF UNITED KINGDOM MILK MARKETING BOARDS (1968). United Kingdom Dairy Facts and Figures.

FORBES R.M. (1950). Protein as an indicator of pasture forage digestibility. J. Anim. Sci. 9 231.

FORBES R.M. and GARRIGUS W.P. (1948). Further investigations of the relationship between chemical composition, digestibility and palatability of pasture forages. J. Anim. Sci. 7 536. (Abs.).

FREER M. and CAMPLING R.C. (1963). Factors affecting the voluntary intake of food by cows. 5. The relationship between the voluntary intake of food, the amount of digesta in the reticulo rumen and the rate of disappearance of digesta from the alimentary tract with diets of hay, dried grass or concentrates. Brit. J. Nutr. 17 79.

FULLER J.M. (1928). Some Physical and Physiological Activities of Dairy Cows. New Hampshire Agr. Expt. Sta. Tech. Bull. 35.

GELLING W.E., SHAW H.E. and HILL J.B. (1958). Self Feeding in a Silo Barn. Agric. 65 379.

GRAHAM N.M. and WILLIAMS A.J. (1962). The effects of pregnancy on the passage of food through the digestive tract of sheep. Aust. J. Agric. Res. 13 894.

GREENHALGH J.F.D. (1969). Personal Communications.

GREENHALGH J.F.D. and CORBETT J.L. (1960). The indirect estimation of the digestibility of pasture herbage. I. Nitrogen and chromogen as faecal index substances. J. Agr. Sci. 55 371.

GREENHALGH J.F.D., CORBETT J.L. and McDONALD I. (1960). The indirect estimation of the digestibility of pasture herbage. II. Regressions of digestibility on faecal nitrogen concentration; their determination in continuous digestibility trials and the effect of various factors on their accuracy. J. Agric. Sci. 55 377.

GREENHALGH J.F.D. and RUNCIE K.V. (1962). The herbage intake and milk production of strip and zero grazed cows. J. Agric. Sci. 59 95.

GUHL A.M. and ATKESON F.W. (1959). Social Organisation in a herd of Dairy Cows. Trans. Kans. Acad. Sci. 62 (1) 80.

HAFEZ E.S.E. (1962). The Behaviour of Domestic Animals. Bailliere, Tindall & Cox, London.

HARDISON W.A. and REID J.T. (1953). Use of indicators in the measurement of the dry matter intake of grazing animals. J. Nutr. 51 35.

HARDISON W.A., REID J.T., MARTIN C.M. and WOOLFOLK P.G. (1954). Degree of herbage selection by grazing cattle. J. Dairy Sci. 37 89.

HARSHBARGER K.E. (1949). Observations on time required for dairy cows to eat grain, silage and hay. J. Dairy Sci. 32 (8) 716.

HILLMAN D., LASSITER C.A. HUFFMAN C.F. and DUNCAN C.W. (1958). Effect of All-hay vs. All-silage rations on dry matter intake of lactating dairy cows; Moisture and pH as factors affecting appetite. J. Dairy Sci. 41 720.

HODGES J. and O'CONNOR L.K. (1960). An Investigation into Self-Feed Silage Practices. Anim. Prod. 2 37.

HOLDER J.M. (1963). Chemostatic regulation of appetite in sheep. Nature, Lond., 200 1074.

HOLT J.S. and BARR W.L. (1962). Large Pennsylvania Dairy Farms Progress Rept. 237, Pennsylvania State University, A.E.S.

HOLTER J.A. and REID J.T. (1959). Relationship between the concentrations of crude protein and apparently digestible protein in forages. J. Anim. Sci. 18 1339.

HUFFMAN C.F. (1958). Adequacy of dairy feeding. Nutritional and Economic Aspects of Feed Utilisation by Dairy Cows. Iowa State College Press, Ames, Iowa.

HUTTON J.B. (1963). The effect of lactation on intake in the dairy cow. Proc. N.Z. Soc. Anim. Prod. 23 39.

IRVIN H.M., WISEMAN H.G., SHAW J.C. and MOORE L.A. (1953). The role of plant pigments in digestion trial studies. J. Anim. Sci. 12 541.

JACKSON M.G., RUNCIE K.V. and GREENHALGH J.F.D. (1962). A comparison of silage consumption of dairy cows self feeding and individually hand-fed. Proc. 36th Meeting of the Brit. Soc. Anim. Prod., Edinburgh, 28 - 29th March.

JONES P.J. (1967). Conserved grass for winter feeding. J. Brit. Grassld. Soc. 22 (1) 73.

KANE E.A., ELY R.E., JACOBSON W.C. and MOORE L.A. (1951). Comparative digestion studies in orchardgrass. J. Dairy Sci. 34 492.

KANE E.A., ELY R.E. JACOBSON W.C. and MOORE L.A. (1953a). Comparison of various digestion trial techniques with dairy cattle. J. Dairy Sci. 36 325.

KANE E.A. and JACOBSON W.C. (1954). An improved method of using plant pigments as an indicator of digestibility. J. Dairy Sci. 37 672.

KANE E.A., JACOBSON W.C., ELY R.E. and MOORE L.A. (1953b). The estimation of the dry matter consumption of grazing animals by ratio techniques. J. Dairy Sci. 36 637.

KANE E.A., JACOBSON W.C. and MOORE L.A. (1950). A comparison of techniques used in digestibility studies with dairy cattle. J. Nutr. 41 583.

KANE E.A., JACOBSON W.C. and MOORE L.A. (1952). Diurnal variation in the excretion of chromium oxide and lignin. J. Nutr. 47 263.

KENNEDY W.K. and LANCASTER R.J. (1957). Comparison of faecal pigments and faecal nitrogen for the estimation of feed-to-faeces ratio of pasture fed cattle. Proc. N.Z. Soc. Anim. Prod. 17 56.

KIDWELL J.F., BOHMAN V.R. and HUNTER J.E. (1954). Individual and Group Feeding of Experimental Beef Cattle as Influenced by Hay Maturity. J. Anim. Sci. 13 543.

KILGOUR R. and SCOTT T.H. (1959). Leadership in a herd of dairy cows. Proc. N.Z. Soc. Anim. Prod. 19 36.

LAMBOURNE L.J. and REARDON T.F. (1962). Use of 'seasonal' regressions in measuring feed intake of grazing animals. Nature, Lond., 196 961.

LAMBOURNE L.J. and REARDON T.F. (1963). The use of chromium oxide and faecal nitrogen concentration to estimate the pasture intake of Merino wethers. Aust. J. Agric. Res. 14 257.

LANCASTER R.J. (1954). Measurement of feed intake of grazing cattle and sheep. V. Estimation of the feed-to-faeces ratio from the nitrogen content of the faeces of pasture-fed cattle. N.Z. J. Sci. Tech. 36 15.

LANCASTER R.J., COUP M.R. and PERCIVAL J.C. (1953). Measurement of feed intake of grazing cattle and sheep. III. Marker technique for investigating the faeces output of grazing cows. N.Z. J. Sci. Tech. 35 117.

LANGLANDS J.P. (1967). Studies on the nutritive value of the diet selected by sheep. III. A comparison of oesophageal fistula and faecal index techniques for the indirect estimation of digestibility. Anim. Prod. 9 325.

LANGLANDS J.P., CORBETT J.L. and McDONALD I. (1963). The indirect estimation of the digestibility of pasture herbage. III. Regressions of digestibility on faecal nitrogen concentration; effects of species and individuality of animal and of the method of determining digestibility upon the relationships. J. Agric. Sci. 61 221.

LARSEN J.B. (1960). Hay and Silage for Dairy Cows. Proc. 8th internat. Grassld. Cong., Reading. p. 697.

LEWIS R.C. and JOHNSON J.D. (1954). Observations of Dairy Cow Activities in Loose Housing. J. Dairy Sci. 37 269.

M.A.F.F. (1967). Cow Behaviour in Loose Housing. Agricultural Land Service. Tech. Rep. No. 13.

MAHAFFEY J.C., MILLER W.J., DONKER J.D. and DALTON H.L. (1954). Effect of certain factors on the diurnal excretion pattern of chromic oxide. J. Dairy Sci. 37 672. (Abstr.).

McBRIDE G. (1958). The influence of the environment upon poultry productivity. II. The effect of peck order on productivity. Aust. J. Sci.

McBRIDE G. (1959). The Influence of Social Behaviour on Experimental Design in Animal Husbandry. Anim. Prod. 1 81.

McCULLOUGH T.A. (1969). A study of factors affecting the voluntary intake of food by cattle. Anim. Prod. 11 (2) 145.

McDONALD I.W. (1962). The nitrogen intake and excretion of grazing ruminants. p. 43. A review of nitrogen in the tropics with particular reference to pastures. Bull. 46. Pub. Commonwealth Agricultural Bureauz, England.

McDONALD I.W. (1968). The nutrition of grazing ruminants. Nutr. Abstr. and Rev. 38 (2) 381 (A review).

McPHEE C.P., McBRIDE G. and JAMES J.W. (1964). Social Behaviour of Domestic Animals. III. Steers in small yards. Anim. Prod. 6 9.

MINSON D.J. and KEMP C.D. (1961). Studies in the Digestibility of Herbage. IX. Herbage and faecal N as indicators of herbage organic matter digestibility. J. Brit. Grassld. Soc. 16 76.

MINSON D.J., TAYLER J.C., ALDER F.E., RAYMOND W.F., RUDMAN J.E., LINE C. and HEAD M.J. (1960). A method for identifying the faeces produced by individual cattle or groups of cattle grazing together. J. Brit. Grassld. Sco. 15 86.

MONTGOMERY M.J. and BAUMGARDT B.R. (1965). Regulation of food intake in ruminants. 1. Pelleted rations varying in energy concentration. J. Dairy Sci. 48 569.

MONTGOMERY M.J., SCHULTZ L.H. and BAUMGARDT B.R. (1963). Effect of intra-ruminal infusion of volatile fatty acids and lactic acid on voluntary hay intake. J. Dairy Sci. 46 (12) 1380.

MOORE L.A., THOMAS J.W. and SYKES J.F. (1960). The acceptibility of grass legume silage by dairy cattle. Proc. 8th internat. grassld. Cong., Reading p. 701.

MURDOCH J.C. (1959a). The effect of feeding hay and silage on the yield and S.N.F. content of milk. N.I.R.D. Report. p. 34.

MURDOCH J.C. (1960). The effect of prewilting herbage on the composition of silage and its intake by cows. J. Brit. Grassld. Soc. 15 (1) 70.

MURDOCH J.C. (1962). Silage for dairy cows. J. Brit. Grassld. Soc. 17 133.

MURDOCH J.C. (1965). The effect of length of silage on its voluntary intake by cattle. J. Brit. Grassld. Soc. 20 54.

MURDOCH J.C. (1960). Factors affecting the voluntary intake of silage and hay. J. Brit. Grassld. Soc. 22 95.

MURDOCH J.C. and ROOK J.A.F. (1963). A comparison of hay and silage for milk production. J. Dairy Res. 30 391.

NEVENS W.B. (1927). Experiments in the Self-Feeding of Dairy Cows. Illinois Agric. Expt. Sta. Bull. No. 289.

NORDFELDT S. (1966). Utilization of hay and/or silage by dairy cows. Proc. X Internat. Grassld. Cong. Helsinki p. 588.

OKAMOTO M., WALDO D.R., MILLER R.W. and MOORE L.A. (1964). Histamine levels in forages and dry matter intake of heifers. J. Dairy Sci. 47 (11) 1231.

PIGDEN W.J. and BRISSON G.J. (1957). Note on a chromium oxide pellet to provide uniform release of this indicator in the rumen of cattle. Canad. J. Anim. Sci. 37 185.

PORTER A.R. (1953). Dairy Cows Vary in Roughage Preferences. Iowa Farm Sci. 7 (2) 9.

PUTNAM P.A. and LOOSLI J.K. (1959). Effect of feeding different ratios of roughage to concentrate upon milk production and digestibility of the ration. J. Dairy Sci. 42 (6) 1070.

PUTNAM P.A., LOOSEI J.K. and WARNER R.G. (1958). Excretion of chromium oxide by dairy cows. J. Dairy Sci. 41 1723.

RAYMOND W.F. (1954). Studies in the digestibilitie of herbage. III. The use of faecal collection and chemical analysis in pasture studies. (a) Ratio and tracer methods. J. Brit. Grassld. Soc. 9 (1) 61.

RAYMOND W.F. (1966). The nutritive value of herbage. Chpt. 3, p.81. Recent Advances in Animal Nutrition. Ed. J.T. Abrams. Publishers J. & A. Churchhill Ltd., London.

RAYMOND W.F., KEMP C.D., KEMP A.W. and HARRIS C.E. (1954). Studies in the digestibility of herbage. IV The use of faecal collection and chemical analysis in pasture studies. (b) Faecal Index methods. J. Brit. Grassld. Soc. 9 69.

RAYMOND W.F. and MINSON D.J. (1955). The use of chromic oxide for estimating the faecal production of grazing animals. J. Brit. Grassld. Soc. 10 282.

RAYMOND W.F., MINSON D.J. and HARRIS C.E. (1959). Studies in the digestibility of herbage. VI Further evidence on the effect of level of intake on the digestive efficiency of sheep. J. Brit. Grassld. Soc. 14 75.

RAYMOND W.F. and TERRY R.A. (1966). Studies of herbage digestibility by an in vitro method. Outl. Agric. 5 (2) 60.

REID J.T. (1962). Indicator methods in herbage quality studies. Chpt. 12, p.45. Pasture and Range Research Techniques". Comstock Publishing Associates, New York.

REID J.T., WOOLFOLK P.G., HARDISON W.A., MARTIN C.M., BRUNDAGE A.L. and KAUFMAN R.W. (1952). A procedure for measuring the digestibility of pasture forage under grazing conditions. J. Nutr. 46 255.

RICHARDS C.R. and REID J.T. (1952). The use of methoxyl groups in forage and faecal materials as an index of the feeding value of forages. J. Dairy Sci. 35 595.

SCHEIN M.W. and FOHRMAN M.H. (1955). Social dominance relationships in a herd of dairy cattle. Brit. J. Anim. Behav. 3 45.

SCHEIN M.W., HYDE C.E. and FOHRMAN M.H. (1955). The effect of psycological disturbances on milk production of dairy cattle. Proc. Ass. Southern Agric. Wkrs. 52nd Convention (Louisville, Ky. 79-80) (Abstr.).

SCHMISSEUR W.E., ALBRIGHT J.L., DILLON W.M., KEHRBERG E.W., AND MORRIS W.H.M. (1966). Animal Behaviour Responses to Loose and Free Stall Housing. J. Dairy Sci. 49 (1) 102.

SHELTON D.R. and REID R.L. (1960). Measuring the nutritive value of forages using in vitro rumen technique. Proc. VIII internal. Grassld. Congr., Reading 524.

SIMKINS K.L and BAUMGARDT B.R. (1963). Evaluation of forages in the laboratory. III Comparison of various methods for predicting silage digestibility. J. Dairy Sci. 46 (4) 338.

SMALL C.A. (1966). Behaviour of a herd of cows with 24 hour access to self feed silage. N.A.A.S. Quart. Rev. 72 178.

SMITH A.M. and REID J.T. (1955). Use of chromic oxide as an indicator of faecal output for the purpose of determining the intake of pasture herbage by grazing cows. J. Dairy Sci. 38 515.

SNEDECOR (1956). Statistical Methods. Pub. Iowa State College Press, Aimes, Iowa.

STEVENSON AUDREY E. (1962). Measurement of feed intake by grazing cattle and sheep. VIII Some observations on the accuracy of the chromic oxide technique for the estimation of faeces output of dairy cattle. N.Z. J. Agric. Res. 5 339.

TAYLER J.C. and DERIAZ R.E. (1963). The use of rumen-fistulated steers in the direct determination of nutritive value of ingested herbage in grazing experiments. J. Brit. Grassld. Soc. 18 29.

THOMAS J.W., MOORE L.A., OKAMOTO M. and SYKES J.F. (1961). A study of factors affecting rate of intake of heifers fed silage. J. Dairy Sic. 44 (8) 1471.

TILLEY J.M.A., DERIAZ R.E. and TERRY R.A. (1960). The 'in vitro' measurement of herbage digestibility and assessment of nutritive value. Proc. 8th internat. Grassld. Cong., Reading 558.

TILLEY J.M.A. and TERRY R.A. (1963). A two stage technique for the in vitro digestion of forage crops. J. Brit. Grassld. Soc. 18 104.

TULLOH N.M. (1961a). Behaviour of Cattle in Yards. 1. Weighing order and behaviour before entering scales. Anim. Behav. 9 20.

TULLOH N.M. (1961b). Behaviour of cattle in yards. II. A study of temperament. Anim. Behav. 9 25.

VOISIN A. (1955). Behaviour and satiety of cattle on pasture and in the stall. Nutr. Abstr. and Rev. 25 1097.

WALKER-LOVE J. (1954). Observations on Self Feeding Roughages to Dairy Cows in Loose Housing. M.S. Thesis, Michigan State College.

WALKER-LOVE J. and LAIRD R. Jnr. (1964). Behaviour of Dairy Cows in Loose Housing with Cubicles. Paper presented at the Winter Meeting of the Brit. Soc. Anim. Prod., London, 24th March, 1964.

WATSON S.J. and NASH M.J. (1960). The conservation of grass and forage crops. Publ. Oliver and Boyd Ltd., Edinburgh and London.

WEBB F.M., COLENBRANDER V.F., BLOSSER T.H. and WALDERN D.E. (1963). Eating Habits of Dairy Cows under drylot conditions. J. Dairy Sci. 46 (12) 1433.

WEIR W.C., MEYER J.H. and LOFGREEN G.P. (1959). The use of the oesophageal fistula, lignin and chromogen techniques for studying selective grazing and digestibility of range and pasture by sheep and cattle. Agron. J. 51 235.

WOOD D.A. (1968). Modern Systems of Dairy Cow Housing with Particular Reference to the West of Scotland. B.Sc. Thesis (Hons.), W.S.A.C.

WOODBURY A.M. (1941). Changing the hook order in cows. Ecology 22 (4) 410.

APPENDIX I

APPENDIX I

LOOSE HOUSING BEHAVIOUR STUDIES

Mean percentage time in each activity				Herd Particulars		
Feeding	Loitering in yard & Milking	Bedded Area		Number of Cows	Breed	Reference
		Loitering	Lying			
		SILAGE ONLY				
15.2	21.9	19.6	43.3	68	F	M.A.F.F. (1967) Farm 1
12.2	29.0	19.4	39.5	30	F	do. Farm 3
17.8	22.3	19.0	40.8	28	F	do. Farm 4
16.6	20.4	23.0	40.0	35	F	do. Farm 5
16.8	11.9	25.1	46.2	49	F/A	do. Farm 6
15.3	22.7	20.1	41.9	54	F	do. Farm 7
7 - 15	1 - 10	47 - 53	24-37	40	-	Clough et al., (1968)
20.8	-	-	-	10	F/A	Jackson et al., (1962)
14.5	-	-	-	-	-	Murdoch, (1959b)
		HAY ONLY				
22.9	9.5	26.7	40.9	23	B.S/H	Walker-Love, (1954)
21.3	13.0	21.3	44.6	20	B.S.	Lewis & Johnson (1954)

(cont'd overleaf)

APPENDIX I (Cont'd)

Mean percentage time in each activity				Herd Particulars		Reference
Feeding	Loitering in yard & Milking	Bedded Area		Number of Cows	Breed	
		Loitering	Lying			
		HAY AND SILAGE				
25.0	-	-	30.2	35	F	Small, (1966)
19.3	20.2	12.1	48.4	40	F/A	Walker-Love & Laird, (1964)
20.6	14.8	21.7	42.9	23	B.S/H	Walker-Love, (1954)
15.6	31.9	8.9	43.6	-	F/A	Wood, (1968)
26.1	-	-	-	4/100	G	Webb et al., (1963)
23.8	22.1	17.9	36.3	20	B.S.	Lewis & Johnson (1954)
21.5	33.1	8.5	36.9	34	F	M.A.F.F. (1967) Farm 2
20.5	32.2	10.5	36.8	53	F	do. Farm 8
-	-	-	44.4	20	H	Schmisseur et al., (1966)
-	-	-	51.3	24	H	do.

F = Friesian A = Ayrshire B.S. = Brown Swiss H = Holstein G = Guernsey

APPENDIX II

APPENDIX II

TABLE (i)

Analysis of Variance for Mean Roughage Dry Matter Intake (lb./day)

Source	d.f.	S.S.	M.S.	F.	Sig.
Ration	1	18.92	18.92	2.82	N.S.
Breed	1	4.41	4.41	0.66	N.S.
Period	1	9.00	9.00	1.34	N.S.
Period x Ration	1	1.10	1.10	0.16	N.S.
Breed x Ration	1	0.00	0.00	0.00	N.S.
Breed x Period	1	1.21	1.21	0.18	N.S.
Breed x Period x Ration	1	2.72	2.72	0.41	N.S.
Error	8	53.66	6.71		
TOTAL	15	91.02			

APPENDIX II

TABLE (ii)

Analysis of Covariance for Effect of Period I on Period II Mean Roughage Dry Matter Intake (lb/day)

x = Period I intake y = Period II intake

Source	d.f.	SSx	SPxy	Ssy	Adj.SSy	d.f.	M.S.	F.	Sig.
Breed	1	0.50	1.60	5.12	-	-	-	-	-
Treatments	3	24.81	0.81	9.67	-	-	-	-	-
Period I Treatment	1	14.58	-0.27	0.01	-	-	-	-	-
Period II Treatment	1	3.38	-4.29	5.45	12.06	1	12.06	2.82	N.S.
Interaction Period I and Period II Treatments	1	6.85	5.37	4.21	0.01	1	0.01	0.002	N.S.
Error	3	21.26	16.05	20.66	8.54	2	4.27	-	-
Total	7	46.57	18.46	35.45	-	-	-	-	-
Period II + error	4	24.64	11.76	26.21	20.60	-	-	-	-
Interaction + error	4	28.11	21.42	24.87	8.55	-	-	-	-

APPENDIX II

TABLE (iii)

Analyses of Variance for mean roughage (R.D.M.I.), concentrate (C.D.M.I.), and total dry matter intake (T.D.M.I.), and for mean digestible organic matter intake (D.O.M.I.) - lb/day

Source	d.f.	Mean Square			
		R.D.M.I.	C.D.M.I.	T.D.M.I.	D.O.M.I.
Ration	1	18.92	2.72	36.00	1.56
Breed	1	4.41	36.60*	15.60	1.10
Period	1	9.00	28.09	5.29	3.80
Period x Ration	1	1.10	7.56	2.89	0.72
Breed x Ration	1	0.00	6.25	6.00	0.02
Breed x Period	1	1.21	0.72	0.06	0.42
Breed x Period x Ration	1	2.72	9.00	1.82	0.90
Error	8	6.71	5.69	6.87	2.95

Non significance may be assumed other than where stated

APPENDIX II

TABLE (iv)

Analyses of variance for mean milk yield and body weight change (lb/day)

Source	d.f.	Mean Square	
		Milk Yield	Body Weight Change
Ration	1	76.56	0.53
Breed	1	455.82*	0.64
Period	1	325.80	0.66
Period x Ration	1	40.96	1.46*
Breed x Ration	1	20.25	0.02
Breed x Period	1	0.36	0.14
Breed x Period x Ration	1	37.82	0.13
Error	8	73.03	0.27

Non significance may be assumed other than where stated

APPENDIX II

TABLE (v)

Analysis of Variance for Percentage weekly decline in milk yield during Period I

Source	d.f.	S.S.	M.S.	F.	Sig.
Ration	1	0.45	0.45	0.04	N.S.
Breed	1	9.95	9.95	0.99	N.S.
Breed x Ration	1	8.69	8.69	0.87	N.S.
Error	4	40.13	10.03		
	7	59.22			

APPENDIX II

TABLE (vi)

Analysis of Variance for mean butterfat (B.F.), solids-not-fat (S.N.F.), total solids (T.S.), Lactose (Lact.) and protein (Prot.) percentages in milk

Source	d.f.	Mean Square				
		B.F.	S.N.F.	T.S.	Lact.	Prot.
Ration	1	0.083	0.066	0.002	0.035	0.008
Breed	1	0.008	0.064	0.052	0.183	0.045
Period	1	0.004	0.002	0.012	0.016	0.124
Period x Ration	1	0.150	0.026	0.300	0.074	0.005
Breed x Ration	1	0.000	0.007	0.005	0.032	0.019
Breed x Period x Ration	1	0.014	0.016	0.026	0.047	0.001
Error	8	0.060	0.020	0.080	0.063	0.024

All the mean squares were non significant

APPENDIX III

APPENDIX III

TABLE (i)

SUMMARY OF THREE BEHAVIOUR STUDIES

Mean Percentage of Behaviour Pattern

Cow Number		1	2	3	4	5	6	7	10	Mean
Breed		F	F	A	A	F	F	A	A	
Treatment		H/H	S/H	H/H	H/S	H/S	S/S	S/H	S/S	
Eating	Study 1	17.7	22.9	15.6	14.6	17.7	17.7	18.8	13.5	17.3
	Study 2	25.0	26.0	20.8	13.5	19.8	15.6	20.8	8.3	18.7
	Study 3	17.7	29.2	19.8	18.8	21.9	21.9	26.0	17.7	21.6
	Mean	20.1	26.0	18.7	15.6	19.8	18.4	21.9	13.2	19.2
Loitering in Yard	Study 1	16.7	7.3	11.5	7.3	13.5	20.8	16.7	5.2	12.4
	Study 2	12.5	7.3	6.3	4.2	15.6	30.2	12.5	9.4	12.3
	Study 3	20.8	7.3	14.6	1.0	5.2	5.2	10.4	4.2	8.6
	Mean	16.7	7.3	10.8	4.2	11.4	18.7	13.2	6.3	11.1
Standing in Cubicles	Study 1	4.2	2.1	4.2	10.4	-	1.0	5.2	-	3.4
	Study 2	4.2	-	5.2	9.4	1.0	-	6.3	1.0	3.4
	Study 3	1.0	-	3.1	1.0	-	1.0	4.2	2.1	1.6
	Mean	3.1	0.7	4.2	6.9	0.3	0.7	5.2	1.0	2.8
Two feet in Cubicle	Study 1	5.2	2.1	6.3	2.1	1.0	1.0	-	3.1	2.6
	Study 2	2.1	1.0	8.3	-	3.1	-	3.1	7.3	3.1
	Study 3	1.0	2.1	2.1	-	1.0	1.0	-	21.9	3.6
	Mean	2.8	1.7	5.6	0.7	1.7	0.7	1.0	10.8	3.1
Standing in Passage	Study 1	6.3	10.4	29.2	5.2	26.0	10.4	9.4	27.1	15.5
	Study 2	5.2	3.1	22.9	18.8	7.3	7.3	14.6	33.3	14.1
	Study 3	6.3	4.2	14.6	8.3	7.3	9.4	14.6	21.9	10.8
	Mean	5.9	5.9	22.2	10.8	13.5	9.0	12.9	27.4	13.5
Lying	Study 1	45.8	51.0	29.2	56.3	37.5	44.8	45.8	46.9	44.7
	Study 2	47.9	59.4	33.3	51.0	50.0	43.8	39.6	37.5	45.3
	Study 3	50.0	54.2	42.7	67.7	61.5	58.3	41.7	29.2	50.7
	Mean	47.9	54.9	35.1	58.3	49.7	49.0	42.4	37.9	46.9
Collecting and Milking	Study 1	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
	Study 2	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
	Study 3	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
	Mean	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5

APPENDIX III

TABLE (ii)

Mean Weekly Climatic Records

DATE	Temperature Outside		Temperature in Cubicle House		Relative Humidity in Cubicle House	
	Mean Min. (°F)	Mean Max. (°F)	Mean Min. (°F)	Mean Max. (°F)	Mean Min. (%)	Mean Max. (%)
19/1/69 - 25/1/69	38.6.	49.4	46.5	53.2	91.3	94.3
26/1/69 - 1/2/69	40.0	44.7	45.4	51.1	81.0	90.7
2/2/69 - 8/2/69	28.9 (5)	39.1	38.6	46.3	71.7	91.0
9/2/69 - 15/2/69	27.1 (7)	38.0	38.1 (1)	44.9	79.1	92.4
16/2/69 - 22/2/69	26.9 (6)	38.1	37.3 (1)	43.4	77.0	90.9
23/2/69 - 1/3/69	35.0 (1)	41.7	42.1	48.0	81.3	93.0
2/3/69 - 8/3/69	26.7 (7)	44.1	36.4	51.1	78.8	96.0
9/3/69 - 15/3/69	32.0 (3)	40.7	40.0	47.6	76.3	92.9
16/3/69 - 22/3/69	34.4 (1)	41.0	40.7	48.4	82.4	93.6
23/3/69 - 29/3/69	27.9 (6)	45.1	40.2	52.8	74.0	97.0
30/3/69 - 5/4/69	33.1 (4)	49.7	41.0	56.3	67.4	96.1
6/4/69 - 12/4/69	37.9	55.7	46.3	60.9	68.0	95.6
13/4/69 - 19/4/69	35.1 (1)	49.6	44.0	58.4	62.7	95.3
20/4/69 - 23/4/69	37.3	49.0	45.0	55.0	61.5	95.0
Trial Means	32.9	44.7	41.5	51.2	75.5	93.8

Figures in brackets indicate the number of days when the temperature fell below freezing point.

APPENDIX III

TABLE (iii)

COW LIVE-WEIGHTS (lb.)

		COW NUMBERS							
PERIOD I		1	2	3	4	5	6	7	10
START	Day 1	1219	1102	1016	1248	1447	1264	891	1017
	Day 2	1231	1092	1013	1230	1458	1262	887	1016
	Day 3	1231	1098	1030	1196	1452	1230	890	1018
	Mean	1227.0	1097.3	1019.7	1224.7	1452.3	1252.0	889.3	1017.0
FINISH	Day 1	1212	1020	1050	1248	1452	1219	912	960
	Day 2	1232	1003	1034	1254	1455	1208	892	955
	Mean	1222.0	1011.5	1042.0	1251.0	1453.5	1213.5	902.0	957.5
Weight Change		- 5.0	- 85.8	+ 22.3	+ 26.3	+ 1.2	- 38.5	+ 12.7	- 59.5

APPENDIX III

TABLE (iv)

COW LIVE-WEIGHTS (lb.)

		COW NUMBERS							
PERIOD II		1	2	3	4	5	6	7	10
START	Day 1	1203	1083	1036	1228	1412	1214	944	926
	Day 2	1219	1092	1050	1228	1427	1212	911	958
	Mean	1211.0	1087.5	1043.0	1228.0	1419.5	1213.0	927.5	942.0
FINISH	Day 1	1188	1103	1049	1212	1420	1240	955	971
	Day 2	1178	1103	1039	1228	1418	1225	940	966
	Day 3	1193	1094	1037	1218	1435	1223	952	950
	Mean	1186.3	1100.0	1041.7	1219.3	1424.3	1229.3	949.0	962.3
Weight change		- 24.7	+ 12.5	- 1.3	- 8.7	+ 4.8	+ 16.3	+ 21.5	+ 20.3

APPENDIX III

TABLE (v)

Mean Daily Dry Matter Intakes and Milk Yield (lb.)

Continuous Treatment

WEEKS OF TRIAL	FRIESIAN 6				AYRSHIRE 10			
	Silage Intake	Conc. Intake	Total Intake	Milk Yield	Silage Intake	Conc. Intake	Total Intake	Milk Yield
0 - 1	18.8	13.8	32.6	55.6	21.4	10.5	31.9	41.1
1 - 2	13.5	13.9	27.4	54.6	17.0	8.5	25.5	38.8
2 - 3	14.3	13.9	28.2	55.7	20.1	8.5	28.6	38.3
3 - 4	9.9	15.0	24.9	57.2	19.2	8.6	27.8	37.1
4 - 5	15.6	15.4	31.0	56.2	21.5	8.6	30.1	38.3
5 - 6	12.9	15.5	28.4	54.3	22.6	8.7	31.3	35.4
6 - 7	20.4	14.6	35.0	51.0	20.0	7.0	27.0	35.1
7 - 8	16.7	13.2	29.9	46.1	19.6	6.9	26.5	31.3
Mean	15.2	14.5	29.7	53.8	20.2	8.4	28.6	36.9
10 - 11	18.3	10.4	28.7	38.4	19.6	6.9	26.5	28.8
11 - 12	16.5	10.4	26.9	39.6	22.8	6.9	29.7	28.4
12 - 13	12.8	9.9	22.7	34.6	23.5	6.9	30.4	30.5
13 - 14	19.2	8.4	27.6	33.4	21.6	6.9	28.5	30.4
Mean	16.7	9.8	26.5	36.5	21.9	6.9	28.8	29.5

Mean Percentage Dry Matter

	Silage	Concentrate	Silage	Concentrate
Period I	24.5	86.3	24.6	86.3
Period II	24.9	86.5	24.7	86.5

APPENDIX III

TABLE (vi)

Mean Daily Dry Matter Intakes and Milk Yield (lb)

Continuous Treatment

WEEKS OF TRIAL	FRIESIAN 1				AYRSHIRE 3			
	Hay Intake	Conc. Intake	Total Intake	Milk Yield	Hay Intake	Conc. Intake	Total Intake	Milk Yield
0 - 1	9.5	11.8	21.3	52.3	19.3	12.1	31.4	49.3
1 - 2	14.7	11.5	26.2	53.2	19.2	12.0	31.2	48.0
2 - 3	18.1	11.4	29.5	48.6	20.7	12.1	32.8	48.7
3 - 4	19.3	12.0	31.3	50.9	18.5	12.1	30.6	49.7
4 - 5	16.5	11.6	28.1	53.1	21.2	12.1	33.3	50.2
5 - 6	21.5	11.7	33.2	56.4	22.9	12.1	35.0	50.1
6 - 7	22.4	11.3	33.7	55.4	21.6	12.1	33.7	48.4
7 - 8	22.0	11.4	33.4	49.6	18.2	12.6	30.8	47.4
Mean	18.0	11.6	29.6	52.4	20.2	12.1	32.3	49.0
10 - 11	23.6	11.7	35.3	47.6	20.4	10.4	30.8	41.2
11 - 12	18.8	11.1	29.9	45.3	20.4	10.4	30.8	42.3
12 - 13	19.7	11.4	31.1	47.1	24.5	10.4	34.9	41.6
13 - 14	17.2	10.6	27.8	44.9	22.6	10.4	33.0	41.5
Mean	19.8	11.2	31.0	46.2	22.0	10.4	32.4	41.6

	Hay	Concentrate	Hay	Concentrate
Period I	86.1	86.3	86.0	86.2
Period II	84.5	86.5	84.9	86.5

APPENDIX III

TABLE (vii)

Mean Daily Dry Matter Intakes and Milk Yield (lb.)

Changeover Treatment

WEEKS OF TRIAL	FRIESIAN 2				AYRSHIRE 7			
	Silage Intake	Conc. Intake	Total Intake	Milk Yield	Silage Intake	Conc. Intake	Total Intake	Milk Yield
0 - 1	23.9	13.3	37.2	51.6	15.6	10.5	26.1	31.1
1 - 2	19.0	13.8	32.8	49.8	16.5	10.5	27.0	34.7
2 - 3	21.0	13.9	34.9	48.1	15.0	8.9	23.9	34.1
3 - 4	17.5	13.7	31.2	44.8	19.2	7.2	26.4	32.4
4 - 5	15.9	12.0	27.9	45.3	14.7	6.9	21.6	29.6
5 - 6	18.1	12.0	30.1	43.4	18.1	6.9	25.0	30.6
6 - 7	19.3	10.4	29.7	38.2	19.4	6.4	25.8	27.2
7 - 8	20.3	10.4	30.7	42.4	18.6	5.2	23.8	27.9
Mean	19.4	12.4	31.8	45.5	17.1	7.8	24.9	31.0
	Hay				Hay			
10 - 11	22.8	11.4	34.2	44.4	20.8	4.8	25.6	21.6
11 - 12	18.5	11.4	29.9	40.4	26.4	3.5	29.9	22.9
12 - 13	22.0	9.9	31.9	36.9	23.5	3.5	27.0	19.1
13 - 14	21.2	8.7	29.9	38.1	24.0	3.5	27.5	20.0
Mean	21.1	10.4	31.5	39.9	23.7	3.8	27.5	20.9

Mean Percentage Dry Matter

	Roughage	Concentrate	Roughage	Concentrate
Silage - Period I	24.9	86.3	24.9	86.3
Hay - Period II	84.4	86.5	84.1	86.5

APPENDIX III

TABLE (viii)

Mean Daily Dry Matter Intakes and Milk Yield (lb.)

Changeover Treatment

WEEKS OF TRIAL	FRIESIAN 5				AYRSHIRE 4			
	Hay Intake	Conc. Intake	Total Intake	Milk Yield	Hay Intake	Conc. Intake	Total Intake	Milk Yield
0 - 1	23.3	9.3	32.6	38.9	15.4	10.3	25.7	41.6
1 - 2	21.1	8.5	29.6	38.9	22.6	10.5	33.1	37.7
2 - 3	22.2	8.6	30.8	39.0	22.7	10.5	33.2	37.1
3 - 4	23.3	8.6	31.9	39.3	21.1	9.3	30.4	35.6
4 - 5	26.5	8.7	35.2	40.0	20.4	8.5	28.9	31.4
5 - 6	26.6	8.7	35.3	40.7	20.5	7.6	28.1	25.1
6 - 7	23.2	8.6	31.8	35.9	20.9	6.3	27.2	23.9
7 - 8	23.4	8.6	32.0	36.4	22.8	4.6	27.4	22.7
Mean	23.7	8.7	32.4	38.6	20.8	8.5	29.3	31.9
	Silage				Silage			
10 - 11	22.3	6.9	29.2	33.2	22.1	3.5	25.6	20.1
11 - 12	23.7	6.9	30.6	33.6	18.3	3.5	21.8	19.9
12 - 13	21.3	6.9	28.2	32.0	14.8	3.5	18.3	18.9
13 - 14	22.6	6.9	29.5	32.4	20.3	3.5	23.8	19.0
Mean	22.5	6.9	29.4	32.8	18.9	3.5	22.3	19.5

Mean Percentage Dry Matter

	Roughage	Concentrate	Roughage	Concentrate
Hay - Period I	86.0	86.2	86.6	86.3
Silage - Period II	24.7	86.5	24.9	86.5

APPENDIX III

TABLE (ix)

Weekly Individual Recordings of Percentage Butterfat in Milk

Number and Breed	Treatment	PERIOD I (Weeks)									PERIOD II (Weeks)				
		1	2	3	4	5	6	7	8	Weighted Mean	1	2	3	4	Weighted Mean
1F	H/H	4.45	4.08	3.88	3.80	4.10	3.90	3.31	3.81	3.91	3.86	3.82	3.89	3.95	3.88
2F	S/H	4.25	3.65	3.66	5.12	4.28	3.64	5.36	4.35	4.26	3.51	3.10	4.22	3.85	3.66
3A	H/H	3.88	3.50	4.00	3.30	3.49	3.04	3.69	3.71	3.57	3.50	3.65	3.60	4.40	3.79
4A	H/S	3.84	3.90	3.50	3.32	3.20	4.18	3.00	3.22	3.54	3.62	3.60	3.59	3.60	3.60
5F	H/S	3.38	3.18	4.31	3.20	3.16	3.14	3.16	3.60	3.40	3.60	3.90	3.64	3.70	3.71
6F	S/S	3.61	3.60	3.38	3.82	3.68	4.30	3.84	3.10	3.68	3.78	3.70	3.95	3.65	3.76
7A	S/H	4.30	4.10	3.59	3.76	2.68	3.62	4.12	3.81	3.75	3.69	3.74	4.29	4.38	3.99
10A	S/S	4.12	4.00	4.12	4.10	3.91	4.29	4.15	4.00	4.08	4.09	3.90	3.95	4.30	4.05

APPENDIX III

TABLE (x)

Weekly Individual Recordings of Percentage Total Solids in Milk

Number and Breed	Treatment	PERIOD I (Weeks)									PERIOD II (Weeks)				
		1	2	3	4	5	6	7	8	Weighted Mean	1	2	3	4	Weighted Mean
1F	H/H	12.73	12.45	12.38	12.09	12.64	12.10	11.70	12.45	12.31	12.50	12.46	12.40	12.52	12.46
2F	S/H	13.08	12.38	12.20	13.11	12.54	12.38	13.60	12.68	12.74	11.98	11.84	12.81	12.52	12.28
3A	H/H	12.52	12.30	12.38	11.80	11.99	11.52	12.43	12.34	12.15	12.08	12.17	12.26	12.99	12.37
4A	H/S	12.47	12.35	12.06	11.56	10.71	12.27	11.02	11.16	11.78	11.82	11.80	11.72	11.83	11.79
5F	H/S	11.92	11.47	12.58	11.64	11.48	11.70	12.12	11.78	11.84	12.28	12.22	11.98	12.12	12.15
6F	S/S	12.24	11.90	11.62	12.06	11.90	12.32	11.98	11.12	11.91	12.44	12.22	12.56	12.06	12.32
7A	S/H	13.15	12.69	12.00	12.28	11.24	11.68	12.32	12.15	12.20	12.18	11.95	12.50	12.58	12.28
10A	S/S	12.62	12.41	12.48	12.36	12.25	12.52	12.14	12.56	12.41	11.94	11.73	12.28	12.58	12.12

APPENDIX III

TABLE (xi)

Weekly Individual Recordings of Percentage Milk Ration

Number and Breed	Treatment	PERIOD I (Weeks)									PERIOD II (Weeks)				
		1	2	3	4	5	6	7	8	Weighted Mean	1	2	3	4	Weighted Mean
1F	H/H	2.53	2.45	2.78	2.81	2.84	2.71	2.89	2.92	2.73	3.08	2.99	3.05	2.99	3.02
2F	S/H	3.13	3.06	2.84	2.76	2.75	2.96	2.98	2.87	2.92	3.15	3.35	3.27	3.26	3.25
3A	H/H	3.02	2.99	2.95	3.04	2.99	3.01	3.12	3.13	3.03	3.21	3.12	3.12	3.12	3.14
4A	H/S	3.49	3.26	3.22	3.11	3.11	3.78	3.40	3.26	3.31	3.37	3.32	3.32	3.19	3.27
5F	H/S	3.09	2.82	2.95	2.94	3.01	3.16	3.34	3.06	3.04	3.17	2.91	3.04	3.14	3.06
6F	S/S	3.25	2.77	2.74	2.75	2.76	2.80	2.93	2.96	2.86	3.19	3.34	3.49	3.21	3.30
7A	S/H	3.58	3.06	2.91	3.01	2.97	2.95	2.93	2.90	3.04	3.32	3.19	3.32	3.32	3.26
10A	S/S	3.19	2.91	2.85	2.98	2.96	2.94	2.87	3.11	2.97	2.95	2.97	3.12	3.01	3.01

APPENDIX III

TABLE (xii)

Weekly Individual Recordings of Percentage Lactose in Milk

Number and Breed	Treat-ment	PERIOD I (Weeks)									PERIOD II (Weeks)				
		1	2	3	4	5	6	7	8	Weighted Mean	1	2	3	4	Weighted Mean
1F	H/H	5.07	5.06	4.98	4.76	4.86	4.80	4.80	5.06	4.92	4.93	4.97	4.88	4.88	4.91
2F	S/H	4.86	4.86	4.88	4.44	4.77	4.90	4.57	4.69	4.75	4.49	4.75	4.74	4.76	4.67
3A	H/H	4.90	4.98	4.68	4.70	4.83	4.83	4.89	4.82	4.82	4.71	4.79	4.88	4.85	4.80
4A	H/S	4.36	4.51	4.53	3.36	3.52	3.58	3.90	4.03	4.01	4.21	4.23	4.32	4.34	4.27
5F	H/S	4.77	4.63	4.66	4.74	4.67	4.75	4.91	4.58	4.71	4.71	4.61	4.61	4.50	4.60
6F	S/S	4.66	4.71	4.71	4.74	4.63	4.43	4.36	3.30	4.57	4.80	4.55	4.48	4.39	4.56
7A	S/H	4.58	4.76	4.82	4.65	4.79	4.54	4.57	4.78	4.68	4.45	4.40	4.22	4.36	4.37
10A	S/S	4.72	4.67	4.72	4.59	4.61	4.60	4.49	4.69	4.63	4.24	4.32	4.52	4.55	4.40

APPENDIX III

TABLE (xiii)

Analyses of Hay

Date	Percentage of fresh matter				Percentage of dry matter	
	D.M.	C.P.	D.C.P.	S.E.	Dy. (O.M.)	D.O.M.
25/12/68	88.2	7.20	3.31	40.0	64.2	57.6
1/ 1/69	87.0	8.90	4.89	42.9	64.9	60.2
8/ 1/69	86.1	9.65	5.63	40.0	64.8	60.1
15/ 1/69	86.8	9.10	5.09	42.9	65.1	60.7
22/ 1/69	86.3	10.00	5.92	40.0	63.8	59.3
29/ 1/69	85.9	8.25	4.36	42.9	65.7	61.1
5/ 2/69	86.2	10.25	6.19	40.0	64.4	59.8
12/ 2/69	85.9	9.80	5.77	42.9	69.2	63.8
19/ 2/69	85.7	9.45	5.45	42.9	69.9	64.5
26/ 2/69	86.0	9.70	5.70	40.0	65.0	60.3
5/ 3/69	85.3	9.80	5.82	46.2	71.4	65.6
12/ 3/69	82.8	9.30	5.45	40.0	62.9	59.7
19/ 3/69	84.6	9.75	5.76	42.9	67.0	62.5
26/ 3/69	84.9	10.05	6.05	40.0	63.4	60.0
2/ 4/69	83.9	9.70	5.75	40.0	63.5	59.5
9/ 4/69	84.5	9.90	5.91	42.9	63.7	61.8
16/ 4/69	86.2	9.95	5.91	42.9	65.5	61.6

D.M. = Dry Matter
C.P. = Crude Protein
D.C.P. = Digestible Crude Protein
S.E. = Starch Equivalent
Dy.(O.M.) = Digestibility of organic matter
D.O.M. = Digestible Organic Matter

APPENDIX III

TABLE (xiv)

Analyses of Silage Composites

Weeks of Trial	Cow Number	Percentage of fresh matter				Percentage of dry matter	
		D.M.	C.P.	D.C.P.	S.E.	Dy.(O.M.)	D.O.M.
0 - 2	2	26.7	4.20	2.77	12.4	74.9	65.6
	6	25.3	3.95	2.57	11.5	73.7	64.2
	7	25.7	4.15	2.77	11.5	72.4	63.7
	10	24.4	3.80	2.46	11.1	73.0	64.2
2 - 4	2	25.7	4.20	2.88	11.5	73.0	63.9
	6	25.4	3.95	2.57	11.6	73.7	64.4
	7	24.3	3.95	2.56	10.8	72.2	63.2
	10	25.3	4.30	2.87	11.0	71.2	62.8
4 - 6	2	24.3	3.80	2.46	11.0	72.9	63.8
	6	24.2	4.00	2.66	11.3	73.0	65.1
	7	24.5	4.00	2.77	11.0	73.0	63.7
	10	26.4	4.20	2.77	12.7	74.6	66.8
6 - 8	4	24.7	4.15	2.87	11.7	74.0	65.6
	6	25.9	4.10	2.77	12.4	74.8	66.6
	7	26.6	4.20	2.88	12.5	75.5	66.1
	10	24.6	4.20	2.87	11.0	71.7	63.4
10-12	4	27.3	4.50	2.99	12.7	73.3	65.9
	5	26.1	4.25	2.77	12.6	74.5	66.9
	6	27.0	4.35	2.88	12.4	73.1	65.2
	10	24.6	4.15	2.87	11.5	73.5	65.2
12-14	4	24.0	4.15	2.86	10.6	71.5	62.9
	5	24.5	4.10	2.87	11.3	73.7	64.7
	6	23.8	4.05	2.76	10.8	71.4	63.9
	10	25.7	4.25	2.88	11.9	73.6	65.1