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Sources of Variation in Voluntary Feed Intake and Nutrient Utilization for Milk Production of Dairy Cows

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APPENDIX CHAPTER 1

1 Diet Evaluation

1.1 INTRODUCTION

It is only when the amount of nitrogen and energy consumed is well defined can one quantify nutritional output-input relationships of dairy cows.

The nitrogen and energy intakes of a dairy cow are estimated from dry matter intake (DMI), that is: fresh weight consumed x DM per unit fresh weight x N or energy content in DM. The accuracy with which DM of the feed is determined is paramount to accurate estimation of nutrient intake.

Oven drying of silage based diets is acknowledged to underestimate the true DM of such feeds due to a loss of volatile fatty acids and alcohol in the silage. Oven drying at 60°C for 72 h reduces these losses (A R Henderson, Personal Communication). Dry matter determinations by toluene distillations prevent these losses (Dewar and McDonald, 1961).

The method used in expressing the energy value of feed should take into account the major energy losses via faeces, urine, fermentation gases and heat losses. Feed energy values should be expressed therefore as metabolizable energy (ME) as this is less influenced by many of the factors that influence digestion and fermentation. It is, however, too expensive to determine regularly in vivo ME of diets in large scale experiments fed for long periods of time. In vitro laboratory methods are therefore useful in these cases. For accuracy, in vitro methods should be standardized against in vivo data periodically (eg after every major diet change).

There is ample evidence of the shortcomings of the use of digestible crude protein systems for ruminants (Roy et al, 1977). Recent research has therefore been directed at developing an alternative system of protein nutrition of the ruminant which takes account of microbial protein synthesis in the rumen (ARC, 1980, 1984). Central to this new system is the determination of protein degradability in the rumen for calculating microbial and by-pass protein to the duodenum.

Animals fed roughage in the long form in which refusals are in excess of 15% of that offered result in feed selection (Zemmelink, 1980). However, with the daily variation in feed intake it is impossible to maintain a fixed percentage of excess feed. It is not known if dairy cows are capable of selecting within a complete mix of grass silage and concentrate. If they are, then calculations on nutrient consumptions that fail to account for this will introduce errors into output-input estimations.

In large scale experiments it is expensive to record individual feed intake of cows daily. The dilemma is, however, how often to record weekly individual feed intakes to be representative of this period. Two factors may affect the accuracy of the estimation of actual feed intakes for the period: sampling frequency and sampling distribution. Techniques which, however, increase accuracy may also be more costly. It is therefore important for the research worker to know how much accuracy is improved by greater effort in measuring and to what extent it may be improved by changing existing procedure.

Five short experiments were therefore initiated to evaluate in the present experiment the system of feed intake recording and the composition of the diet fed to the animals.

Experiment 1: The objective was to estimate the accuracy of 4 daily recordings per week using analysis of variance components.

Experiment 2: The aim of this experiment was to investigate if dairy cows fed a complete mix of grass silage and concentrate have the ability to select the feed.

Experiment 3: The objective in this experiment was to establish a relationship between oven dry matter (ODM) and dry matter determined by toluene distillation (TDM) of the diet fed.

Experiment 4: The aim was to obtain quantitative relationships between in vitro ME estimated from in vitro digested organic matter determination and in vivo ME determined from digestibility studies using sheep.

Experiment 5: The objective was to obtain degradability values for the silage, concentrate mix and draff used in the mixed diet fed to the cows by in sacco method (Mehrez and Orskov, 1977).

1.2 EXPERIMENT 1: ACCURACY OF FOUR DAILY RECORDINGS PER WEEK

1.2.1 Materials and Methods

Daily DMI records of 164 cows recorded 4 times weekly over 24 weeks of lactation and covering 5 years were used in the analysis. The data were obtained as described in General Materials and Methods (Chapter 2). Each yearly data were subjected to hierarchical analysis of variance (Genstat, 1984). Variance components were partitioned into lactation months, weeks within months, days within weeks and replicates within days. Periods of high proportion of total variance would need to be recorded more frequently to reduce variation. The total variance (S^2y) was estimated as (Sokal and Rohlf, 1969):

$$S^2y = \frac{S^2}{ncba} + \frac{S^2C{:}B}{cba} + \frac{S^2B{:}A}{ba} + \frac{S^2A}{a} \qquad (1)$$

Where S^2_A = Variance components for lactation months

$S^2_B{:}A$ = Variance components of weeks within lactation months

$S^2_C{:}B$ = Variance components of days within lactation weeks

S^2 = Variance component attributable to replicates within days of lactation

n = number of animals

c = days within lactation week

b = weeks of recording within lactation month

a = lactation months of recording

The efficiency of each number of recording days within a week can therefore be estimated from equation 1 and then compared to the variance estimated for 7 days per week recording.

1.2.2 Results and Discussion

The proportion of variance and variance components are presented in Table A.1.1. As expected, animals within days accounted for the largest variance. This was followed by weeks within months of lactation and then months of lactation. Days within lactation weeks accounted for

Table A.1.1 Proportion (%) of variance components (PVC) and variance components (VC) attributable to various stages of lactation

YEAR	MONTH		WEEK		DAY		ERROR	
	PVC	VC	PVC	VC	PVC	VC	PVC	VC
1	15.36	2.313**	6.16	0.927**	0.00	-0.015	78.48	11.81
2	11.79	1.361*	1.74	0.201*	0.00	-0.008	86.47	9.98
3	17.36	1.411**	3.53	0.287**	0.00	-0.004	79.11	6.43
4	9.95	1.120**	2.87	0.324*	0.00	-0.017	87.17	9.82
5	31.60	2.534**	2.61	2.104**	0.00	-0.013	65.79	5.30
All	17.20	1.748	3.38	0.396	0.00	-0.114	79.40	8.67

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

almost no variance in feed intake recording.

The variance of 7 days per week recording can be estimated from the equation using n = 40 as:

$$\frac{8.67}{7x40x4x6} + \frac{0.396}{4x6} + \frac{1.748}{6} + \frac{0.0}{7x4x6} = 0.296$$

Variance of various days per week recording and efficiency lost is shown below:

Number of days per week of recording	Total variance	Efficiency lost (%)
6	0.2963	0.10
5	0.2966	0.20
4	0.2971	0.26
3	0.2978	0.51
2	0.2993	1.02
1	0.3038	2.54

The estimated efficiency lost indicates that recording 4 days per week using 40 animals, as was done in this investigation, instead of 7 days per week loses only 0.26% efficiency. This is certainly negligible. These variances can be criticised in that the data were estimated from 4 days per week recordings rather than 7 days per week recordings. Although this was the case, the recordings were randomly distributed in the weeks of lactation which is considered here in the analysis of variance.

It can be seen from the above equation (1) for estimating the total variance that the larger the number of animals the smaller the total variance. This is because animals account for a large part of the variation in voluntary feed intake.

1.3 EXPERIMENT 2: DIET SELECTION

1.3.1 Materials and Methods

Monthly over a period of 13 months feed offered (sampled in quadruplicate) and individual feed refusals of animals in the experiment were sampled, oven dried at 60°C for 72 h, ground in a laboratory mill, and analysed for ash, nitrogen (N) and modified acid detergent fibre (MADF). All analytical procedures were previously described (see General Materials and Methods - Chapter 2).

Once, individual samples of feed offered to and refused by 35 animals were sampled and analysed for dry matter (DM), ash, N and MADF, to check on the uniformity (variation) of the diet fed and also differences between feed offered and refused.

Differences between composition of feed offered (O) and feed refused (R) were tested for significance at the 5% level using "paired t" test (Sokal and Rohlf, 1969). Where t = mean difference between feed offered and feed refused (D) ÷ standard error of the mean of these differences (S_D)

$$t = D/S_D$$

1.3.2 Results and Discussion

The mean composition and differences between feed offered and refused are given in Table A.1.2.

As expected, the feed offered was less variable than feed refused, when the diets offered and refused from the same animal were compared. The coefficient of variation (CV%) was 3.4, 2.4, 9.9 and 3.9% for feed offered and 9.1, 2.3, 10.7 and 7.3% for feed refusals of DM, ash, N and

Table A.1.2 Composition and difference in composition between feed offered (O) and feed refused (R)

TRAIT	Number of Samples	Dry Matter (g/kg)		Ash (g/kg DM)		Nitrogen (g/kg DM)		MADF (g/kg DM)	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Feed offered	13			71.8	6.20	27.8	1.11	195	15.7
Feed refusals	520			75.4	5.71	27.4	1.12	214	20.7
O - R[a]				0.311±0.011**		-0.039±0.002**		1.81±0.044*	
Observed intake/ actual intake (%)				100.8	1.92	99.8	1.13	101.6	0.70
Feed offered (- same animal (OS))	35	335	11.5	86.8	3.40	27.4	0.67	196	19.4
Feed refusals (- same animal (RS))	35	329	29.8	89.2	6.51	26.9	0.62	209	22.4
OS - RS[a]		-5.61±36.92		2.42±7.23		-0.46±0.87		12.57±29.10	
Observed intake/ actual intake (%)		99.8	1.85	100.6	1.76	99.7	1.21	100.9	0.93

[a] ± standard error of mean

** $P < 0.01$

* $P < 0.05$

MADF respectively. Differences between feed bins were low from the CV indicating that complete diet fed was uniform. The results indicated that animals did not vary in the way they selected these diets. Differences between feed offered and feed refused in this group were not significantly different. However, when the diet offered was sampled en masse and compared to individual animal refusals there were differences ($P < 0.01$) in composition between feed offered and refused.

These results would tend to indicate that, taking into consideration analytical and sampling errors and variation in feed composition between feed bins, there does not seem to be any appreciable selection of the diet by the animals.

1.4 EXPERIMENT 3: RELATIONSHIP BETWEEN OVEN AND TOLUENE DRY MATTERS

1.4.1 Materials and Methods

Over a period of 9 months (1983/84) the complete mix of grass silage and concentrate and also the grass silage alone were sampled twice monthly and analysed for dry matter (DM) by

(1) oven drying at 60°C for 72 h, and

(2) by distillation with toluene (Dewar and McDonald, 1961) and correcting for ethanol content of the distillate (Henderson, 1978).

Regression of the toluene dry matter (TDM) on the oven dry matter (ODM) was computed for both the complete diet and the silage. Two equations were established: one with intercept and the other without intercept.

1.4.2 Results and Discussion

The following equations were derived from the regression of TDM on ODM.

Complete Diet

1 TDM = 0.9669 ± 0.00465 ODM
($R^2 = 98.0$, RSD = 0.609, Mean TDM = 36.5,
SD = 5.39; Mean ODM = 37.8, SD = 6.02)

2 TDM = $2.986 \pm 0.906 + 0.8895 \pm 0.021$ ODM
($R^2 = 98.7$, RSD = 0.608)

Silage

3 TDM = 1.0203 ± 0.0101 ODM
($R^2 = 96.3$, RSD = 1.116, Mean TDM = 25.1,
SD = 5.99; Mean ODM = 24.4, SD = 6.75)

4 TDM = $3.573 \pm 0.525 + 0.8336 \pm 0.0208$ ODM
($R^2 = 99.0$, RSD = 0.595)

The interesting aspect of the present results is the overestimation of the DM of the complete diet by about 3.4% by oven drying whereas this underestimates the silage DM by 2% compared to toluene distillation. For some unknown reason which could not be detected in the present experiment the oven drying failed to dry properly the complete mix. During drying, however, it was always observed that the silage and concentrate tended to cake together. Whether this could have influenced the partial drying of the diet is not clear.

1.5 EXPERIMENT 4: *IN VIVO* ME DETERMINATION

1.5.1 Materials and Methods

A complete mix of ryegrass silage and concentrate mix fed to the

Table A.1.3 Composition of diets

	DIETS		
	1	2	3
Toluene DM(g/kg)	407	374	326
Organic matter (g/kg DM)	924	929	918
Crude protein (g/kg DM)	169	185	178
Gross energy (MJ/kg DM)	19.2	20.5	18.6
Modified acid detergent fibre (g/kg DM)	179	180	206
Neutral detergent fibre (g/kg DM)	325	325	343
In vitro OMD (g/kg DM)[a]	749	789	772

[a] OMD = digestible organic matter

Table A.1.4 Apparent digestibility coefficients, digestible nutrients, nitrogen retention and metabolisable energy of diets

	DIETS		
	1	2	3
Apparent digestibility			
Dry matter	0.783	0.767	0.764
Organic matter	0.748	0.795	0.795
Crude protein	0.769	0.768	0.739
Energy	0.791	0.789	0.766
Digestible nutrients (g/kg DM)			
Organic matter	692	739	730
Crude protein	130	142	131
Energy	15.2	16.2	14.2
Modified acid detergent fibre	140	111	137
Nitrogen retention (gN/day)	1.76	1.56	2.04
Metabolizable energy (MJ/kg DM)	12.6	13.5	11.9
Dry matter intake (g/day)	568	479	485
Dry matter intake (g/kg LW)	12.9	14.0	14.5
Dry matter intake (g/kg $LW^{0.75}$)	33.1	33.9	35.0
Metabolizable energy intake (MJ/day)	7.04	6.47	5.77

experimental cattle was sampled in 1981 (Diet 1) and, from 15 September 1983 to 30 April 1984, bagged in polythene bags and frozen for digestiblity trials with sheep. The 1983/84 sample was divided into 2 diets. Diet 2 was the ration fed from September to December and Diet 3 was the diet fed from January to April.

A week prior to the commencement of the digestibility trials each group of diets were thawed, well mixed and composited into either Diets 1, 2 or 3 and refrozen. During the trial, twice weekly, the daily feed requirements of the sheep was thawed for feeding.

Three Suffolk-cross wether sheep (average weight 44 kg) were allocated to Diet 1 in 1981 whereas 4 Suffolk-cross wether sheep of approximately 35 kg liveweight were randomly allocated to each of Diets 2 and 3 in 1984. After a 14-day preliminary feeding period, digestibility, metabolizable energy (ME) and nitrogen (N) retention were measured over a 10-day period. Feed was offered twice daily, half in the morning (0900 h) and the other half in the afternoon (1530 h). The feed was offered at maintenance level (ARC, 1980) based on ME values estimate from <u>in vitro</u> digestible organic matter of the diet (Table A.1.3).

Faeces and urine were collected daily. Faeces were deep frozen and urine was acidified to pH 2-3 with dilute sulphuric acid to prevent ammonia loss. The 10 daily samples were combined, thoroughly mixed before samples were taken for chemical analysis.

Digestibility values were calculated as intake - faecal loss ÷ intake.

The ME values were calculated from gross energy intake minus the faecal and urinary energy losses and estimated methane loss (Blaxter and Clapperton, 1965). Gross energy of feed, faeces and urine were determined by adiabatic bomb calorimetry. All other nutrients (N, MADF and DM) were analysed for as described under General Materials and Methods (Chapter 2).

1.5.2 Results and Discussion

The aim of the experiment was to estimate the similarities between ME estimate from in vitro DOM and ME determined in vivo with sheep. The in vivo ME determined for Diets 1, 2 and 3 ranged from 11.9-13.5 MJ per kg DM (Table A.1.4). The high value of 13.5 MJ recorded for Diet 2 was due to its high gross energy content (20.5 MJ/kg DM). The high gross energy in this diet is difficult to explain since the gross energy of the concentrate in the diet mix was 18.7 MJ/kg DM. At 50:50 ratio of concentrate to forage this gross energy value of the silage would be 22.8 MJ/kg DM. This value is quite high for grass silage diets (see Wilkins, 1982). The high value could not be attributed to error of measurement since this was rechecked twice and each time in duplicate.

The ME values were obtained at maintenance level with sheep. High yielding cows eat over 4 times maintenance (Tyrrel and Moe, 1975). Also sheep have a more efficient digestive capabilities of energy (3.7%) than dairy cattle (Lindgren, 1981). Ignoring these digestibility differences but adjusting the ME values for depression in digestibility due to high level of intake (4 times maintenance) from the equation dde = 0.107 - 0.113 de (ARC, 1980). The digestibility of energy (de) is depressed from 0.791, 0.789, 0.766 to 0.721, 0.718 and 0.684 respectively for Diets 1, 2 and 3 and digestible energy from 15.2, 16.2

and 14.2 to 13.8, 14.7 and 12.7 respectively and ME from 12.6, 13.5, 11.9 to 11.2, 12.0 and 10.4 MJ/kg DM respectively for Diets 1, 2 and 3.

If ME is estimated from the formula

ME (MJ/kg/DM) = 0.157 x in vitro OMD

or = 0.157 x DOMD (Blaxter, 1982)

then the ME values are 11.7, 12.4 and 12.1 MJ/kg DM from in vitro OMD but 10.9, 11.6 and 11.5 MJ/kg DM from DOMD. ME values estimated from DOMD seem closer to the in vivo ME values adjusted for level of intake. Even so, the differences ranged from 0.3-1.1 MJ/kg DM and was 0.4-1.8 MJ/kg DM for the difference between the in vivo ME and ME estimated from in vitro OMD. For a cow eating daily 20 kg DM this could mean an overestimation of ME intake of 8-36 MJ per day if calculations are based on ME estimated from in vitro OMD. These differences between in vivo and in vitro OMD are similar in trend to the results of Phipps et al (1984b) with dairy cows. They noted that in vitro OMD were higher than in vivo values. This difference was 6.2 and 2.3% units for 11.7 and 10.7 MJ ME/kg DM complete diets respectively. Differences between the 2 diets were attributed to level of intake (intakes were higher for the high energy diet than the low energy diet). In contrast, Blaxter (1982) observed that in vitro OMD underestimated actual ME values of 8 out of 10 feeds. It is not clear if differences in the type of diets fed (complete vs separate ingredients) were responsible for these discrepancies.

In conclusion, ME values estimated from in vitro OMD overestimated ME values of feed determined in vivo with sheep. However, when all the errors and adjustments involved in estimating in vivo ME values are considered *in vitro* OMD is of sufficient accuracy for estimating input-output relationships.

1.6 EXPERIMENT 5: DETERMINATION OF DEGRADABILITY OF DIET COMPONENTS

1.6.1 Materials and Methods

The composition of grass silage, brewers' grain and concentrate use in the study are given in Table A.1.5.

Rumen losses of nitrogen were measured using the nylon bag technique (Mehrez and Orskov, 1977). The bags (17 x 19 cm) were made from polyester material (pore size of about 43 μm). A strong dacron line was threaded through the tops of the bags to close them after filling. The dacron line also acted as a means of attachment to a perspex strip. The strip was also attached to a screwed cap which could be screwed on to a fitted rumen canula.

In the estimation of degradability of silage, brewers' grain and concentrate 17, 17 and 11 g fresh samples respectively of these feeds were weighed into the nylon bags. Five bags were placed in the rumen of each of 3 mature wether sheep weighing 30-40 kg at 0900 h and were withdrawn after 3, 5, 8, 24 and 48 h. The sheep were fed ryegrass hay daily *ad libitum* and this was supplemented with 125 g soya and 100 g brushed oats per sheep at 0830 h. Upon removal from the rumen, the bags were washed in running tap water for 20 min until the water squeezed from the bags ran clear. The bags were then oven dried at 60°c to a constant weight. Dried residues from each bag were ground and residual nitrogen was determined by micro-Kjeldahl method.

Nitrogen disappearing at each incubation interval was calculated as:

Table A.1.5 Composition of diets

	Silage	Brewers' Grain	Concentrate
Dry matter (g/kg)	233	269	903
Ash (g/kg DM)	82	44	72
Modified acid detergent fibre (g/kg DM)	295	253	
Crude protein (g/kg DM)	145	262	192
pH	3.91	3.57	
Ammonia-N (g/kg Total N)	71		

Table A.1.6 Parameters derived from the exponential function $P = a + b(1-e^{-ct})$

Diet	a	b	c
SILAGE			
1	54.8	37.5	0.252
2	49.7	38.1	0.277
3	55.9	36.6	0.252
Mean	53.5	37.4	0.260
BREWERS' GRAIN			
1	39.2	40.3	0.945
2	42.3	34.7	0.445
3	38.8	35.6	0.484
Mean	40.1	36.9	0.625
CONCENTRATE			
1	46.4	47.8	0.586
2	44.5	77.2	0.019
3	23.1	58.4	0.586
Mean	38.0	61.1	0.397

Table A.1.7 Percentage disappearance of nitrogen at intervals of time and estimated effective degradability

DIET	PERCENT OF N DISAPPEARANCE					Effective Degradability (%)
	3	5	8	24	48	
SILAGE						
1	76.2	76.2	85.3	91.1	95.0	82.3
2	74.9	81.8	82.6	93.3	93.9	82.9
3	73.6	75.5	78.8	86.4	92.3	78.5
Mean	74.9	77.8	82.2	90.3	93.7	81.2
CONCENTRATE						
1	63.0	52.0	56.8	89.8	88.2	65.2
2	48.4	51.0	55.5	72.7	90.4	57.8
3	32.8	35.2	40.5	70.9	76.7	46.2
Mean	48.1	46.1	50.9	77.8	85.1	56.4
BREWERS' GRAIN						
1	45.9	56.8	62.0	71.6	81.2	59.9
2	50.6	51.8	52.0	69.9	71.3	53.8
3	43.3	46.0	50.4	62.8	71.1	51.2
Mean	46.6	51.5	54.8	68.1	74.5	55.0

Initial N in feed - N remaining in incubated residue.

To calculate effective degradability, the percentage of nitrogen disappearance from the bags at various time intervals were fitted by an iterative least squares computer program to the exponential function $P = a + b\,(1 - e^{-ct})$ (Orskov and McDonald, 1979).

Effective degradability was calculated as:

$$P = \frac{a+bc}{c+k}$$

Where

k = is outflow rate from the rumen

a = proportion of nitrogen disappearing at time t

b = insoluble but potentially degradable protein which is degraded by micro-organisms according to first-order kinetics with rate constant c.Outflow rate (k) was assumed as 0.09 (9%/h) for high yielding dairy cows (Elliman and Orskov, 1984).

1.6.2 Results and Discussion

The parameters derived from the exponential function are given in Table A.1.6. These parameters tended to be very variable between experimental units for concentrate and brewers' grain. These large variations are also reflected in the estimated effective degradabilities (Table A.1.7). It is, however, not surprising that animals were so variable for the concentrate diet. The fine particle size probably resulted in losses into the rumen and during washing of the bags.

The 81.2% effective degradability obtained for silage here is similar to the 78-82% degradabilities found in different studies by ARC (1980). Also the 54% effective degradability for concentrate is within the range of 51-70% degradability recommended by ARC (1980) for concentrate diets.

APPENDIX CHAPTER 2

2 Health and Fertility

2.1 RESULTS AND DISCUSSION

Health of animals is an important factor influencing voluntary dry matter intake (Weston, 1982). The incidence of disease recorded for the two Trials are indicated in Table A.2.1. In Trials 1 and 2 on average the incidence of disease was 1.6 and 0.77 respectively. The health expressed as cases of diseases recorded for each year of the experiment are also provided in Table A.2.2. Lameness and leg problems were the most serious problems among the animals followed closely by mastitis and milk fever. The only cases of ketosis were in years 1 and 3 (5 and 4 incidence respectively). The low level of ketosis is rather surprising. For several cows in most years were in high negative balance and cows in greater energy deficit are more prone to ketosis (Baird, 1981).

Analysis of variance of incidence of disease by Model 1 (Trial 1) only showed significant ($P < 0.012$) parity differences (Table A.2.3). This was due to a higher incidence of disease among cows calving in parities subsequent to parity 4. In Trial 2 also cows calving in more than two parities were significantly ($P < 0.01$) more prone to disease than younger cows (Table A.2.4). Incidence of disease increased with increasing calving condition score though this was not significant. Fat cows are acknowledged to be more prone to incidence of disease such as ketosis (Haresign, 1982).

The average days from calving to first oestrus, days from first insemination to conception, number of services per conception and calving intervals (days) were 37.9, 37.5, 2.0 and 393.1 in Trial 1 and 41.6, 22.8, 1.66 and 380.7 in Trial 2 respectively.

Analysis of variance of measures of reproductive performance by model 1 (Trial 1) only showed significant ($P < 0.05$) year differences for days from first service to conception and calving interval (Table A.2.5). Year differences were due to the poor reproductive performance of year 2 cows (Table A.2.3).

As milk yield increased number of services per conception, calving interval and days from first service to conception increased though this was not significant. It is acknowledged that there is some antagonism between milk yield potential and fertility (see review by Smidt and Farries, 1981). High condition score at calving was associated with longer intervals from calving to first oestrus and calving intervals though this was not significant. High body fatness is reported to have a negative effect on the fertility of cows (Haresign, 1982). This is associated with low feed intakes and thus high negative energy balance.

In Trial 2 there were significant parity differences ($P < 0.01$) in calving interval (Table A.2.4). Year 5 heifers and cows calving subsequent to parity 2 had the longest calving intervals.

Table A.2.1 Means of reproductive performance and incidence of disease for Trials 1 and 2

TRAIT	TRIAL 1		TRIAL 2	
	Mean	SD	Mean	SD
Calving to first oestrus (days)	37.9	24.5	41.6	31.7
First insemination to conception (days)	37.5	52.9	22.8	47.0
Number of services per conception	2.00	1.30	1.66	1.21
Calving interval (days)	393.1	54.8	380.7	51.2
Incidence of disease	1.6	1.4	0.77	1.1

Table A.2.2 Health expressed by cases of disease for year of calving

Year	Milk Fever	Ketosis (Acetonemia)	Mastitis	Lameness	Other
1	4	5	7	12	28
2	6	-	7	25	14
3	4	4	13	25	5
4	1	-	9	10	12
5	1	-	2	13	5

Table A.2.3 Least squares means of reproductive performance and incidence of disease - TRIAL 1

Source	Number	Calving to 1st oestrus (days)		1st service to conception (days)		Number of services per conception		Calving interval (days)		Incidence of disease	
		Mean	Se	Mean	Se	Mean	Se	Mean	Se	Mean	Se
All	113	39.3	4.51	32.0	9.35	2.0	0.25	386.8	9.7	1.5	0.22
Year 1	32	40.3	7.31	21.9[a]	15.10	2.1	0.40	386.8[a]	15.7	1.2	0.34
2	34	36.0	6.04	60.5[b]	12.47	2.4	0.33	413.1[b]	13.6	1.3	0.29
3	36	38.1	5.43	18.3[a]	11.22	1.5	0.30	369.2[a]	11.7	1.5	0.28
4	11	42.7	9.13	27.4[a]	18.84	2.1	0.50	378.0[a]	19.7	1.9	0.44
Month 1	46	41.9	5.30	32.0	10.95	2.1	0.29	396.0	11.4	1.58	0.26
2	53	37.1	5.19	35.9	10.71	1.9	0.29	387.8	11.2	1.4	0.25
3	14	38.9	8.16	28.2	16.86	2.2	0.45	387.6	17.6	1.4	0.41
Parity 2	23	34.4	7.82	30.3	16.15	2.0	0.43	383.3	16.8	1.2[a]	0.38
3	34	40.7	6.15	26.0	12.70	1.9	0.34	383.2	13.2	1.1[a]	0.30
4	27	36.8	6.37	45.8	13.15	2.1	0.35	396.8	13.7	1.5[a]	0.31
5	29	45.2	6.45	26.2	13.32	2.1	0.36	383.9	13.9	2.2[b]	0.31
Milk yield 1	16	45.4	10.20	17.7	21.07	1.8	0.56	371.9	22.6	1.3	0.51
2	42	33.8	5.17	33.1	10.68	2.1	0.28	382.0	11.1	1.7	0.25
3	55	39.6	5.32	45.4	9.31	2.3	0.25	406.5	9.7	1.4	0.21
Calving condition score 1	62	40.9	5.32	35.1	10.99	2.1	0.29	383.1	11.5	0.8	0.54
2	29	30.2	5.92	29.9	12.23	2.0	0.33	386.6	12.8	1.8	0.26
3	22	46.7	11.14	31.1	23.00	2.0	0.61	309.6	24.0	1.8	0.29
Liveweight change (b,SE)	113	-0.013	0.571	0.897	1.180	0.006	0.032	1.049	1.230	-0.132	0.068
Calving liveweight (b,SE)	113	-0.036	0.066	-0.034	0.136	-0.001	0.004	-0.092	0.142	0.0029	0.0030

ab Different superscripts in column indicate significant difference

Table A.2.4 Means of reproductive performance and incidence of disease - TRIAL 2

Source	Number	Calving to 1st oestrus (days)		1st service to conception (days)		Number of services per conception		Calving interval (days)		Incidence of disease	
		Mean	Se	Mean	Se	Mean	Se	Mean	Se	Mean	Se
All	67	41.6	3.59	22.8	5.32	1.7	0.14	380.7	5.8	0.89	0.14
Parity groups											
1a	20	39.0	6.33	18.7	9.38	1.8	0.24	380.8[a]	10.2	0.53[a]	0.28
1b	22	41.9	6.04	36.4	8.94	1.6	0.23	395.7[a]	9.7	0.41[a]	0.23
2	14	40.0	7.56	31.5	11.21	1.1	0.29	350.5[c]	2.2	0.65[a]	0.39
>2	11	45.4	8.54	34.6	12.64	2.2	0.33	395.8[b]	13.8	1.98[b]	0.42
Level of significance		NS		NS		NS		*		**	

* $P < 0.05$, ** $P < 0.01$, NS = not significant

APPENDIX CHAPTER 3

3 Measures of Assessing Body Reserves

3.1 INTRODUCTION

Results on the importance of body tissue reserves (body condition), especially at calving, on feed intake and milk production are conflicting. Some reports indicate an advantage for animals in good condition at calving, others found no such advantage (see Broster and Broster, 1984). These conflicting results are partly due to discrepancies involved in assessing body reserves or condition of the animal. In the past terms such as fat, medium and thin or skeletal size and body weight were used. This resulted in difficulties of interpretation, especially when comparing results from different sources.

Recently an attempt has been made at standardizing a system of describing body conditions. Such a system was adapted for use with beef cows and dairy cows (Lowman, Scott and Sommerville, 1976; Mulvany, 1977). The system defines a 5-grade scale (1-5) and describes each score in terms of the amount of adipose tissue covering the transverse processes of the lumbar vertebra and around the tailhead. This system of body condition scoring has been recommended by the Agricultural Advisory Services in the UK as an aid to beef and dairy management.

Ultrasonic methods have also been used in measuring backfat area as an index of body tissue reserves. This has been successfully used in predicting fat and lean tissues of beef cattle (Simms, 1983b, Wright, 1982).

Live body weight and live body weight change has been used for decades and still used as a measure of changes in body tissue reserves. It is easy and cheap to use. It has, however, been criticized due to interference from gut fill (Moe and Tyrell, 1971). Live body weight change may, however, give more erroneous results with foraged based diets than balanced diets due to gut fill variations (Rohr and Daenicke, 1984).

Any system of measuring body reserves must relate quantitatively with body composition. For practical applicability, it must be simple, inexpensive, labour efficient and reproducible by different operators.

The aim in this chapter is:

(1) To relate body condition score and backfat area measurements and live body weight to carcass fat, protein and energy.

(2) To investigate the reproducibility of condition scoring by different assessors.

(3) To estimate the repeatability of ultrasonic measurements of backfat area on the same site and in the same day.

(4) To investigate if gut fill variation is a problem for live body weight measurements of animals fed ad libitum on a balanced diet.

3.2 MATERIALS AND METHODS

For objective 1, body composition data were available from 19 lactating cows at different stages of lactation, body weight and parity. These animals were culled and slaughtered during a period of 3 years for the following reasons: feet and leg problems (5 animals), reproductive problems (7), mastitis, low yield and damaged teats (2 each) and old age

(1). A day prior to slaughter measurements collected on the live animal included liveweight, condition score and ultrasonic backfat areas using a Danscan. Procedures are as described under General Materials and Methods.

After slaughter one side of each carcass was dissected by the Meat and Livestock Commission (MLC) technique. The carcass and non-carcass components were minced and analysed for dry matter and energy, lipid (fat) and nitrogen contents in the dry matter. The chemical composition of the whole body was then calculated in terms of protein (6.25 x N), lipid (fat) and energy.

For objectives 2, 3 and 4, yearly, over a period of 3 years, 40 lactating cows were weighed twice and condition scored by 2 assessors 5-6 hours apart on the same day. Measurements were recorded at less than one week after calving, then at 6, 12 and 18 weeks post-partum. Ultrasonic backfat area was recorded once, per animal, at each of these periods.

3.2.1 Statistical Analysis

Multiple regression equations were constructed to predict total body energy, fat and protein using live body measurements. Fitting quadratic terms in these measurements did not significantly improve the precision of prediction; these were therefore dropped. Regression intercepts were chosen only if they were statistically significant ($P < 0.05$).

Sources of variation in condition scoring and live body weight measurements were estimated by analyses of variance (GENSTAT - Lawes Agricultural Trust, 1984) from the random model (Evans, 1978).

$$Y_{ijk} = M + c_i + a_j + (ca)_{ij} + t_k + (ct)_{ik} + (at)_{ik} + e_{ijk}$$

Where:

Y_{ijk} = score or liveweight for cow_i

M = over all means

c_i = random effect of the ith cow, i = 40

a_j = random effect of the jth assessor or weighing time, j = 2

t_k = fixed effect of kth period, k = 4

$(ca)_{ij}$ = cow x assessor interaction effect

$(ct)_{ik}$ = cow x period interaction effect

$(at)_{jk}$ = assessor x period interaction effect

e_{ijk} = random error term

Reproducibility, the correlation between an animal's condition score assessed by 2 assessors or liveweight recorded at different times of day was estimated by regression techniques. Assessor bias was estimated as the difference between individual assessor score and the mean scores of the 2 assessors. Similarly, time of measurement of liveweight bias was estimated as the difference between morning or evening liveweight measurements and the mean of the 2 measurements. The standard error of an animal's score or weight was the square root of the variance estimated from the above model (Evans, 1978) as:

For condition score estimated by a mean of n scores by the same assessor, the variance is:

$$Var (M + c_i) = \sigma^2{}_a + \sigma_c{}^2{}_a + \sigma_e{}^2/n$$

If it is estimated by the mean of n scores by different assessors, the variance of estimate is:

$$Var (M + c_i) = 1/n (\sigma^2{}_a + \sigma_c{}^2{}_a + \sigma_e{}^2)$$

Similarly, the variance of live body weight was obtained from the above equations.

3.3 RESULTS

A summary of live animal measurements and composition of empty body weight and other animal variables is given in Table A.3.1. The range of variables measured were considerable. For live body weight 495-820 kg; condition score 1.75-5.00; total body energy 3166.7-11,925.6 MJ; total body protein 70.9-101.9 kg; total body fat 32.6-235.7 kg; parity 1-10 and stage of lactation 19-436 days. These animals had predicted or actual 305 day milk yield ranging from 4400-8720 kg.

Equations relating total body energy to animal measurements are given in Table A.3.2. Equations (5-8) containing empty body weight and backfat area measurements were better predictors of estimated body energy than a combination of liveweight and backfat area measurements (equations 1-4). These equations had low residual standard deviations and accounted for the highest variances. Prediction equations (9 and 10) containing condition score and either live body weight or empty body weight did not predict estimated body energy with the same precision as equations containing backfat area measurements and live body weight or empty body weight. These equations, however, had reduced residual coefficients of variation (11.9-16.5%). The energy value, respectively, of 1 kg lipid and protein (equation 14) was 40.2 and 23.0 MJ. The energy value of 1 kg change in liveweight, empty body weight and 1 unit change in condition score was 23.0, 31.2 and 2,746.9 MJ respectively.

Equations for predicting total body fat are given in Table A.3.3. Similar to the prediction of estimated body energy, prediction equations (19-22) containing backfat area and empty body weight gave better predictions of total body fat than those containing backfat area and live

Table A.3.1 Weights, condition score, backfat area (3 sites), components of the empty body and other measures of cull cow data.

Variable	Mean	SD	Range
Live body weight (LW-kg)	671	89	495 - 820
Empty body weight (EBW-kg)	542	78	392 - 665
Condition score (BS)	2.99	0.94	1.75 - 5.00
Backfat area (cm^2)			
3rd lumbar vertebra (BF_1)	6.38	3.59	0.81 - 12.95
13th rib (BF_2)	6.68	3.53	0.97 - 13.31
10th rib (BF_3)	6.92	3.53	0.29 - 13.49
Mean - all sites (BF_4)	6.65	3.46	0.76 - 13.25
Total body energy (MJ)	8045.2	2608.2	3166.7 - 11925.6
Total body protein (kg)	86.4	9.6	70.9 - 101.9
Total body fat (kg)	149.9	63.4	32.6 - 235.7
Lactation number	4	2.2	1 - 10
Stage of lactation	287	122	19 - 436

Table A.3.2 Relationship between body measurements and estimated body energy (MJ)

Equation	Model	a	b_1		b_2		RSD	R^2 (%)
			Coefficient	SE	Coefficient	SE		
1	$a + b_1BF_1 + b_2LW$	-5807.0	307.6**	95.4	18.3**	4.18	1108.4	78.1
2	$a + b_1BF_2 + b_2LW$	-6095.9	315.0*	91.9	18.5**	4.02	1073.3	79.5
3	$a + b_1BF_3 + b_2LW$	-6726.8	256.4*	120.0	19.9**	4.86	1311.0	69.4
4	$a + b_1BF_4 + b_2LW$	-6188.7	316.1*	103.2	18.6**	4.27	1136.8	77.0
5	$a + b_1BF_1 + b_2EBW$	-7159.4	204.7**	62.5	26.1**	3.18	678.7	91.8
6	$a + b_1BF_2 + b_2EBW$	-7447.5	205.5**	62.4	26.2**	3.17	676.7	91.8
7	$a + b_1BF_3 + b_2EBW$	-8083.8	167.3	76.3	28.1**	3.58	802.5	88.5
8	$a + b_1BF_4 + b_2EBW$	-7447.0	208.5*	67.7	26.5**	3.25	700.0	91.3
9	$a + b_1BS + b_2LW$	-2891.0	1616.2	789.8	9.63	8.04	1328.8	68.5
10	$a + b_1BS + b_2EBW$	-7435.3	435.0	650.9	26.7	7.69	955.6	83.7
11	$a + b_1LW$	-6864.5	23.0**	5.3			1509.1	59.4
12	b_1BS		2746.9**	116.4			1334.2	68.3
13	$a + b_1EBW$	-8513.6	31.2**	3.82			931.3	84.5
14	b_1 total body fat + b_2 total body protein		40.2**	0.557	23.0**	1.13	112.4	99.8

* $P < 0.05$ ** $P < 0.01$ SE = standard error RSD = residual standard deviation

LW = liveweight EBW = empty body weight BS = condition score

BF_1 = backfat area (3rd lumbar vertebra) BF_2 = backfat area (13th rib) BF_3 = backfat area (10th rib)

BF_4 = backfat area (mean of all anatomical areas)

Table A.3.3 Relationship between body measurements and total body fat (kg)

Equation	Model	a	b_1		b_2		RSD	R^2 (%)
			Coefficient	SE	Coefficient	SE		
15	$a + b_1BF_1 + b_2LW$	-151.8	8.54**	2.59	0.384**	0.113	30.1	73.0
16	$a + b_1BF_2 + b_2LW$	-159.9	8.71**	2.50	0.390**	0.109	29.2	74.5
17	$a + b_1BF_3 + b_2LW$	-177.2	7.35*	3.22	0.426**	0.131	35.2	62.8
18	$a + b_1BF_4 + b_2LW$	-162.3	8.84**	2.78	0.391**	0.115	30.6	71.9
19	$a + b_1BF_1 + b_2EBW$	-192.8	6.12**	1.91	0.575**	0.097	20.7	87.1
20	$a + b_1BF_2 + b_2EBW$	-195.3	6.18**	1.90	0.575**	0.096	20.6	87.3
21	$a + b_1BF_3 + b_2EBW$	-220.0	5.20*	2.27	0.629*	0.107	23.9	82.9
22	$a + b_1BF_4 + b_2EBW$	-201.1	6.32*	2.04	0.584	0.098	21.1	86.7
23	$a + b_1BS + b_2LW$	-70.8	44.9*	21.6	0.144	0.220	36.3	60.6
24	$a + b_1BS + b_2EBW$	-200.5	13.3*	19.7	0.591**	0.233	28.9	75.0
25	$a + b_1LW$	-181.2	0.515*	0.146			41.4	48.6
26	$a + b_1EBW$	-234.0	0.726**	0.115			28.1	76.3
27	b_1BS		53.4**	2.96			33.9	65.5

* $P < 0.05$ ** $P < 0.01$ SE = standard error RSD = residual standard deviation

LW = liveweight EBW = empty body weight BS = condition score

BF_1 = backfat area (3rd lumbar vertebra) BF_2 = backfat area (13th rib) BF_3 = backfat area (10th rib)

BF_4 = backfat area (mean of all anatomical areas)

Table A.3.4 Relationship between body measurements and total body protein (kg)

Equation	Model	a	b_1		b_2		RSD	R^2 (%)
			Coefficient	SE	Coefficient	SE		
28	$a + b_1BF_1 + b_2LW$	28.8	-1.36**	0.505	0.0980**	0.0222	5.87	61.4
29	$a + b_1BF_2 + b_2LW$	30.3	-1.31**	0.516	0.0958**	0.0226	6.03	59.4
30	$a + b_1BF_3 + b_2LW$	32.7	-1.45**	0.538	0.0946**	0.0217	5.88	61.2
31	$a + b_1BF_4 + b_2LW$	30.3	-1.47**	0.524	0.0976**	0.0217	5.79	62.6
32	$a + b_1BF_1 + b_2EBW$	32.6	-1.70**	0.579	0.117**	0.0294	6.28	55.8
33	$a + b_1BF_2 + b_2EBW$	33.4	-1.69**	0.581	0.117**	0.0295	6.30	55.6
34	$a + b_1BF_3 + b_2EBW$	39.7	-1.64**	0.628	0.106	0.0295	6.61	51.1
35	$a + b_1BF_4 + b_2EBW$	34.6	-1.81**	0.599	0.116	0.0288	6.19	57.1
36	$a + b_1BS + b_2LW$	20.6	-5.25**	4.27	0.120	0.0436	7.20	42.0
37	$a + b_1BS + b_2EBW$	33.1	-4.37	5.67	0.112	0.0669	8.32	22.5
38	$a + b_1EBW$	43.9	0.0753	0.0335			8.16	25.3
39	$a + b_1LW$	33.5	0.0771	0.0260			7.36	39.3
40	$a + b_1BS$	71.7	4.35	2.16			9.11	6.9

* $P < 0.05$ ** $P < 0.01$ SE = standard error RSD = residual standard deviation

LW = liveweight EBW = empty body weight BS = condition score

BF_1 = backfat are (3rd lumbar vertebra) BF_2 = backfat area (13th rib) BF_3 = backfat area (10th rib)

BF_4 = backfat area (mean of all anatomical areas)

body weight (equations 15-18). Also backfat area and either live body weight or empty body weight predicted total body fat more precisely than a combination of condition score and these same measures (equations 23 and 24). Estimated body energy was more precisely predicted by these variables (Table A.3.2) than total body fat (Table A.3.3). They accounted for the highest variance in predicting estimated body energy than in predicting total body fat. Approximately 52% and 73% of 1 kg change in live body weight and empty body weight (equations 25 and 26), respectively, was fat. A unit change of one condition score is equivalent to 53.4 kg of body fat (equation 27).

Equations predicting total body protein (Table A.3.4) from body measurements lack the precision found in predicting estimated body energy and total body fat. The maximum variance accounted for by these equations was only 62.6% (equation 32). Surprisingly, prediction equations containing live body weight (equations 28-32) accounted for higher variances than those containing empty body weight (equations 33-36). Equations containing condition score predicted total body protein with high residual standard deviations (equations 36, 37 and 40) and with low variance accounted for. Approximately 7.7 and 7.5% of 1 kg change in live body weight and empty body weight, respectively was protein.

A change in 1 unit of condition score is equivalent to a change in 4.4 kg of body protein. This regression coefficient was not different from zero. If the protein content of 1 unit change in condition score is estimated from its energy value 2,946.9 MJ and fat content 53.4 kg, it is 26.0 kg. That is (2,746.9 - 53.4 x 40.2)/23.0.

3.3.1 Variation in Condition Scoring and Live Body Weight Measurements

Estimated variance components, for a 3-year period, for condition score (BS) and live body weight (LW) are presented in Tables A.3.5 and A.3.6.

Most of the variation in BS was attributable to differences between cows in years 2 and 3 (60 and 47.4% respectively), but to assessor difference in year 1 (41.4%). Between assessor differences were low in years 2 and 3 (3.2 and 12.5% respectively). Animal x assessor variation was also low in year 3 (6.3%) but high in years 1 and 2 (12.2 and 17.1% respectively).

The obvious major source of variation in LW was due to differences between cows. Variance due to time of day of recording was almost negligible in all cases.

Standard errors of an animal's score or weight on the basis of one of several measurements are presented in Table A.3.7. The standard error of an animal's score was reduced significantly when the same scorer assessed BS more than once or when different assessors were involved. There was 6.2-18.0% reduction in standard error of an animal's score if the mean of 2 scores by the same assessor was used instead of one. Two different assessors resulted in a reduction of about 29% compared with one assessor.

Similarly, there was a reduction of 29.3 and 42.3% in the standard error of an animal's liveweight measurement when this was recorded 2 or 3 times, respectively, instead of once in the same day.

The correlations between an animal's score by 2 assessors (reproducibility) or LW measured at different times of the same day are shown in Table A.3.8. The reproducibility of BS was variable across

Table A.3.5 Variance components estimates for condition score*

Year	No. of cows	No. of Assessors	Cow	Assessor	Cow x Assessor	Residual	Total
1	40	2	0.0713	0.0980	0.0291	0.0400	0.2384
2	40	2	0.2996	0.0160	0.0853	0.0078	0.4992
3	40	2	0.0527	0.0139	0.0070	0.0150	0.1111

* No. = Number

Table A.3.6 Variance components estimates for live body weight*

Year	No. of Cows	No. of Times	Cow	Time	Cow x Time	Residual	Total
1	40	2	4440.8	4.63	3.15	60.4	4509.0
2	40	2	2622.2	13.4	0.00	150.8	2786.4
3	40	2	4693.0	0.044	0.00	63.7	4756.8

* No. = Number

Table A.3.7 Standard errors of an animal's score or weight on the basis of one or several measurements

Measurement	Year 1		Year 2		Year 3	
	BS	LW	BS	LW	BS	LW
A single assessment	0.446	8.26	0.409	12.81	0.242	7.98
Same Assessor (Day)						
Mean of 2 assessments	0.388	5.84	0.384	9.06	0.199	5.65
Mean of 3 assessments	0.258	4.77	0.235	7.40	0.139	4.61
Different Assessors						
Mean of 2 assessments	0.316		0.289		0.171	
Mean of 3 assessments	0.258		0.235		0.139	

Table A.3.8 Reproducibility for condition score and live body weight at different periods of lactation

Year	PERIOD OF LACTATION (WEEK) 1	6	12	18
	Condition Score			
1	0.63	0.70	0.77	0.73
2	0.67	0.51	0.65	0.62
3	0.54	0.56	0.46	0.71
Mean	0.61	0.59	0.63	0.69
	Live Body Weight			
1	0.99	0.98	0.99	0.99
2	0.97	0.98	0.91	0.97
3	0.99	0.99	0.98	0.98
Mean	0.98	0.98	0.96	0.98

Table A.3.9 Mean condition score, live body weight and estimates of bias at different stages of lactation

Year	PERIOD OF LACTATION (WEEK)							
	1		6		12		18	
	Mean	Bias	Mean	Bias	Mean	Bias	Mean	Bias
1								
Standard score	3.22		3.06		3.07		3.13	
Assessor (A_1)	3.59^a	+0.37	3.27^a	+0.21	3.29^a	+0.22	3.37^a	+0.24
Assessor (A_2)	2.86^b	-0.37	2.85^b	-0.21	2.85^b	-0.22	2.90^b	-0.24
2								
Standard score	2.80		2.47		2.48		2.60	
Assessor (A_1)	3.10^a	+0.30	2.72^a	+0.25	2.66^a	+0.18	2.75^a	+0.15
Assessor (A_2)	2.50^b	-0.30	2.21^b	-0.25	2.29^b	-0.18	2.45^b	-0.15
3								
Standard score	2.76		2.53		2.57		2.59	
Assessor (A_1)	2.88^a	+0.13	2.70^a	+0.17	2.63^a	+0.06	2.58^a	-0.01
Assessor (A_2)	2.63^b	-0.13	2.36^b	-0.17	2.51^b	-0.06	2.60^b	+0.01

[ab] Columns with different superscripts are significantly different ($P < 0.05$)

Table A.3.10 Mean live body weight and estimates of bias at different stages of lactation

	PERIOD OF LACTATION (WEEK)							
Year	**1**		**6**		**12**		**18**	
	Mean	**Bias**	**Mean**	**Bias**	**Mean**	**Bias**	**Mean**	**Bias**
1								
Standard weight	667		652		650		659	
Morning	668	+1	650	-2	648	-2	656^{a}	-3
Afternoon	666	-1	654	+2	652	+2	662^{b}	+3
2								
Standard weight	635		607		619		630	
Morning	633	-2	604^{a}	-3	613	-6	631	+1
Afternoon	637	+2	610^{b}	3	625	+6	629	-1
3								
Standard weight	564		565		583		603	
Morning	565	+1	563^{a}	-2	584	+1	602	-1
Afternoon	563	-1	567^{b}	+2	582	-1	604	+1

^{ab} Columns with different superscripts are significantly different ($P < 0.05$)

years. This ranged from 0.46-0.77 with means of 0.61, 0.59, 0.63 and 0.69 for lactation weeks 1, 6, 12 and 18 of recordings, respectively. There were no trends that could be attributable to periods or years.

The correlations between 2 weights on the same animal recorded in the morning and late in the afternoon were very high ($r = 0.91-0.99$). There were no time trends recognisable in these correlations.

Estimates of bias (mean deviation from the mean score of 2 assessors or from the mean of morning and afternoon LW) are given in Tables A.3.9 and A.3.10. In almost all years assessor A_1 always condition scored higher than A_2. Differences between assessors were statistically significant ($P < 0.05$) in all years and periods of lactation. The bias was not consistent across years and periods. There was no time trend in the bias.

In more than 75% of the cases (Table A.3.10) morning weight underestimated the mean weight of the animal. This is not surprising because cows eat little at night (Tanida et al, 1984), thus morning weight will be low, especially if their early morning feeding is upset by the act of weighing. Differences between morning and afternoon weights were small, ranging from 2-12 kg. These differences were significant ($P < 0.05$) in 30% of the periods. There was no trend across years and periods in the differences between morning and afternoon weights.

3.3.2 Repeatability of Ultrasonic Measurements

Repeatabilities (correlations) between fat area measurements recorded at 3 different anatomical positions on the same animal are shown in Table A.3.11. Correlations ranged from 0.66-0.83 and were variable across years. Correlations were generally higher for Danscans

Table A.3.11 Correlations between backfat area measurements recorded at three different anatomical positions

Year	POSITION 3rd lumbar	13th rib	10th rib	All
1				
3rd lumbar		0.83	0.75	0.92
13th rib			0.80	0.90
10th rib				0.92
2				
3rd lumbar		0.78	0.67	0.90
13th rib			0.66	0.93
10th rib				0.89
3				
3rd lumbar		0.78		0.95
13th rib				0.93
10th rib		-	-	-

Table A.3.12 Correlations between the interpretations of two Danscan scans of fat area measurements recorded at the same anatomical position

Year	POSITION 3rd lumbar	13th rib	10th rib
1	0.86	0.84	0.87
2	0.71	0.64	0.67
3	0.90	0.86	-

interpreted by more experienced operators (years 1 and 3).

Correlations between the interpretations of 2 Danscan fat area measurements taken at the same position (Table A.3.12) ranged from 0.64-0.90. Correlations were similarly higher for scans interpreted by more experienced interpreters (years 1 and 3).

3.4 DISCUSSION

3.4.1 Prediction of Body Composition

The data available from the cull cows for predicting body composition was very variable and therefore good material for generating prediction equations covering different fatness levels, ages and liveweights.

Of the body measurements investigated in this study, the most effective indexes for estimating body energy and body fat were empty body weight and ultrasonic fat area measures. A model containing condition score and either live body weight or empty body weight could also be used to predict estimated body energy and total body fat but with reduced precision. The condition scores used in the prediction equations were not assessed by one assessor in all instances but by 2 assessors at different times of the culling period. This probably influenced the precision of prediction due to assessor bias shown in this chapter.

Due to the costs involved in slaughtering and analysing dairy cows and also recording live body measurements, no comparable studies have been carried out to relate condition score and fat area measures and total body energy. Wright (1982) related body condition score and ultrasonic measurement of fat depth to the chemical composition of mature beef cows of several beef breeds. A combination of condition score and liveweight and liveweight and fat depths measured at the 12th and 13th ribs gave significantly lower residual mean square. A change in one unit condition score was equivalent to 48.6-84.2 kg of body fat in his study. The mean value calculated was 53.4 kg in the current study. The 2747 MJ energy value of one unit change of condition score was within the range 2242-3478 MJ reported by the same author. The energy values of 40.2 and 23.0 MJ/kg of fat and protein respectively, estimated by regression, are similar to 39.7 and 23.8 MJ/kg reported by Reid et al (1968). The energy value of 1 kg change in live body weight is similar to other reports (Bath et al, 1965; Moe et al, 1971; ARC, 1980). The fat content of 1 kg liveweight change is smaller than the 59% reported by Chigaru and Topps (1981) for lactating beef cattle but within the values 42-68% reported by Wright (1982).

In contrast to the results of Wright (1982) who observed a curvilinear relationship between body protein and liveweight, with a higher precision of prediction (R^2 = 91.8%), the relationship between the 2 variables was more linear in the present experiment. Certainly, differences between the body composition of beef and dairy breeds of cattle could not have accounted for such differences between the 2 results. One factor which might explain the differences could be variation in gut fill.

In studies of dairy cattle in various physiological states, knowledge of the nature and extent of the storage and mobilization of body tissues is essential for a clearer understanding of the responses of animals to changes in nutrition. The nature and extent of the body tissue changes cannot, however, be determined without some objective methods of measuring body composition serially in the same animals during periods of a study. This study has indicated that ultrasonic area measures in combination with live body weight or empty body weight are good predictors of these changes. These measures are, however, useful scientifically. The relationship between condition score and live body weight, though less precise in predicting estimated body energy and fat, have more practical use. In the practical situation it is important to be able to feed animals to target reserves or condition score. Also, the efficiency of conversion of dietary and body energy to milk can then be estimated without resorting to calorimetric measurements.

The data used in the present experiment could be criticised in some respects for the reasons aforementioned for culling the animals. One could argue that the animals were not in a physiologically healthy state and therefore the composition of their bodies may not be representative of animals in perfect health and producing normally. This, however, does not detract from the fact that this is a start in providing relationships between live body measurements and body composition of dairy cattle.

3.4.2 Variation in Body Condition Scoring and Liveweight Measurements

Variations attributable to assessors and animal x assessor interaction were for the most part higher than values reported elsewhere (Evans, 1978; Nichols, 1981). Variation attributable to cows was similar to these reports. These results indicate that the greatest sources of variation in condition scoring in this experiment were between cows, assessors and cow x assessor interaction. The source due to cows is largely due to genotype, however, assessor and cow x assessor interaction creates problems in condition scoring. Assessors condition scored animals differently, they also varied in their interpretation of the scale of condition scoring from one animal to another. Whereas differences between assessors in condition scoring can be decreased by periodic standardisation between assessors or training assessors together, animal x assessor interaction would be difficult to correct. One could argue that since only 2 assessors were involved in this experiment, these could well be atypical of a population of assessors.

Nichols (1981) who also used 2 assessors in his investigation noted a higher animal x assessor interaction variance than assessor variance. Similar results were also obtained by Evans (1978) using several assessors.

Reproducibility values obtained here were slightly less than 0.7 reported by Evans (1978) but similar to 0.48-0.67 reported by Nichols (1981).

Ranking of animals for body condition was consistent throughout the period of the current experiment; with one assessor scoring higher each time.

The greatest source of variation in liveweight was due to differences between animals. Time of measurement and cow x time interaction variation were negligible. The coefficients of variation between animals in the morning and afternoon were similar (mean = 10.1 and 10.2% respectively). This would indicate that for animals fed *ad libitum* on a balanced diet the variation in their liveweights between periods in the same day was almost equal.

Repeatabilities between measures of liveweight at the 2 different times was very high. It would seem that an animal kept its rank in liveweight througout most of the day. Morning weights were generally lower than afternoon weights. In the morning there is a period of almost one and a half hours before food is provided during cleaning up. And these animals were weighed half to one hour after feeding. These results indicate that for animals on a mixed balanced diet fed ad libitum, changes in gut fill are negligibly low if animals are weighed at the same time each period. More than one weight recorded on the same animal at different times of the day reduced significantly the standard error of liveweight. Where cost is low, weighing more than once per day will reduce the error in measurement due to changes in gutfill. Three times per week or per day has been recommended by some researchers (Broster and Broster, 1984). This is supported by the present results.

3.4.3 Repeatability of Ultrasonic Measurements

Correlations between backfat area measurements at different anatomical areas were found to be highly correlated, indicating that one is as good as the other as a measure of backfat area. The magnitude of these correlations, however, depended on the experience of the operator. This is also seen in the correlations between interpretations of scans taken at the same anatomical site. The error involved in repeat interpretation of ultrasonic measurements may be due to:

(1) tracing of different signals on paper especially where pictures (scans) are of poor quality;

(2) erratic digitising of the fat area after tracing on to paper.

Although Danscan measures of backfat area is more objective than condition score, there is some subjectivity in the method of final measurement. Simms (1983b) who made a thorough study of repeatability of Danscan measurements also found operator differences. He concluded that the experience of the operator was important in digitising fat areas.

3.4.4 Conclusion

Body condition score and backfat area in conjunction with live body weight and empty body weight are good predictors of estimated body energy and fat. They are, however, less precise in predicting total body protein. The condition scoring of dairy cattle, though a good subjective method of assessing body fat reserves, can result in large assessor differences. Regular standardisation of condition scoring between assessors and/or the central training of assessors can make condition scoring a useful tool in dairy cattle management.

Variations in liveweight due to gut fill effects can be reduced by weighing animals more than once per day. Where costs are high, but the feeding *ad libitum*, weighing once a day at the same time each period would suffice.

APPENDIX CHAPTER 4

RELATIONSHIPS BETWEEN FEED INTAKE (DMI), MILK PRODUCTION TRAITS, NUTRIENT UTILIZATION TRAITS AND LIVE BODY MEASUREMENTS

4.1 Statistical Methods

Multiple regression equations and simple correlations between variables were computed by the least squares method (Harvey, 1977). In the estimate of prediction equations for dry matter intake (DMI) and estimated energy balance (MEB) for results of Trial 1, data were adjusted for year of calving effect. The total variance explained (R^2%) by various prediction models given in Appendix Tables A.55 and A.56, however, excludes this effect.

Selecting the best multiple regression equation is difficult with unbalanced data, especially where repeated recordings on the same animal are present. Leaving poor predictors in the equation may reduce precision of prediction. Likewise, leaving out a predictor when it is a primary source of variation either by default or ignorance of their existence may cause variation associated with these variables to accrue to terms in the regression model to which they are correlated. In this investigation two methods were used in selecting the best prediction models. With method A, which was used for predicting stage of lactation, DMI, MEB and efficiency traits, predictor variables were dropped one at a time and were only retained in the selected model if the coefficients were significant at the 5% level of probability.

With method B, which was used to select the best prediction model for DMI across weeks of lactation, individual cow effects were ignored and individual weekly observations as units were used. Since repeated observations were made on each cow the standard errors are likely to be underestimated.

Predictor variables were therefore only included in the selected best model if the regression coefficients were significant at 1% level of probability.

In Tables A.4.2 and A.4.3 DMI and MEB, per stage of lactation, were predicted from the equation y = a + b_1 milk yield (kg/day) + b_2 condition score + b_3 liveweight (kg) + b_4 liveweight change (kg/week).

4.2 Results

4.2.1 SIMPLE CORRELATION

Correlation coefficients between DMI and milk yields, live body measurements and nutrient utilization traits are provided in Table A.4.1. Appendix Table A.53 shows correlations between milk production variables, live body measurements and nutrient utilization traits.

Daily milk and FCM yields were positively ($P < 0.01$) correlated with DMI (r = +0.35-+0.763 and +0.268-+0.754 respectively). The coefficients were higher in Trial 2, due to a greater between animal variation, than Trial 1. Noticeably, these correlations generally declined for milk yield, but increased for FCM yield as lactation progressed. LW, within the period, were correlated moderately with DMI (r = +0.354-+0.540, $P < 0.05$). These correlations also tended to decline with advancing lactation. Correlations between DMI and BS and LWC were mostly small; suggesting that increasing DMI does not always result in increased BS or LW gain.

DMI was positively associated with energy balance (r = 0.426-0.490, $P < 0.01$), but negatively with efficiency traits. These correlation coefficients declined with advancing lactation.

Table A.4.1 Simple correlations* between dry matter intake, liveweight, milk yield, condition score, liveweight change and other variables per stage of lactation.

STAGE OF LACTATION		1		2		3		4		1-4	
TRIAL		1	2	1	2	1	2	1	2	1	2
Number	VARIABLE	DRY MATTER INTAKE									
1	Milk yield	0.451	0.763	0.345	0.713	0.418	0.568	0.441	0.449	0.431	0.713
2	FCM yield	0.268	0.754	0.346	0.685	0.456	0.611	0.497	0.523	0.481	0.722
3	Liveweight	0.354	0.540	0.426	0.538	0.367	0.445	0.377	0.360	0.437	0.523
4	Condition score	0.088	-0.119	0.074	-0.083	0.038	-0.160	-0.051	-0.073	0.084	-0.071
5	Liveweight change	0.359	0.018	0.160	0.021	0.0117	0.115	0.138	0.306	0.100	0.074
6	Condition score change	0.011	-0.145	0.202	-0.138	0.121	0.167	-	-	-	-
7	ME balance	0.493	-0.084	0.490	0.425	0.437	0.426	0.460	0.477	0.448	0.245
8	Gross energy efficiency	-0.424	0.254	-0.335	-0.045	-0.257	-0.041	-0.125	-0.077	-0.197	-0.131
9	Net energy efficiency	-0.553	0.033	-0.478	-0.244	-0.483	-0.220	-0.337	-0.264	-0.284	-0.057
10	Milk nitrogen efficiency	-0.381	0.244	-0.235	-0.039	-0.181	0.032	-0.032	0.169	-0.134	0.191
11	Calving condition score	-0.009	-0.091	-0.171	-0.071	-0.135	-0.01	-0.073	-0.037	-0.109	-0.051
12	Calving backfat area	-0.161	-0.061	-0.156	-0.062	0.059	0.045	0.044	0.101	-0.056	0.008
13	Calving liveweight	0.146	0.527	0.188	0.516	0.254	0.478	0.276	0.360	0.265	0.526

* Trial 1 $P < 0.05$ $r > 0.195$ and $P < 0.01$ $r > 0.254$

Trial 2 $P < 0.05$ $r > 0.232$ and $P < 0.01$ $r > 0.302$

Table A.4.2 Best prediction equations for dry matter intake (DMI) selected from Appendix Table A.55 per stage of lactation

Weeks of lactation	Constant ± SE	Milk yield b_1 ± SE	Condition score b_2 ± SE	Liveweight b_3 ± SE	Liveweight change b_4 ± SE
			TRIAL 1 - DMI		
2-6	3.22±1.85	0.2099±0.0301	-1.1612±0.3270	0.01599±0.0033	0.1802±0.0237
7-12	4.09±2.28	0.1623±0.0349	-1.0705±0.4730	0.01720±0.0042	0.1609±0.0512
13-18	3.85±2.39	0.2079±0.0492		0.01318±0.0030	
19-24	3.46±1.97	0.2463±0.0341	-0.9081±0.4118	0.01711±0.0036	
2-24	3.44±1.94	0.2207±0.0347	-1.1033±0.3897	0.01762±0.0034	0.2201±0.0706
2-24	6.75±2.31	0.1899±0.0364		0.01126±0.00253	
			TRIAL 2 - DMI		
2-6	4.95±1.75	0.2673±0.0291		0.00937±0.00279	0.1233±0.0384
7-12	6.75±1.96	0.2890±0.0475	-1.8019±0.7728	0.01901±0.00392	0.1660±0.0765
13-18	6.83±2.01	0.2514±0.0502	-1.5603±0.7591	0.01746±0.00345	0.2260±0.0803
19-24	3.54±1.25	0.3090±0.0450		0.01080±0.00262	0.3674±0.0912
2-24	3.02±1.85	0.3585±0.0376		0.01006±0.00234	0.3449±0.1003
2-24	4.51±2.10	0.3003±0.0364		0.01218±0.0024	

Table A.4.3 Best prediction equations for energy balance (MJ ME/day) selected from Appendix Table A.56 per stage of lactation

Weeks of lactation	Constant ± SE	Milk yield b_1 ± SE	Condition score b_2 ± SE	Liveweight b_3 ± SE	Liveweight change b_4 ± SE
					TRIAL 1 - MEB
2-6	16.53 ± 6.27	-2.7316 ± 0.4034	-14.998 ± 4.410	0.1126 ± 0.0443	2.909 ± 0.320
7-12	24.41 ± 12.02	-3.4312 ± 0.4549	-15.873 ± 6.173	0.1729 ± 0.0544	1.869 ± 0.688
13-18	12.03 ± 5.01	-2.7846 ± 0.4560	-9.923 ± 3.996	0.1826 ± 0.0494	
19-24	17.58 ± 9.62	-2.9077 ± 0.3926	-12.607 ± 4.747	0.1890 ± 0.0420	
2-24	13.71 ± 5.26	-2.7371 ± 0.3817	-12.032 ± 4.290	0.1571 ± 0.0371	2.970 ± 0.777
			TRIAL 2 - MEB		
2-6	26.16 ± 12.78	-2.1629 ± 0.3645		0.02148 ± 0.00891	2.194 ± 0.483
7-12	41.18 ± 15.26	-1.2026 ± 0.5046		0.09313 ± 0.03617	2.642 ± 0.942
13-18	75.56 ± 20.86	-2.1818 ± 0.4477		0.09483 ± 0.02725	3.206 ± 0.801
19-24	66.75 ± 25.76	-2.2920 ± 0.5134		0.07003 ± 0.02986	3.335 ± 1.039
2-24	43.35 ± 15.87	-1.4316 ± 0.4088		0.06450 ± 0.02538	4.165 ± 1.090

$Y = a + b_1$ milk yield $+ b_2$ condition score $+ b_3$ liveweight $+ b_4$ liveweight change

Table A.4.4 Regression of energy balance - MJ ME/day (MEB) on liveweight change (LWC, kg/day) or condition score change (BSC) for different stages of lactation

Weeks of lactation	Prediction equation	R^2	Error degrees of freedom
HEIFERS			48
2-6	MEB = 12.06 ± 3.41 + 19.96** ± 6.29 LWC	27.4	
	MEB = 11.78 ± 5.41 + 21 ± 502 BSC	1.5	
6-12	MEB = 16.83 ± 4.49 + 20.93** ± 6.75 LWC	26.4	
	MEB = 27.61 ± 3.51 - 31 ± 336 BSC	0.1	
12-18	MEB = 22.75 ± 6.11 + 33.9** ± 11.6 LWC	24.0	
	MEB = 35.75 ± 3.78 + 1061 ± 537 BSC	10.8	
1-18	MEB = 18.76 ± 3.89 + 23.84* ± 9.61 LWC	17.7	
	MEB = 26.29 ± 2.94 + 87 ± 1158 BSC	0.3	
COWS			114
2-6	MEB = 13.61 ± 3.19 + 26.27** ± 2.76 LWC	32.8	
	MEB = 16.25 ± 3.85 + 1015* ± 270 BSC	10.9	
6-12	MEB = 8.06 ± 3.20 + 18.23** ± 5.17 LWC	9.6	
	MEB = 7.75 ± 3.54 + 763* ± 330 BSC	3.9	
12-18	MEB = 21.71 ± 3.06 + 11.06* ± 4.60 LWC	4.2	
	MEB = 24.21 ± 2.96 + 150 ± 303 BSC	0.2	
1-18	MEB = 5.09 ± 2.15 + 35.18** ± 5.15 LWC	29.7	
	MEB = 5.27 ± 2.44 + 2107** ± 592	9.7	

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

Table A.7.5 Relationship between estimated ME intake, body energy change (TE), milk energy yield (EV) all scaled by metabolic body size ($W^{0.75}$) per year of experiment

Equation number			Prediction equation	R^2%	RSD
<u>Year 1</u>					
1	ME intake	=	1.274 ± 0.1931 + 0.6231* ± 0.2590 EV + 0.5811 ± 0.3652 TE	10.6	0.160
2	EV	=	0.3541 ± 0.1611 + 0.2223* ± 0.0921 ME intake - 0.5103** ± 0.0923 TE	18.0	0.099
3a	ME intake	=	58.6 ± 51.7 + 0.2009 ± 0.0873 $W^{0.75}$ + 0.594* ± 0.262 EV + 0.766* ± 0.3811 TE	17.3	20.7
<u>Year 2</u>					
4	ME intake	=	0.962 ± 0.148 + 1.051** ± 0.1941 EV + 0.8870** ± 0.2109 TE	49.8	0.140
5	EV	=	0.0181 ± 0.1360 + 0.4303** ± 0.0752 ME intake - 0.5503** ± 0.1302 TE	49.5	0.099
6a	ME intake	=	48.0 ± 31.2 + 0.1485* ± 0.0551 $W^{0.75}$ ± 1.067** ± 0.1961 EV + 1.127 + 0.2571 TE	59.9	18.5
<u>Year 3</u>					
7	ME intake	=	0.8753 ± 0.1391 + 1.095** ± 0.1882 EV + 0.8441* ± 0.3432 TE	54.3	0.117
8	EV	=	0.1102 ± 0.1440 + 0.4009* ± 0.0859 ME intake - 0.9710** ± 0.1783 TE	73.0	0.079
9a	ME intake	=	20.3 ± 43.9 + 0.1849** ± 0.0675 $W^{0.75}$ + 1.045** ± 0.196 EV + 0.9861** ± 0.3782 TE	46.4	14.6
<u>Year 4</u>					
10	ME intake	=	1.126 ± 0.3461 + 1.0112* ± 0.4223 EV + 0.0453 ± 0.6851 TE	29.5	0.156
11	EV	=	0.1083 ± 0.2953 + 0.3611* ± 0.1510 ME intake - 0.4771 ± 0.3813 TE	39.0	0.0932
12a	ME intake	=	41.2 ± 25.6 + 0.1875** ± 0.0451 $W^{0.75}$ + 0.8881** ± 0.1562 EV + 0.9610** ± 0.2145 TE	46.2	19.5
<u>Heifers</u>					
13	ME intake	=	1.035 ± 0.1682 + 1.031** ± 0.2654 EV + 0.5403 ± 0.3112 TE	37.2	0.097
14	EV	=	0.0513 ± 0.1752 + 0.4112** ± 0.1021 ME intake - 0.4973** ± 0.1811 TE	46.8	0.061
15a	ME intake	=	35.3 ± 29.4 + 0.1780** ± 0.0375 $W^{0.75}$ + 0.9943** ± 0.1651 EV + 0.7411** ± 0.2152 TE	38.3	17.6

a ME intake, milk energy and body energy not scaled by metabolic body size

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

Correlations between milk yield and LW, BS, LWC and BSC were small and mostly non-significant (Appendix Table A.53). High milk yields were, however, associated with low MEB (r = -0.273 - -0.640), but high efficiency traits (r = +0.360-+0.803).

LW was positively associated with MEB, but was negatively associated with efficiency traits; correlations, though significant in some stages of lactation, were small (Appendix Table A.53). Likewise, LWC was positively correlated with MEB (r = +0.150-+0.662, $P < 0.05$), but was negatively related to efficiency traits (r = -0.04 - -0.652). Correlations were generally high in early lactation, but declined with advancing lactation.

4.2.2 LINEAR AND MULTIPLE REGRESSION EQUATIONS

In Appendix Tables A.55 and B.56 are presented the range of equations used for selecting the best prediction equations for DMI and MEB. The best prediction equations for these same variables are respectively presented in Tables A.4.2 and A.4.3.

The complete models containing the predictor variables average daily milk yield (MY), LW, BS and weekly LWC in the period of lactation, accounted for 43.1-71.0 and 29.7-70.7% of the total variation in DMI and MEB respectively. The important predictor variables in the selected best prediction equations tended to be influenced by the stage of lactation and also trial. Thus in Trial 1 the complete models for DMI and MEB were selected in lactation stages 1, 2 and over stages 1-4. In Trial 2 only for DMI was the complete model selected in lactation stages 2 and 3. BS and LWC were inconsistent in their significant association with DMI and MEB and were the variables generally dropped from the prediction models.

The best prediction models selected for predicting DMI when cow effects were ignored, contained the variables week of lactation (WL), MY, LWC, LW and daily protein yield (PY). The selected models were:

TRIAL 1

$$DMI = 1.635 \pm 0.365 + 0.2058 \pm 0.0063\ MY + 0.5210 \pm 0.0184\ WL - 0.01503 \pm 0.0001\ WL^2 + 0.012 \pm 0.00055\ LW$$

$(R^2 = 41.1\%, RSD = 2.30)$

$$DMI = 1.351 \pm 0.348 + 0.6888 \pm 0.0177\ PY + 0.5435 \pm 0.0186\ WL - 0.01548 \pm 0.00058\ WL^2 + 0.001124 \pm 0.00053\ LW$$

$(R^2 = 45.7\%, RSD = 2.21)$

TRIAL 2

$$DMI = 1.942 \pm 0.398 + 0.2662 \pm 0.008\ MY + 0.3813 \pm 0.02001\ WL - 0.01141 \pm 0.00064\ WL^2 + 0.01222 \pm 0.00062\ LW$$

$(R^2 = 49.7\%, RSD = 1.83)$

$$DMI = 2.936 \pm 0.375 + 0.7672 \pm 0.0218\ PY + 0.3761 \pm 0.0195\ WL - 0.01155 \pm 0.00063\ WL^2 + 0.01083 \pm 0.00062\ LW$$

$(R^2 = 52.5\%, RSD = 1.79)$

In Appendix Tables A.57-B.59 are provided the range of equations used for selecting the best regression relationships between efficiency traits and some animal production variables. Models which included MY, LW, LWC and BS explained 55.1-77.4, 32.7-61.3 and 34.8-65.2% of the variation in gross, net and nitrogen efficiency respectively. The inclusion of daily ME intake as a predictor variable to the above models improved the precision of predictions (models explained 80.4-88.3, 81.8-87.8 and 48.6-79.3%). Not surprisingly, the inclusion of ME intake and MY in the models rendered other animal factors (LW, BS and LWC) less effective as predictor variables for efficiency traits (Appendix Table A.54).

There were significant interactions ($P < 0.01$) between calving BS (CS) and ME intake on all efficiency traits in lactation stage 4 (Appendix Tables A.57-A.59). The individual CS group (see Chapter 2.8) regression coefficients of efficiency traits on ME intake were (b ± SE):

<u>Gross efficiency</u>

0.0107 ± 0.0255; -0.0327 ± 0.0493; 0.1651** ± 0.0572

<u>Net efficiency</u>

-0.0700* ± 0.0349; -0.1350* ± 0.0675; 0.1366 ± 0.0783

<u>Nitrogen efficiency</u>

0.0143 ± 0.0169; -0.0155 ± 0.0327; 0.1214** ± 0.0379%/MJ ME; for CS1, 2 and 3 respectively.

Where ** = $P < 0.01$ and * = $P < 0.05$

In a model containing DMI, LW calving BS and LWC there was also a significant interaction of DMI and calving BS on daily milk yield in lactation stage 4 and over stages 1-4. Individual CS group regression coefficients of milk yield on DMI were (b ± SE):

<u>Lactation Stage 4</u>

1.134 ± 0.1808; 0.8072 ± 0.3646; 2.473 ± 0.3962

<u>Lactation Stage 1-4</u>

1.130 ± 0.1998; 0.6743 ± 0.3646; 2.042 ± 0.3553 kg/kg for CS1, 2 and 3 respectively. All the coefficients were different ($P < 0.05$) from zero.

A 1 kg increase in daily LWC was equivalent to 11.0-35.2 MJ ME for cows, but 20.0-33.9 MJ ME for heifers. Likewise, a unit change in BS was equivalent to 763-2107 MJ ME for cows (Table A.4.4). The coefficients of energy balance on BSC for heifers were not significant.

In Table A.4.5 an attempt was made to estimate the partial efficiency of ME utilization for milk energy yield (K_l) based on body tissue energy as estimated from backfat area measurements and body composition data (described in Chapter 6.1.1). The exclusion of year 1 data, which were very variable compared to other years, still resulted in high estimates of K_l which ranged from 0.91-0.99 for cows and 0.97 for heifers, when ME intake was the dependent variable. When milk energy yield (EV) was the dependent variable K_l declined to 0.36-0.43 for cows and 0.41 for heifers. The efficiency of conversion of body tissue energy to milk energy ranged from 0.48-0.97.

4.3 Discussion

The prediction of VFI of dairy cows is of great practical importance (Vadiveloo and Holmes, 1979; see also Table 1.4 of Chapter 1); providing a basis for ration formulation. The prediction equations available have shown that even in the best complex models 16% of the total variation in VFI is unaccounted for. An attempt was made in the present study to predict VFI from animal characteristics, not for farm use, but to provide a better understanding of the relationships between DMI and these factors.

The best prediction equations containing the predictor variables MY, LW, BS and LWC accounted for 41.1-70.1% of the total variation in DMI for different stages of lactation (Table A.4.2). The effectiveness of these predictor variables generally declined with advancing lactation due to a decreasing influence of BS and LWC. When, however, cow effects were ignored, the predictor variables MY, LW and linear and quadratic effect of WL (undoubtedly representing LWC) explained only 41.1-49.7% of the variation in DMI.

Equations derived in this study are difficult to compare directly with those reported in the literature (Table 1.4, Chapter 1) because of differences in presentation of the data. However, Coppock et al (1974) and Bieri et al (1982) noted that animal factors accounted for 32-64% of the variation in DE (digestible energy) intake and 49-68% of the variation in DMI.

It has been reported that data transformed to natural or common logarithms gave better predictions than the original data (Conrad et al, 1964; Brown et al, 1977; Vadiveloo and Holmes, 1979). In the present investigation, transformed data were found to explain slightly less variation in DMI than the original data. Probably the use of mean values for each stage of lactation made logarithmic transformations unnecessary in this investigation.

FCM yield in prediction equations have been observed to give better predictions than milk yield (Yungblut et al, 1981). It would seem that these differences would depend on the milk fat content. For example, Curran et al (1970) observed that milk yield was as a good predictor variable of DMI as FCM yield. In the current study because of high milk fat contents (42.1 g/kg over the experimental period) the substitution of FCM yield for milk yield did not improve R^2. This is further evidenced by similar correlation coefficients between DMI and these traits (Table A.4.1). It is useful to note that in the report of Yungblut et al (1981) milk fat content ranged from 35.0-39.0 g/kg, which is much lower than that of the present work. It is also important to note that correlations of DMI with milk yield declined whereas those with FCM yield increased as lactation progressed. Differences in the pattern of correlations between DMI and these traits can be explained by body tissue changes. In early lactation, due to body fat mobilization into milk fat, FCM will not be produced completely from dietary sources. Milk volume, other than fat, on the other hand, due to negative energy balance, is produced directly from dietary sources. With advancing lactation body fat mobilization declined and milk fat and thus FCM is produced from dietary sources, whereas the partition of feed between milk yield and weight gain reduced the close association between milk yield and DMI.

There is a discrepancy in the information available on the influence of LW on DMI. Some reports indicate that LW raised to power 1.0 or 0.73 had no influence on DMI (Johnson et al, 1966; Curran et al, 1970). Other reports indicate that LW raised to the power 0.73 or 0.75 was a better predictor of DMI than LW, for concentrate supplemented diets (Conrad et al, 1964; Yungblut et al, 1981) while other reports noted the opposite (Yadava et al, 1970). Both LW, $LW^{0.75}$ or $LW^{0.73}$ accounted for similar variation in DMI in the current work. As pointed out by Curran et al (1970), the influence of LW or DMI depends on its variability in the data used. This is borne out by the higher correlation coefficients between LW and DMI in Trial 2 containing both cows and heifers than Trial 1 containing only cows (Table A.4.1). The lack of adjustments of LW for differences in body fatness (eg Conrad et al, 1964; Yungblut et al, 1981) could also have influenced these results.

The inclusion of LWC in both the present investigation and other reported experiments improves prediction equations for intake (Johnson et al, 1966; Bines et al, 1977). Current LWC, however, cannot be used to predict current DMI. In the farm situation therefore this variable, though effective as a predictor, may have to be deleted from intake prediction equations (Curran et al, 1970). The declining effectiveness of LWC in Trial 1 of this experiment supports previous observations by Curran et al (1970). These authors noted that, as the standard deviations of LWC decreased, the effectiveness of LWC as a predictor of DMI declined. Vadiveloo and Holmes (1979), on the other hand, observed no significant influence of LWC on DMI in lactation weeks 1-12 and 13-24. It would therefore appear that reasons for the changing relationship of LWC to DMI are more complex than declining standard deviations. This is borne out by the results of Trial 2 where LWC was significantly associated with DMI in all lactation stages. As discussed in Chapter 3.2.1, variations in composition and size of LWC between animals could be involved in these differences.

There are no known similar situations in which BS has been used as a predictor variable, though several reports indicate a negative association between calving BS and feed intake (Garnsworthy and Topps, 1982b; Garnsworthy and Garner, 1985). BS was an important factor on intake in most stages of lactation except stage 3 (weeks 13-18) when most animals would have reached minimum BS levels for Trial 1. The lack of significant effect of BS on DMI in lactation weeks 2-6 for Trial 2 are difficult to interpret. Perhaps low intakes of heifers and of fat animals, which tend to be mostly cows, at this time helps to explain this effect.

In computing prediction equations across weeks of lactation, ignoring cow effects, it was observed that a model containing milk protein yield accounted for more variation in DMI than one containing either milk yield, FCM yield, fat yield or milk fat plus protein yield. This is the first time that such a result has been reported. Brown et al (1977) have reported that fat yield in prediction equations gave good prediction of VFI. This result is difficult to explain since 1 kg of fat yield contains more energy than 1 kg of protein yield. Could the energy cost of synthesising one unit of milk protein be higher than a unit of milk fat? Webster (1980) showed that the amount of ME required to deposit one gram of protein and fat was the same (53 MJ).

If this value is accepted, then the apparent difference may be due to low energy cost associated with the transfer of long chain fatty acids from mobilized body tissues to milk fat (Kronfeld, 1982) as compared with the energy cost of de novo synthesis of milk protein from different absorbed amino acids.

From the foregoing it is reasonable to expect that MY, LW, LWC and BS, which are important factors related to the energy situation of an animal, would account for most of the variation in DMI. The probable reasons for the 30-59% unexplained variation in DMI were discussed in Chapter 3.2.1.

This is further evidenced by lack of significant association of some factors as LWC and BS with DMI in some stages of lactation. Also correlations and coefficients between DMI and other animal characteristics are influenced by the stage of lactation (Miller et al, 1973; Grieve et al, 1976; Korver, 1982; Bertilsson and Burstedt, 1983). It would therefore appear that for improved precision of predictions, equations should be estimated for different stages of lactation.

The present experiment also demonstrated that LW, BS, LWC and milk yield, in the stage of lactation, were all important factors influencing MEB and efficiency traits. These variables explained in MEB 42.5-71.0 and 29.7-54.5% of the total variation for Trials 1 and 2 respectively. The lower variation observed in Trial 2 is difficult to explain. Energy balance depends on maintenance requirements and milk energy yield. LW and MY should therefore have explained a large amount of the variation in MEB. Variation in size of LWC or LW and errors in estimation of energy balance could explain some of this discrepancy.

Differences between animals in efficiency were mostly due to differences in milk yield and ME intake. It would therefore seem that high yielding cows produce more milk per unit ME intake than low yielding cows. They also eat more (high correlations between milk yield and DMI) but still partition more of their ME intake into milk (high negative correlations between efficiency and DMI). These results are in agreement with experimental observatinos (Bryant, 1981; Davey et al, 1983) that cows of high breeding index eat more and still partition more food into milk than cows of low breeding index.

It is significant to note that in the equation which included milk yield and ME intake, LWC, which was highly correlated with efficiency traits, was not an important factor influencing efficiency variables. This gives support to the contention that LWC is the effect of level of DMI and not the reverse (Bines, 1979).

The most interesting aspect of the present study, never previously reported, was the significant interaction of DMI and calving BS on milk yield in lactation weeks 19-24 and over weeks 2-24 and ME intake and calving BS on efficiency traits in lactation weeks 19-24. Cows calving in fat condition tended to partition more of their DMI into milk than cows in thin and in medium condition at calving. Thin cows also partitioned more DMI into milk than cows in medium condition. This was reflected in fat cows being more efficient in gross milk energy and milk nitrogen production at this time. These results are less surprising when it is recalled that at this time fat cows are still mobilizing body fat while other groups are replenishing fat. This is further evidenced by declining net efficiency for cows in thin and medium condition at this time. These results, though, are consistent with the hypothesis (Chapter 4.2.2.2) that fat animals which deplete their body reserves in early lactation decline in body fat to a plateau and there switch from body fat mobilization to deposition.

The energy value of 1 kg change in LWC for cows (11.0-35.2 MJ ME or 6.8-21.8 MJ at K_g = 62%; MAFF, 1975) and heifers 20.0-33.9 MJ ME or 12.4-21.0 MJ) are less than those reported in the literature. For example, ARC (1980) recommended 26 MJ net energy/kg weight change; Alderman et al (1982) observed 27.4-49.1 MJ ME for heifers and 31.3-89.1 MJ ME/kg LWC for cows and MAFF (1975) recommended 20 MJ net energy/kg LWC. Probable causes of differences between experiments in energy value of LWC was discussed in Chapter 5.2.2.7 and was attributed to the confounding effects of gut fill on LWC.

The higher estimated energy value of LWC in early lactation may be attributable to the higher energy value of body fat which would be mobilized shortly after calving, but may also reflect underestimation of true LW loss in early lactation, due to changing gut contents between lactation weeks 2-6 (Moe et al, 1971). The opposite would be the case for heifers which have less body fat at calving to mobilize (Table A.4.5). The significant intercept values are probably an indication of energy needed for growth which was not allowed for in estimation of energy balance of immature animals.

The energy value of one unit of BSC (763-2107 MJ ME) in this study appears very low when compared with 2242-3478 MJ net energy value obtained by Wright (1982). Differences between the two experiments are probably due to the method of estimating these values. Wright (1982) regressed body energy estimated from slaughter experiments on BS. Furthermore, energy value of a subjective measure such as BS cannot be absolute due to differences between operators (Evans, 1979; Nicols, 1981). The non-significant coefficients of energy value of BSC for heifers possibly reflects lack of significant BSC change between lactation weeks 2-18.

4.3.1 ESTIMATION OF PARTIAL EFFICIENCY OF ME UTILIZATION FOR LACTATION

Estimation of K_l is normally by calorimetric methods and regression techniques (Flatt et al, 1969; Moe et al, 1971; Van Es and Van der Honig, 1979). In these methods K_l is determined through simultaneous measurement of milk energy yield (EV) and tissue energy change (TE) under conditions where they vary relative to each other. The results are then analysed by fitting into a model as:

$$\text{ME intake} = a + b_1 W^{0.75} + b_2 EV + \text{positive TE} + b_4 \text{ negative TE}$$

Where $K_l = {}^1/_{b_2}$

Such methods are costly and time consuming and yet K_l is important for feed formulations. Few attempts have been made to estimate K_l from live body measurements. The use of ultrasonic backfat area measurements and equations derived from cow body composition data to estimate K_l fell short of expectations (Table A.4.5). The results indicatd that K_l ranged from 0.91-0.99 when ME intake was the dependent variable but 0.36-0.43 when EV was the dependent variable. The efficiency of conversion of TE to EV was estimated within the range 0.48-0.97. The two methods of calculating K_l are expected to be similar since theoretically they measure the same factor (Moe et al, 1971). The present results differ from 0.54-0.68 reported for K_l from all forage to high concentrate diets or the 0.82-0.84 reported for the efficiency of conversion of TE to milk energy (Flatt et al, 1969; Moe et al, 1971; Van Es and Van der Honig, 1979). These poor estimations were no doubt due to cumulative errors in estimation of body energy from many predictive equations and also in the measure of backfat area.

4.4 Conclusion

LW, MY LWC and BS accounted for 43.1-71.0 and 29.7-70.7% of the total variation in DMI and MEB respectively, within different stages of lactation. The proportion of variation explained in DMI tended to decline with advancing lactation due to the decreasing effectiveness of BS and LWC as predictor variables. When cow effects were ignored the predictor variables MY, LW and linear and quadratic effects of WL explained only 41.1-49.7% of the total variation in DMI. Prediction equations containing protein yield accounted for more variation in DMI than equations containing milk or FCM or fat yields. The precision of prediction of DMI increased more with variability of the data than with sample size (Curran et al, 1970). Milk yield was as good a predictor of DMI as was FCM yield. LW, $LW^{0.73}$ and $LW^{0.75}$ accounted for similar variation in DMI.

Correlations of DMI with milk yield declined whereas correlations with FCM yield increased as lactation progressed. High yielding cows consumed more feed, but still partitioned more of the feed into milk yield and were therefore more efficiency than low yielding cows.

Fat cows at calving partitioned more DMI into milk yield and were more efficient than cows calving in thin or medium condition in lactation weeks 19-24. Cows in thin condition also partitioned more DMI into milk yield than cows in medium condition, at this time.

The energy value of 1 kg change in LWC was estimated as 7-22 MJ for cows and 12-21 MJ for heifers. Partial efficiency of ME utilization for milk energy yield (K_l), estimated from ultrasonic backfat area measurements and cow body composition data, ranged from 0.36-0.99.

In conclusion: simple empirical relations are not precise enough for the prediction of VFI using animal factors. The use of more complex relatinoships will, however, render predictions of little practical farm use. Improved predictions of DMI more precisely than $\pm$1.3-1.9 kg will require improved recording of LW and LWC (affected by gutfill) and BS (affected by operator bias). These equations can further be improved by the use of stage of lactation constants or the estimation of individual stage of lactation prediction equations. Body fat mobilization results in low correlations between DMI and FCM yield but not with uncorrelated milk yield. Milk yield is as good a predictor varible as FCM yield for DMI provided the average milk fat composition of the animals is above 40 g/kg. The estimation of K_l from backfat area and body composition is too inaccurate to be of practical significance in further estimation of input-output relationships; one of the initial objectives of the Langhill project (Neilson et al, 1983). Improvements in the digitising of backfat area scans are needed for more precise predictions of body energy change. The present use of Scanogram to read backfat area directly may prove to be a more accurate method for predicting body composition than the more subjective method of Danscanning.

Table A.1 Least squares means, standard errors (SE) and the variance (R^2%) explained by each factor for daily dry matter intake (kg) per stage of lactation - TRIAL 1

STAGE OF LACTATION		1		2		3		4		1-4	
WEEKS OF LACTATION		2-6		7-12		13-18		19-24		2-24	
Factors	Number of records	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Year of calving											
1	33	16.1^a	0.41	18.7^a	0.50	20.0	0.51	19.3^a	0.46	18.6^a	0.39
2	35	17.8^b	0.36	20.1^b	0.45	19.4	0.46	17.5^b	0.41	18.8^a	0.35
3	35	15.5^c	0.34	17.8^c	0.42	18.7	0.43	17.4^b	0.39	17.4^b	0.33
4	12	17.1^d	0.32	20.0^b	0.64	19.5	0.68	18.9^a	0.60	18.8^a	0.52
R^2		11.9		8.8		4.2		9.0		11.6	
Month of Calving											
1	47	16.9	0.32	19.4	0.39	20.2^a	0.41	19.1^a	0.36	18.9	0.32
2	56	16.4	0.30	19.3	0.37	19.3^b	0.38	18.0^b	0.35	18.4	0.29
3	12	16.5	0.50	18.7	0.61	18.6^c	0.63	17.6^b	0.57	17.9	0.48
R^2		0.8		0.1		5.0		6.5		3.1	
Milk yield groups											
1	16	14.4^a	0.63	18.1^a	0.77	19.2^a	0.80	18.0^a	0.71	17.6^a	0.61
2	45	17.1^b	0.30	19.0^b	0.37	18.7^a	0.38	17.7^a	0.34	18.1^a	0.29
3	54	18.4^c	0.26	20.3^c	0.32	20.2^b	0.33	19.1^b	0.30	19.6^b	0.25
R^2		17.9		11.7		7.8		12.1		13.1	

abcd Different superscripts in column indicate significant difference $P < 0.05$

Table A.2 *Least squares means, standard errors (SE) and estimates of the effects of calving liveweight (kg) and liveweight change - kg/week (regression coefficients (b)) and the variance (R^2%) explained by each factor for daily dry matter intake as % liveweight per stage of lactation - TRIAL 1*

STAGE OF LACTATION		1		2		3		4		1-4		Maximum intake	
WEEKS OF LACTATION		2-6		7-12		13-18		19-24		2-24			
Factors	Number of records	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
All	115	2.67	0.041	3.06	0.050	3.03	0.057	2.81	0.051	2.99	0.041	3.47	0.059
Year of calving													
1	33	2.57^{a}	0.062	3.03^{a}	0.078	3.10	0.084	2.91	0.078	2.94^{a}	0.063	3.54	0.092
2	35	2.83^{b}	0.054	3.16^{b}	0.067	3.04	0.073	2.73	0.068	2.95^{a}	0.054	3.52	0.079
3	35	2.50^{a}	0.050	2.90^{c}	0.062	3.00	0.068	2.76	0.064	2.80^{b}	0.050	3.33	0.073
4	12	2.77^{b}	0.079	3.16^{b}	0.096	3.00	0.107	2.81	0.098	3.01^{a}	0.080	3.49	0.113
R^2(%)		11.1		6.3		0.9		2.4		3.8		3.2	
Month of calving													
1	47	2.71	0.048	3.08	0.058	3.13	0.065	2.89	0.060	3.00	0.485	3.52	0.069
2	46	2.65	0.046	3.08	0.056	3.05	0.061	2.82	0.058	2.92	0.045	3.51	0.066
3	12	2.64	0.074	3.02	0.092	2.92	0.100	2.71	0.094	2.85	0.074	3.39	0.109
R^2(%)		0.7		0.1		3.3		2.7		1.7		0.6	
Parity													
2	26	2.66	0.069	2.98	0.085	2.93	0.094	2.79	0.088	2.89	0.070	3.34	0.100
3	34	2.61	0.054	3.02	0.067	2.99	0.073	2.73	0.068	2.88	0.055	3.45	0.079
4	25	2.73	0.058	3.15	0.071	3.12	0.072	2.85	0.073	2.98	0.057	3.60	0.084
5	30	2.67	0.057	3.09	0.070	3.10	0.078	2.85	0.072	2.94	0.057	3.49	0.082
R^2		2.0		1.6		2.0		1.0		1.6		2.5	
Milk yield groups													
1	16	2.42^{a}	0.095	2.97^{a}	0.115	3.07^{a}	0.126	2.83^{a}	0.118	2.88^{a}	0.094	3.53^{a}	0.137
2	45	2.69^{a}	0.044	2.97^{a}	0.055	2.85^{a}	0.060	2.63^{b}	0.056	2.81^{a}	0.045	3.31^{b}	0.064
3	54	2.89^{c}	0.039	3.24^{b}	0.048	3.18^{c}	0.053	2.95^{c}	0.049	3.07^{b}	0.039	3.58^{a}	0.056
R^2		12.0		10.6		11.9		18.9		16.1		11.4	
Calving condition score groups													
1	65	2.81^{a}	0.046	3.18	0.057	3.08	0.061	2.74	0.058	2.97	0.045	3.51	0.070
2	26	2.73^{a}	0.054	3.08	0.066	2.98	0.072	2.77	0.067	2.93	0.054	3.40	0.077
3	24	2.41^{b}	0.100	2.92	0.123	3.03	0.014	2.91	0.126	2.87	0.099	3.5	0.146
R^2		3.9		4.9				5.9		4.4		6.1	
Weight change (b,SE)	115	0.0181	0.0042**	0.0061	0.0081	0.0077	0.0102	0.0125	0.0093	-0.0200	0.0120	-0.0145	0.00611**
R^2		5.9		0.2		0.3		1.0		0.3		2.8	
Calving liveweight (b, SE)	115	-0.00225	0.00056**	-0.00244	0.00066**	-0.00187	0.00072*	-0.00135	0.00068*	-0.00230	0.00055*	-0.00324	0.00087**
R^2		5.2		5.6		5.2		3.9		6.8		7.5	

abcd Different superscripts in column indicate significant difference $P < 0.05$, * $P < 0.05$, ** $P < 0.01$

Table A.3 *Least squares means, standard errors (SE) and estimates of the effects of calving liveweight (kg) and weight change - kg/week (regression coefficients (b)) and the variance (R^2%) explained by each factor for daily dry matter intake/$W^{0.75}$(g) per stage of lactation - TRIAL 1*

STAGE OF LACTATION		1		2		3		4		1-4		Maximum intake	
WEEKS OF LACTATION		2-6		7-12		13-18		19-24		2-24			
Factors	Number of records	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
All	115	133.2	2.06	153.0	2.48	152.5	2.68	141.7	2.50	146.4	2.04	174.5	2.77
Year of calving													
1	33	128.0^a	3.16	150.9^a	3.88	156.2	4.13	147.7	3.83	147.0^a	3.13	179.0^a	4.31
2	35	141.7^b	2.74	158.6^b	3.33	152.5	3.57	137.6	3.09	148.6^a	2.69	177.7^a	3.69
3	35	124.8^a	2.55	144.3^c	3.09	149.9	3.33	138.6	4.81	139.8^b	2.52	166.4^b	3.44
4	12	138.1^b	3.97	158.7^b	4.77	151.4	5.23	143.2	2.92	150.6^c	4.02	175.1^a	5.32
R^2		12.4		7.4		1.5		3.7		4.9		5.7	
Month of calving													
1	47	135.5	2.41	154.1	2.88	157.9	3.18	146.5	2.92	150.4	2.42	177.7	5.31
2	56	132.2	2.30	154.2	2.77	153.0	2.98	141.8	2.80	146.2	2.26	176.0	3.24
3	12	131.8	3.76	150.9	4.57	146.6	4.90	136.8	4.59	142.6	3.71	170.0	3.10
R^2		0.7		0.2		4.0		3.6		2.2		1.0	
Parity													
2	26	132.4	3.51	148.7	4.23	146.7	4.62	141.0	4.31	144.0	3.50	169.0	5.12
3	34	130.4	2.76	151.4	3.35	150.8	3.80	138.8	3.33	144.6	2.75	173.0	4.73
4	25	136.2	2.91	157.4	3.52	155.6	3.78	143.7	3.54	149.5	2.87	180.3	3.71
5	30	133.7	2.88	154.6	3.49	153.5	6.19	143.5	3.50	147.5	2.84	176.3	3.95
R^2		1.2		1.8		2.2		0.7		1.7		2.6	
Milk yield groups													
1	16	119.4^a	4.79	147.5^a	5.74	153.5^a	2.96	142.3^a	5.76	143.3^a	4.69	175.4^a	6.46
2	45	135.0^b	2.24	149.5^a	2.71	144.5^b	2.96	134.0^b	2.73	141.6^a	2.25	166.5^b	3.63
3	54	145.0^c	1.99	162.2^b	2.39	159.5^c	2.59	148.9^c	2.41	154.1^b	1.95	181.8	2.62
R^2		14.4		12.0		11.4		18.2		17.2		12.0	
Calving condition score groups													
1	65	141.2^a	2.30	159.7	2.82	155.9	7.64	139.1	2.81	149.5	1.95	178.8	3.27
2	26	136.8^b	2.72	154.7	3.28	150.8	6.38	140.5	3.29	147.3	2.70	172.3	3.59
3	24	121.5^c	5.05	144.6	6.12	150.7	4.38	145.7	6.12	142.3	4.97	172.5	6.89
R^2		4.9		5.7		4.2		4.9		4.6		4.8	
Weight change (b, SE)	115	1.095	0.2129*	0.566	0.4044	0.529	0.4997	0.662	0.4550	-0.315	0.5996	-0.441	0.2878
R^2		9.6		1.0		0.8		2.4		0.1		1.2	
Calving liveweight (b, SE)	115	-0.0604	0.02818*	-0.0758	0.0329*	-0.0489	0.0355	-0.0284	0.0331	-0.0645	0.0274*	-0.0881	0.0389*
R^2		1.6		1.8		1.6		1.0		2.1		2.7	

abcd Different superscripts in column indicate significant difference $P < 0.05$, * $P < 0.05$

Table A.4 Least squares means, standard errors (SE) and estimates of the effects of calving liveweight (kg) and liveweight change - kg/week (regression co-efficients (b)) for parameters of daily dry matter intake curves - TRIAL 1

Parameters		a		b		c		Maximum intake		Week of maximum intake	
Factors	Number of records	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
All	115	12.9	0.46	0.3048	0.0277	-0.0246	0.0028	21.8	0.34	17.1	3.78
Year of calving											
1	33	11.2^{a}	0.35	0.3544	0.0432	-0.0243	0.0043	22.6^{a}	0.53	20.0	5.89
2	35	13.8^{b}	0.32	0.3169	0.0371	-0.0309	0.0037	22.1^{ac}	0.45	12.0	5.05
3	35	12.1^{c}	0.28	0.2780	0.0345	-0.0219	0.0034	20.8^{b}	0.42	17.2	4.70
4	12	14.4^{b}	0.27	0.2699	0.0534	-0.0221	0.0052	21.7^{c}	0.65	16.8	7.27
Month of calving											
1	47	13.2	0.54	0.2879	0.0326	-0.0208	0.0032	22.4	0.40	18.2	4.44
2	56	13.8	0.52	0.3096	0.0312	-0.0260	0.0039	21.8	0.38	17.0	4.24
3	12	12.3	0.86	0.3168	0.0511	-0.0269	0.0051	21.3	0.62	16.2	6.99
Parity											
2	26	13.7	0.79	0.2299	0.0475	-0.0172	0.0046	20.9	0.58	25.0	6.46
3	34	12.3	0.62	0.3387	0.0373	-0.0274	0.0037	21.7	0.47	15.4	5.08
4	25	13.1	0.6	0.3042	0.0397	-0.0245	0.0039	22.4	0.49	13.2	5.40
5	30	12.5	0.65	0.3463	0.0389	-0.0291	0.0038	22.1	0.48	15.2	5.30
Milk yield groups											
1	16	9.4^{a}	1.07	0.4778^{a}	0.0649	-0.0332	0.0064	21.2^{a}	0.79	19.2	8.83
2	45	14.4^{b}	0.51	0.2113^{b}	0.0304	-0.0197	0.0030	21.2^{a}	0.37	13.8	4.14
3	54	14.8^{b}	0.43	0.2253^{b}	0.0263	-0.0208	0.0026	23.0^{b}	0.32	18.4	3.58
Calving condition score group											
1	65	13.6	0.43	0.3216	0.0390	-0.0315	0.0032	22.7	0.40	11.4	4.48
2	26	13.7	0.55	0.2801	0.0361	-0.0250	0.0036	21.8	0.44	16.6	4.91
3	24	11.3	0.60	0.3126	0.0692	-0.0182	0.0068	20.9	0.85	23.4	9.42
Weekly liveweight change (b, SE)	115			0.00322	0.00289	-0.00092	0.00029**	0.0665	0.0354	-1.056	0.394**
Calving liveweight (b, SE)	115	0.00113	0.00156	0.00032	0.00039	-0.00002	0.00004	0.01208	0.00479	-0.00127	0.0533

abcd Different superscripts in column indicate significant difference $P < 0.05$, * $P < 0.05$, ** $P < 0.01$

Table A.5 Least squares means, standard errors (SE) and estimates of the effects of daily milk yield in lactation week 2 - kg (regression coefficients (b)) and the variance (R^2%) explained by each factor for daily dry matter intake (kg) per stage of lactation - TRIAL 2

STAGE OF LACTATION		1		2		3		4		1-4	
WEEKS OF LACTATION		2-6		7-12		13-18		19-24		2-24	
Factors	**Number of records**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
All	75	17.0	0.17	18.9	0.20	18.6	0.19	17.6	0.20	18.1	0.17
Month of calving											
1	27	16.8	0.25	19.0	0.28	18.8	0.28	17.9	0.31	18.1	0.25
2	24	17.1	0.27	19.1	0.31	19.0	0.30	17.9	0.34	18.2	0.26
3	24	17.3	0.29	18.7	0.35	18.0	0.34	17.6	0.37	17.8	0.30
R^2		0.7		0.1		4.5		5.2		1.3	
Parity groups											
1a	24	15.5^a	0.35	17.4^a	0.40	18.3	0.39	17.9^a	0.41	17.3^a	0.34
1b	25	16.7^b	0.29	18.5^b	0.32	18.9	0.31	17.8^a	0.32	18.1^b	0.28
2	14	18.0^c	0.48	19.3^c	0.55	18.1	0.54	16.2^b	0.56	17.9^c	0.47
3	12	18.0^c	0.53	20.6^d	0.57	19.2	0.56	18.3^c	0.59	19.0^d	0.50
R^2		6.1		8.4		4.6		8.6		5.9	
Milk yield (b, SE)	75	0.0932	0.0397*	0.0521	0.0432	0.1323	0.0419**	0.1420	0.0438**	0.1096	0.0373**
R^2		2.0		0.3		3.6		3.6		2.3	

abcd Different superscripts in column indicate significant difference $P < 0.05$, * $P < 0.05$, ** $P < 0.01$

Table A.6 Least squares means, unadjusted parity group means, standard errors (SE) and estimates of the effects of certain variables (regression coefficients (b)) and the variance (R^2%) explained by each factor on daily dry matter intake as % of liveweight per stage of lactation - TRIAL 2

STAGE OF LACTATION		1		2		3		4		1-4		Maximum intake	
WEEKS OF LACTATION		2-6		7-12		13-18		19-24		2-24			
Factors	Number of records	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
All	75	3.10	0.032	3.35	0.038	3.19	0.038	2.93	0.039	3.16	0.031	3.65	0.039
Month of calving													
1	27	3.03	0.048	3.30	0.054	3.16	0.055	2.92	0.057	3.14	0.046	3.64	0.060
2	24	3.11	0.050	3.36	0.059	3.25	0.060	2.95	0.062	3.20	0.048	3.66	0.065
3	24	3.16	0.055	3.38	0.066	3.14	0.067	2.91	0.073	3.13	0.053	3.65	0.069
R^2		1.9		0.2		3.1		2.3		0.7		0.1	
Parity groups													
1a	24	2.81[a]	0.067	3.19[a]	0.077	3.27[a]	0.078	3.10[a]	0.080	3.07[a]	0.063	3.52[a]	0.082
1b	25	3.05[c]	0.054	3.39[b]	0.061	3.39[b]	0.061	3.11[a]	0.063	3.20[b]	0.051	3.64[b]	0.067
2	14	3.26[b]	0.092	3.32[b]	0.106	2.96[c]	0.106	2.61[b]	0.109	3.08[a]	0.086	3.61[b]	0.104
3	12	3.28[b]	0.100	3.50[c]	0.110	3.13[d]	0.110	2.89[c]	0.114	3.28[c]	0.093	3.83[c]	0.120
R^2		7.8		9.9		5.5		8.1		6.8		3.1	
Weight change (b, SE) x 100	75	-0.00730	0.00835	-0.00081	0.01472	0.01051	0.01602	0.02376	0.02013	-0.05582	0.02091**	-0.03526	0.00968**
R^2		0.4		0.1		0.3		1.2		4.3		0.2	
Liveweight at calving (b, SE)	75	-0.00351	0.00077**	-0.00250	0.00091**	-0.00255	0.00091**	-0.00272	0.00095**	-0.00316	0.00074**	-0.00302	0.00097**
R^2		10.2		9.4		12.0		11.0		13.8		6.4	
Milk yield (b, SE)	75	0.0151	0.0075*	0.0216	0.0083*	0.0393	0.0083**	0.0369	0.0085**	0.0233	0.0069**	0.0194	0.0088*
R^2		2.0		0.6		4.6		4.7		3.1		3.2	
Calving condition score (b, SE)	75	-0.267	0.139	-0.339	0.169	-0.160	0.170	-0.135	0.175	-0.211	0.135	-0.502	0.179**
R^2		1.9		3.0		0.8		0.7		1.6		5.2	
						Unadjusted Means							
Parity groups													
1a	24	2.81[a]	0.065	3.11[a]	0.069	3.10[a]	0.072	2.97	0.043	3.00[a]	0.063	3.47[a]	0.083
1b	25	3.07[b]	0.060	3.38[b]	0.068	3.32[b]	0.071	3.06	0.076	3.22[b]	0.062	3.66[b]	0.083
2	14	3.36[c]	0.087	3.50[c]	0.093	3.27[bc]	0.096	2.88	0.096	3.25[b]	0.084	3.77[c]	0.108
3	12	3.10[c]	0.091	3.44[cb]	0.096	3.23[c]	0.100	2.97	0.099	3.19[b]	0.088	3.69[cb]	0.116
All	75	3.04	0.039	3.33	0.041	3.23	0.043	2.98	0.043	3.15	0.038	3.62	0.049
Level of significance		***		**		NS		NS		*		*	

abcd Different superscripts in column indicate significant difference $P < 0.05$

*** $P < 0.001$; ** $P < 0.01$; * $P < 0.05$; NS = not significant

Table A.7 *Least squares means, unadjusted parity means, standard errors (SE) and estimates of the effects of certain variables (regression coefficients (b)) and the variance (R^2%) explained by each factor for daily dry matter intake/$W^{0.75}$(g) per stage of lactation - TRIAL 2*

STAGE OF LACTATION		1		2		3		4		1-4		Maximum intake	
WEEKS OF LACTATION		2-6		7-12		13-18		19-24		2-24			
Factors	Number of records	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
All	75	150.0	1.54	163.3	1.76	156.6	1.74	144.8	1.82	154.3	1.47	178.5	1.80
Month of calving													
1	27	146.8	2.29	161.6	2.55	156.1	2.55	145.0	2.66	153.9	2.26	178.7	2.73
2	24	150.5	2.41	164.1	2.76	159.9	2.77	146.2	2.88	156.1	2.32	179.2	2.95
3	24	152.8	2.62	164.1	3.10	153.7	3.07	143.3	3.37	152.8	2.55	177.7	3.13
R^2(%)		1.8		0.1		4:0		3.5		0.9		0.1	
Parity groups													
1a	24	136.3^{a}	3.19	154.2^{a}	3.61	159.0^{a}	3.58	151.9^{a}	3.72	149.8^{a}	3.01	171.1	3.74
1b	25	147.4^{b}	2.57	163.7^{b}	2.84	164.7^{b}	2.82	152.3^{a}	2.91	156.0^{b}	2.45	176.0	3.07
2	14	157.9^{c}	4.39	162.7^{b}	4.98	147.2^{c}	4.89	130.0^{b}	5.08	150.9^{a}	4.13	178.8	4.74
3	12	158.5^{c}	4.80	172.4^{c}	5.16	155.4^{d}	5.10	145.1^{c}	5.31	160.6^{c}	4.44	188.2	5.45
R^2(%)		8.0		10.5		5.9		9.8		7.4		3.8	
Weight change (b, SE)	75	-0.1055	0.3997	0.3198	0.6929	0.7960	0.7387	1.4887	0.9359	-1.677	1.004	-1.364	0.441**
R^2(%)		0.1		0.2		1.0		2.4		2.0		0.2	
Liveweight at calving (b, SE)	75	-0.1025	0.0370**	-0.0590	0.0428	-0.0719	0.0418	-0.0860	0.0443	-0.0911	0.0354*	-0.0928	0.0442*
R^2(%)		4.0		3.4		6.2		5.8		6.4		2.9	
Milk yield (b, SE)	75	0.753	0.358*	0.898	0.388*	1.724	0.382*	1.658	0.395**	1.097	0.329*	0.873	0.400*
R^2(%)		2.3		0.6		5.3		5.3		3.5		3.3	
Calving condition score (b, SE)	75	-13.677	6.679*	-17.449	7.920*	-7.495	7.849	-7.012	8.149	-10.678	6.473	-20.431	8.151*
R^2(%)		2.2		3.4		0.8		0.9		2.0		4.4	
						<u>Unadjusted Means</u>							
Parity groups													
1a	24	134.1^{a}	2.80	149.9^{a}	2.98	150.6^{a}	3.14	144.3	3.19	145.1^{a}	2.69	167.5^{a}	3.47
1b	25	147.3^{b}	2.71	162.6^{b}	2.92	161.0^{b}	3.07	149.6	3.14	155.4^{b}	2.64	176.7^{b}	3.47
2	14	164.4^{c}	3.70	171.7^{c}	3.98	161.8^{b}	4.19	143.4	4.27	160.2^{b}	3.60	186.1^{c}	4.49
3	12	154.5^{d}	3.84	172.6^{c}	4.13	163.1^{b}	4.35	150.8	4.43	160.6^{b}	3.73	185.3^{c}	4.82
All	75	147.4	1.65	161.8	1.78	158.1	1.87	147.0	1.90	153.8	2.64	177.0	2.05
Level of significance		***		***		*		NS		***		***	

abcd Different superscripts in column indicate significant difference $P < 0.05$

*** $P < 0.001$; ** $P < 0.01$; * $P < 0.05$; NS = not significant

Table A.8 *Least squares means, unadjusted parity group means, standard errors (SE) and estimates of the effects of certain variables (regression coefficients (b)) for parameters of daily dry matter intake curves - TRIAL 2*

Parameters		a		b		c		Maximum intake		Week of maximum intake	
Factors	Number of records	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
All	75	13.8	0.26	0.2477	0.0171	-0.0229	0.0017	20.7	0.23	12.7	2.58
Month of calving											
1	27	13.1	0.40	0.2673	0.0260	-0.0229	0.0017	21.0	0.38	14.2[a]	5.44
2	24	13.8	0.43	0.2492	0.0282	-0.0227	0.0026	20.7	0.38	15.5[a]	5.88
3	24	14.4	0.46	0.2262	0.0299	-0.0226	0.0028	20.2	0.46	8.3[b]	6.24
Parity groups											
1a	24	13.4	0.54	0.1852	0.0357	-0.0233[a]	0.0029	20.3	0.48	26.2	7.46
1b	25	13.8	0.44	0.2002	0.0293	-0.0169[b]	0.0029	20.2	0.39	14.6	6.13
2	14	14.2	0.68	0.2980	0.0453	-0.0330[c]	0.0044	20.5	0.61	7.9	9.46
3	12	14.3	0.77	0.3069	0.0523	-0.0297[d]	0.0051	21.7	0.70	9.8	10.94
Weight change (b, SE)	75	0.0147	0.0057	0.00118	0.00421	0.00051	0.00041	-0.0229	0.0566	-2.526	0.880**
Calving liveweight (b, SE)	75	0.0146	0.0065*	-0.00042	0.00042	0.00002	0.00004	0.0147	0.0057*	0.0577	0.0880
Milk yield (b, SE)	75	0.124	0.0548*	-0.0057	0.0038	0.00055	0.00037	0.0909	0.0516	0.822	0.797
Calving condition score (b, SE)	75	-3.426	1.191**	0.139	0.0778	-0.0109	0.00763	-2.286	1.052*	5.437	16.251
					<u>Unadjusted Means</u>						
Parity groups											
1a	24	11.7[a]	0.45	0.2393	0.0265	-0.0165	0.0026	19.2[a]	0.38	25.0	5.97
1b	25	13.2[b]	0.45	0.2232	0.0265	-0.0181	0.0026	19.8[b]	0.38	14.3	5.97
2	14	16.0[c]	0.56	0.2240	0.0342	-0.0269	0.0034	21.7[c]	0.49	8.6	7.71
3	12	15.7[c]	0.62	0.2533	0.0368	-0.0256	0.0036	23.3[d]	0.53	10.3	8.28
All	75	13.7	0.26	0.2331	0.0171	-0.0205	0.0022	20.6	0.223	16.0	3.531
Level of significance		***		NS		NS		***		NS	

abcd Different superscripts in column indicate significant difference $P < 0.05$

*** $P < 0.001$; ** $P < 0.01$; * $P < 0.05$; NS = not significant

TABLE A.9 Means and standard deviations (SD) for milk yield traits per stage of lactation - TRIALS 1 & 2

	TRIAL			
	1		2	
TRAIT	**Mean**	**SD**	**Mean**	**SD**
Fat yield (kg/day)				
Stage 1	1.37	0.303	1.12	0.293
2	1.26	0.253	1.09	0.209
3	1.12	0.225	1.03	0.204
4	1.02	0.229	0.96	0.207
1-4	1.19	0.209	1.05	0.200
Protein yield (kg/day)				
Stage 1	1.10	0.165	0.87	0.204
2	1.06	0.166	0.89	0.159
3	0.94	0.153	0.84	0.140
4	0.83	0.158	0.77	0.147
1-4	0.99	0.138	0.85	0.146
Parameters of milk yield* curve				
a	27.6	8.04	22.6	8.18
b	0.251	0.230	0.223	0.162
c	-0.0430	0.0258	-0.0311	0.0191

* a = level parameter (kg)

b = parameter describing the initial increase in production from lactation week 2 to week of peak yield (kg/day)

c = the slope during the decline in production after week of peak yield to lactation week 24 (kg/day)

Table A.10 Least squares means, standard errors (SE) and the variance (R^2%) explained by each factor for daily milk yield (kg) per stage of lactation - TRIAL 1

STAGE OF LACTATION		1		2		3		4		1-4	
WEEKS OF LACTATION		2-6		7-12		13-18		19-24		2-24	
Factors	Number of records	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Year of calving											
1	33	29.3	0.89	31.9	1.17	27.7	1.11	24.0	1.09	28.5	0.90
2	35	31.1	0.78	29.6	1.11	25.8	0.97	22.6	0.95	27.1	0.78
3	35	29.2	0.73	29.9	0.93	26.7	0.91	24.4	0.89	27.4	0.73
4	12	29.7	1.13	30.1	1.43	26.0	1.40	23.1	1.38	28.3	1.16
R^2		2.0		1.2		1.6		1.5		0.3	
Month of calving											
1	47	29.9	0.69	30.1	0.87	26.8	0.86	23.8	0.84	28.2	0.71
2	56	29.8	0.66	31.4	0.84	27.0	0.80	23.7	0.80	28.0	0.65
3	12	29.8	1.08	29.8	1.39	25.9	1.33	23.1	1.33	27.3	1.09
R^2		0.1		2.2		0.6		0.2		0.7	
Milk yield groups											
1	16	25.6[a]	1.36	28.4[a]	1.73	25.5[a]	1.67	23.1[a]	1.66	26.3[a]	1.36
2	45	29.4[b]	0.64	29.2[a]	0.82	25.5[a]	0.80	22.5[a]	0.79	27.0[a]	0.66
3	54	34.5[c]	0.56	33.5[b]	0.71	28.7[b]	0.68	24.9[b]	0.68	30.4[b]	0.55
R^2		34.4		23.6		19.6		15.3		25.0	

abcd Different superscripts in column indicate significant difference $P < 0.05$

Table A.11 Least squares means, standard errors (SE) and the variance (R^2%) explained by each factor for daily fat corrected milk (FCM, kg) per stage of lactation - TRIAL 1

STAGE OF LACTATION		1		2		3		4		1-4	
WEEKS OF LACTATION		2-6		7-12		13-18		19-24		2-24	
Factors	Number of records	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Year of calving											
1	33	29.6[a]	1.03	30.8	1.28	28.4	1.17	25.0	1.25	28.8	0.98
2	35	33.3[b]	0.90	30.2	1.10	26.7	1.02	23.6	1.09	28.3	0.85
3	35	33.7[b]	0.84	30.8	1.02	26.4	0.95	25.2	1.02	28.8	0.80
4	12	30.9[a]	1.30	30.8	1.57	27.6	1.48	25.4	1.57	29.0	1.26
R^2		5.4		0.1		1.7		1.1		0.1	
Month of calving											
1	47	31.7	0.79	30.5	0.95	27.7	0.91	25.0	0.96	29.3	0.76
2	56	31.6	0.77	31.4	0.92	27.4	0.85	24.0	0.92	28.8	0.71
3	12	32.4	1.25	30.0	1.52	26.3	1.41	24.4	1.52	28.5	1.18
R^2		0.1		1.8		0.6		0.4		0.4	
Milk yield groups											
1	16	28.9[a]	1.58	29.5[a]	1.96	26.4[a]	1.76	24.1[a]	1.89	27.8[a]	1.48
2	45	30.9[b]	0.74	29.1[a]	0.90	25.7[a]	0.84	23.5[a]	0.90	27.6[a]	0.71
3	54	35.9[c]	0.64	33.3[b]	0.78	29.4[b]	0.72	26.2[b]	0.77	31.1[b]	0.60
R^2		20.1		18.0		19.3			14.5		22.2

[abcd] Different superscripts in column indicate significant difference $P < 0.05$

Table A.12 Least squares means and standard errors (SE) of milk fat content (g/kg) per stage of lactation - TRIAL 1

STAGE OF LACTATION		1		2		3		4		1-4	
WEEKS OF LACTATION		2-6		7-12		13-18		19-24		2-24	
Factors	Number of records	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Year of calving											
1	33	41.0[a]	1.46	38.1	1.30	41.7[a]	1.20	43.0	1.23	41.0	1.05
2	35	45.0[b]	1.30	41.3	1.15	42.4[a]	1.07	43.3	1.10	42.8	0.93
3	35	49.8[c]	1.22	41.9	1.08	39.3[b]	1.00	42.3	1.04	43.1	0.88
4	12	42.9[a]	1.91	41.0	1.66	42.1[a]	1.57	42.9	1.61	42.1	1.40
Month of calving											
1	47	44.0	1.16	41.0	1.01	42.0	0.96	43.3	0.98	42.5	0.85
2	56	44.6	1.10	40.3	0.96	41.2	0.89	41.9	0.93	41.8	0.78
3	12	45.5	1.80	40.4	1.58	41.0	1.47	43.4	1.53	42.5	1.29
Milk yield groups											
1	16	45.2	2.29	42.0	1.99	41.9	1.87	42.8	1.92	43.3	1.64
2	45	43.4	1.08	39.8	0.95	40.6	0.89	42.6	0.91	41.6	0.78
3	54	42.4	0.95	40.0	0.83	41.7	0.77	43.3	0.80	41.8	0.67

[abcd] Different superscripts in column indicate significant difference $P < 0.05$

Table A.13 Least squares means and standard errors (SE) of milk protein content (g/kg) per stage of lactation - TRIAL 1

STAGE OF LACTATION		1		2		3		4		1-4	
WEEKS OF LACTATION		2-6		7-12		13-18		19-24		2-24	
Factors	Number of records	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Year of calving											
1	33	34.4	0.67	32.7^{a}	0.58	32.8^{a}	0.59	33.2^{a}	0.67	33.1^{a}	0.52
2	35	35.6	0.59	35.1^{b}	0.51	36.0^{b}	0.51	35.9^{b}	0.58	35.8^{b}	0.45
3	35	33.9	0.55	32.4^{a}	0.47	34.5^{c}	0.48	34.6^{c}	0.55	34.0^{c}	0.42
4	12	34.2	0.85	33.9^{c}	0.72	36.0^{b}	0.74	37.7^{d}	0.84	34.9^{d}	0.67
Month of calving											
1	47	34.0	0.52	33.9	0.44	35.6^{a}	0.45	36.8^{a}	0.51	34.8	0.41
2	56	34.4	0.49	33.2	0.42	34.4^{b}	0.43	35.1^{b}	0.49	34.4	0.38
3	12	35.0	0.82	33.4	0.70	34.4^{b}	0.71	34.2^{b}	0.81	34.2	0.63
Milk yield groups											
1	16	34.1	1.03	33.4	0.87	35.0	0.89	35.6	1.01	34.4	0.79
2	45	35.2	0.48	33.6	0.42	35.0	0.42	35.1	0.48	34.5	0.38
3	54	34.4	0.42	35.5	0.35	34.5	0.36	35.4	0.41	34.4	0.32

abcd Different superscripts in column indicate significant difference $P < 0.05$

Table A.14 Least squares means, standard errors (SE) and estimates of the effects of calving liveweight (kg) and liveweight change - kg/week (regression coefficients (b)) for 305-day milk and fat corrected milk (FCM) yields (kg) - TRIAL 1

		TRAIT			
		MILK YIELD		FCM YIELD	
Factors	**N**	**Mean**	**SE**	**Mean**	**SE**
Year of calving					
1	33	7332	278.3	7669	342.5
2	35	6858	247.9	7464	305.1
3	35	6986	233.4	7440	287.3
4	12	6952	372.8	7243	458.7
Month of calving					
1	47	7271	225.0	7771	276.9
2	56	7190	207.8	7532	255.8
3	12	6635	342.1	7058	421.0
Parity					
2	26	6941	320.2	7581	394.1
3	34	6942	252.8	7607	311.1
4	25	6960	262.3	7229	322.8
5	30	7278	253.9	7398	312.4
Milk yield groups					
1	16	6803[a]	433.2	7449[a]	533.2
2	45	6821[a]	208.2	7421[a]	256.3
3	54	7572[b]	178.6	7891[b]	219.9
Calving condition score groups					
1	65	6873	201.6	7433	248.1
2	26	6895	240.6	7184	304.8
3	24	7328	447.1	7744	550.2
Weight change (b,SE)[c]	115	-145.7	57.28*	-161.8	7.495*
Calving liveweight (b,SE)	115	-1.124	1.661	0.4114	0.2045
All observations	115	7032	187.2	7454	230.5

ab Different superscripts in column indicate significant difference P < 0.05

N = number of records

* P < 0.05

c Lactation weeks 2-6

Table A.15 Least squares means and standard errors (SE) and estimates of the effects of liveweight at calving (kg) and liveweight change - kg/week (regression coefficients (b)) for parameters of milk yield curve - TRIAL 1

Parameters		a		b		c		Week of peak yield		Peak yield (kg/day)		Persistency index	
Factors	Number of records	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
All	115	25.6	1.09	0.2629	0.0368	-0.0412	0.0043	7.8	1.06	35.5	0.70	4.06	0.086
Year of calving													
1	33	23.1[a]	1.69	0.3360	0.0572	-0.0457	0.0067	8.1	1.71	36.6	1.09	4.18	0.134
2	35	28.6[b]	1.44	0.1926	0.0491	-0.0379	0.0057	6.7	1.42	35.5	0.93	3.93	0.115
3	35	26.0[c]	1.35	0.2316	0.0457	-0.0354	0.0053	8.3	1.32	34.7	0.87	4.08	0.107
4	12	24.8[d]	2.07	0.2913	0.0707	-0.0458	0.0082	8.1	2.05	35.3	1.34	4.06	0.165
Month of calving													
1	47	25.8	1.26	0.2389[a]	0.0431	-0.0374	0.0050	7.6	1.25	35.0	0.82	4.18	0.101
2	56	23.6	1.21	0.3340[b]	0.0412	-0.0483	0.0048	7.1	1.19	35.8	0.78	4.06	0.096
3	12	27.5	2.01	0.2157[a]	0.0680	-0.0378	0.0079	8.8	1.97	35.8	1.29	3.94	0.159
Parity													
2	26	25.4	1.86	0.1983	0.0628	-0.0310	0.0073	8.3	1.82	34.0	1.19	4.15	0.147
3	34	25.9	1.45	0.2557	0.0493	-0.0418	0.0057	7.2	1.42	35.4	0.94	4.02	0.115
4	25	26.0	1.55	0.2852	0.0525	-0.0465	0.0061	8.3	1.52	35.6	0.99	3.93	0.123
5	30	25.3	1.52	0.3123	0.0515	-0.0457	0.0060	7.6	1.49	37.1	0.98	4.14	0.120
Milk yield groups													
1	16	19.0[a]	2.52	0.3718	0.0860	-0.0459	0.0010	10.9	2.49	32.7[a]	1.63	4.34	0.201
2	45	26.1[b]	1.19	0.2112	0.0402	-0.0376	0.0047	7.4	1.16	34.2[b]	0.76	3.98	0.094
3	54	31.8[c]	1.01	0.1996	0.0348	-0.0402	0.0041	5.1	1.01	39.7[c]	0.66	3.86	0.081
Calving condition score groups													
1	65	27.1	1.29	0.2573	0.0435	-0.0444	0.0051	8.6	1.26	34.9	0.83	4.08	0.102
2	26	25.5	1.40	0.2722	0.0477	-0.0459	0.0056	6.0	1.38	35.7	0.91	3.94	0.112
3	24	24.1	2.71	0.2591	0.0916	-0.0334	0.0107	8.9	2.65	36.0	1.74	4.17	0.214
Weekly weight change (b,SE)				0.00406	0.00383	-0.00051	0.00045	-0.2750	0.0111*	-0.0191	0.0726	0.00293	0.00894
Liveweight at calving (b,SE)		0.0079	0.0150	0.00007	0.00052	-0.000002	0.000061	0.02019	0.01499	0.00024	0.00982	0.00129	0.00121

abcd Different superscripts in column indicate significant difference $P < 0.05$, * $P < 0.05$

Table A.16 Correlation coefficients between the same milk production variables in different periods of lactation for both Trials 1 and 2

Periods of lactation (wk)	2–6 x 7–12	2–6 x 13–18	2–6 x 19–24	2–6 x 2–24	7–12 x 13–18	7–12 x 19–24	7–12 x 2–24	13–18 x 19–24	13–18 x 2–24	19–24 x 2–24
TRAIT										
TRIAL 1										
Milk yield	0.745	0.601	0.492	0.791	0.853	0.708	0.944	0.860	0.938	0.948
FCM yield	0.641	0.487	0.403	0.741	0.814	0.704	0.929	0.841	0.911	0.835
Milk fat content	0.442	0.136	0.120	0.610	0.584	0.551	0.848	0.774	0.789	0.778
Milk protein content	0.720	0.477	0.397	0.738	0.728	0.647	0.901	0.889	0.910	0.870
TRIAL 2										
Milk yield	0.873	0.705	0.450	0.885	0.855	0.605	0.954	0.862	0.941	0.767
FCM yield	0.832	0.662	0.476	0.854	0.862	0.686	0.953	0.902	0.942	0.825
Milk fat content	0.378	0.312	0.201	0.596	0.769	0.669	0.866	0.814	0.904	0.837
Milk protein content	0.518	0.429	0.375	0.674	0.699	0.612	0.845	0.815	0.901	0.874

Trial 1 - correlation coefficients > 0.2521 $P < 0.01$

Trial 2 - correlation coefficients > 0.302 $P < 0.01$

Table A.17 Correlation coefficients between certain milk production variables or between milk yield in consecutive lactations of the same cow and regression coefficients of 2nd parity cows on 1st parity cows of the same cow

WEEK OF LACTATION	2-6	7-12	13-18	19-24	2-24	305-day milk yield	305-day FCM yield
TRIAL 1							
Milk yield vs milk fat content	-0.015	-0.089	-0.111	-0.005	-0.058		
Milk yield vs milk protein content	-0.355	-0.036	-0.363	-0.237	-0.359		
Milk fat content vs milk protein content	0.090	0.523	0.384	0.368	0.383		
TRIAL 2							
Milk yield vs milk fat content	-0.005	-0.074	-0.012	0.111	0.076		
Milk yield vs milk protein content	-0.139	-0.103	-0.132	-0.048	-0.062		
Milk fat content vs milk protein content	0.177	0.099	0.299	0.447	0.234		
REPEATED RECORDS (Milk yield)							
2nd parity and older cows[1] (n = 30)	0.237	0.343	0.344	0.268	0.250	0.423	0.584
1st parity vs 2nd parity cows[2] (n = 14)	0.400	0.222	0.036	0.453	0.251	0.422	0.543
b + SE	1.475±0.0497	1.233±0.0400	1.128±0.0513	1.053±0.0449	1.224±0.0434	1.112±0.0389	1.125±0.0396
All parities (n = 44)	0.381	0.409	0.359	0.340	0.333	0.468	0.598

1 = correlation coefficients > 0.353 $P < 0.05$

2 = correlation coefficients > 0.514 $P < 0.05$

3 = correlation coefficients > 0.304 $P < 0.05$

n = number of records

Table A.18 Least squares means, unadjusted parity group means, standard errors (SE) and estimates of the effects of certain variables (regression coefficients (b)) for 305-day milk and fat corrected milk (FCM) yields (kg) - TRIAL 2

		TRAIT			
		MILK YIELD		FCM YIELD	
Factors	**N**	**Mean**	**SE**	**Mean**	**SE**
All	75	6710	106.0	7117	134.0
Month of calving					
1	27	6708	137.3	7152	195.6
2	24	6519	145.8	6970	207.7
3	24	6364	161.0	6663	229.3
Parity groups					
1a	24	6594[a]	186.0	6824[a]	265.0
1b	25	6970[b]	154.0	7701[b]	219.4
2	14	6043[c]	258.0	6347[c]	367.4
3	12	6514[a]	277.6	6842[a]	395.4
Weight change (b,SE)[d]	75	-247.6	63.03	-247.3	89.78
Calving liveweight (b, SE)	75	0.9131	2.139**	-0.2441	0.3047**
Calving condition score (b,SE)	75	-739.3	392.3	-920.4	558.6
Milk yield lactation week 2 (b,SE)	75	90.84	20.67	95.00	29.45
		UNADJUSTED MEANS			
Parity groups					
1a	24	5997[a]	178.1	6197[a]	225.1
1b	25	6815[b]	174.0	7554[b]	220.7
2	14	6951[b]	247.0	7305[b]	300.8
3	12	7076[b]	246.0	7414[b]	312.1
All	75	6621	92.0	7051	131.0
Level of significance		*		**	

abc Different superscripts in column indicate significant difference

N = number of records

** P < 0.01   * P < 0.01

d Lactation weeks 2-6

Table A.19 Least squares means, standard errors (SE) and estimates of the effects of daily milk yield in lactation week 2 (kg) (regression coefficients (b)) and the variance (R^2%) explained by each factor on daily milk yield (kg) per stage of lactation - TRIAL 2

STAGE OF LACTATION		1		2		3		4		1-4	
WEEKS OF LACTATION		2-6		7-12		13-18		19-24		2-24	
Factors	**Number of records**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
All	75	26.3	0.26	26.9	0.34	23.8	0.37	21.6	0.43	24.8	0.28
Month of calving											
1	27	26.4	0.38	26.7	0.49	23.5	0.54	21.8	0.68	25.0	0.42
2	24	25.9	0.42	26.6	0.53	23.7	0.59	22.1	0.73	24.7	0.45
3	24	26.3	0.47	27.5	0.60	24.1	0.65	21.7	0.82	24.7	0.49
R^2		0.2		0.7		0.1		0.2		0.2	
Parity groups											
1a	24	24.7^a	0.53	24.7^a	0.69	24.4^a	0.76	22.9^a	0.43	23.7^a	0.58
1b	25	25.0^a	0.43	26.3^b	0.55	25.5^b	0.60	24.4^b	0.88	24.8^b	0.47
2	14	26.8^b	0.73	26.6^b	0.95	21.4^c	1.04	19.0^c	1.20	24.0^c	0.79
3	12	28.8^c	0.81	30.2^c	0.99	23.8^c	1.09	20.1^d	1.26	26.8^d	0.86
R^2		1.9		7.7		6.9		9.2		4.9	
Milk yield (b,SE)	75	0.5910	0.0601**	0.3170	0.0742**	0.4332	0.0811**	0.3513	0.0934**	0.3494	0.0631**
R^2		11.9		6.2		11.4		7.8		10.9	

abcd Different superscripts in column indicate significant difference $P < 0.05$, ** $P < 0.01$

Table A.20 Least squares means, standard errors (SE) and estimates of the effects of daily milk yield in lactation week 2 (kg) (regression coefficients (b)) and variance (R^2%) explained by each factor on daily fat corrected milk (kg) per stage of lactation - TRIAL 2

STAGE OF LACTATION		1		2		3		4		1-4	
WEEKS OF LACTATION		2-6		7-12		13-18		19-24		2-24	
Factors	Number of records	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
All	75	27.6	0.38	27.5	0.40	24.7	0.46	22.6	0.52	25.8	0.38
Month of calving											
1	27	26.9	0.57	27.2	0.57	24.2	0.68	22.4	0.76	25.9	0.55
2	24	27.7	0.61	27.3	0.62	25.1	0.73	22.8	0.83	26.1	0.58
3	24	27.5	0.69	28.0	0.70	24.7	0.81	22.5	0.97	25.4	0.64
R^2		0.3		0.0		0.5		0.1		0.0	
Parity groups											
1a	24	25.5	0.78	24.4[a]	0.81	24.9[a]	0.95	23.8[a]	1.07	24.3[a]	0.75
1b	25	26.5	0.63	27.4[b]	0.64	27.1[b]	0.75	25.9[b]	0.84	26.2[b]	0.61
2	14	29.1	1.07	27.6[b]	1.12	21.7[c]	1.28	18.9[c]	1.46	24.8[a]	1.03
3	12	29.4	1.17	30.7[c]	1.17	25.0[a]	1.35	21.6[d]	1.53	27.9[c]	1.12
R^2		1.3		9.8		10.4		12.2		6.8	
Milk yield (b,SE)	75	0.5242	0.0872**	0.2690	0.0873**	0.4192	0.1009**	0.3971	0.1134**	0.3343	0.0842**
R^2		7.9		2.8		5.9		6.5		6.7	

abcd Different superscripts in column indicate significant difference $P < 0.05$, ** $P < 0.01$

Table A.21 Least squares means, standard errors (SE) and estimates of the effects of daily milk yield in lactation week 2 (kg) (regression coefficient (b)) for milk fat content (g/kg) per stage of lactation - TRIAL 2

STAGE OF LACTATION		1		2		3		4		1-4	
WEEKS OF LACTATION		2-6		7-12		13-18		19-24		2-24	
Factors	Number of records	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
All	75	43.2	0.65	41.5	0.56	42.5	0.57	42.9	0.63	42.5	0.50
Month of calving											
1	27	41.5^a	0.97	41.3	0.81	41.8	0.83	43.0	0.92	42.0	0.74
2	24	45.3^b	1.02	41.9	0.87	43.6	0.90	43.2	0.99	43.5	0.79
3	24	42.8^a	1.12	41.4	0.99	42.1	1.01	42.7	1.17	42.1	0.87
Parity groups											
1a	24	41.9	1.33	39.1	1.13	41.1	1.16	42.6	1.26	41.2	1.00
1b	25	44.4	1.09	43.1	0.90	44.0	0.92	44.1	1.01	44.0	0.83
2	14	44.9	1.85	42.5	1.57	41.6	1.59	40.6	1.74	42.3	1.39
3	12	41.6	2.01	41.5	1.63	43.2	1.66	44.5	1.82	42.7	1.50
Milk yield (b,SE)	75	-0.7330	2.739	-1.324	2.421	-3.957	2.475	-2.064	2.710	-1.969	2.115

abcd Different superscripts in column indicate significant difference $P < 0.05$

Table A.22 Least squares means, standard errors (SE) and estimates of the effects of daily milk yield in lactation week 2 (kg) (regression coefficients (b)) for milk protein content (g/kg) per stage of lactation - TRIAL 2

STAGE OF LACTATION		1		2		3		4		1-4	
WEEKS OF LACTATION		**2-6**		**7-12**		**13-18**		**19-24**		**2-24**	
Factors	**Number of records**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
All	75	34.3	0.32	33.9	0.28	35.0	0.31	35.2	0.35	34.6	0.27
Month of calving											
1	27	33.3^{a}	0.47	32.9^{a}	0.41	35.5	0.46	35.2	0.51	34.4	0.40
2	24	34.3^{b}	0.50	35.3^{b}	0.44	35.0	0.50	35.6	0.55	35.0	0.42
3	24	35.4^{c}	0.54	33.6^{c}	0.50	34.6	0.55	34.7	0.65	34.3	0.47
Parity groups											
1a	24	33.4^{a}	0.65	33.5^{a}	0.57	34.3^{a}	0.63	34.8^{a}	0.70	34.1^{a}	0.54
1b	25	32.6^{b}	0.53	32.8^{b}	0.46	34.2^{a}	0.51	34.0^{b}	0.56	33.5^{b}	0.45
2	14	34.3^{c}	0.90	33.7^{a}	0.80	34.5^{a}	0.87	33.5^{b}	0.97	33.9^{ba}	0.75
3	12	36.9^{d}	0.98	35.7^{c}	0.83	37.0^{b}	0.90	38.3^{c}	1.01	36.8^{c}	0.81
Milk yield (b,SE)	75	-1.540	1.328	0.4841	1.229	0.5443	1.358	0.2365	1.502	-0.1201	1.137

abcd Different superscripts in column indicate significant difference $P < 0.05$

Table A.23 Least squares means and unadjusted parity group means and standard errors (SE) and estimates of the effects of certain variables (regression coefficients (b)) for parameters of milk yield curve - TRIAL 2

Parameters		a		b		c		Week of peak yield		Peak yield (kg/day)		Persistency index	
Factors	Number of records	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
All	75	22.6	0.36	0.2502	0.0153	-0.0354	0.0021	8.4	0.95	30.7	0.29	4.29	0.048
Month of calving													
1	27	22.5	0.55	0.2541	0.0231	-0.0374	0.0032	7.3	1.44	30.8	0.45	4.26	0.065
2	24	22.6	0.59	0.2253	0.0251	-0.0332	0.0034	10.9	1.56	30.8	0.48	4.28	0.076
3	24	22.4	0.63	0.2713	0.0266	-0.0357	0.0036	7.1	1.66	30.3	0.51	4.34	0.071
Parity groups													
1a	24	23.6	0.75	0.1316^{a}	0.0318	-0.0192^{a}	0.0044	11.2	1.98	28.9^{a}	0.61	4.42^{a}	0.089
1b	25	22.2	0.62	0.1888^{a}	0.0261	-0.0216^{a}	0.0036	9.5	1.63	30.0^{b}	0.50	4.60^{b}	0.073
2	14	23.3	0.96	0.2571^{b}	0.0403	-0.0412^{b}	0.0055	7.4	2.51	30.4^{b}	0.77	4.10^{c}	0.113
3	12	20.7	1.10	0.4236^{c}	0.0466	-0.0597^{c}	0.0064	5.7	2.91	33.3^{c}	0.90	4.05^{c}	0.131
Weight change (b,SE)	75			0.00505	0.00375	-0.00064	0.00051	-0.1906	0.2339	-0.1906	0.2339	-0.0052	0.0105
Liveweight at calving (b,SE)	75	0.0126	0.0089	-0.00055	0.00038	0.00006	0.00005	-0.0068	0.0235	-0.0068	0.0234	0.00013	0.00105
Milk yield (b,SE)	75	1.031	0.0805**	-0.0183	0.0034**	0.0012	0.0005*	0.0262	0.2119	0.6092	0.0652	-0.0178	0.0095
Calving condition score (b,SE)	75	-3.250	1.641	0.0140	0.0693*	-0.0219	0.0095*	0.5852	4.319	-0.1921	1.3301	-0.2011	0.1940
UNADJUSTED MEANS													
Parity groups													
1a	24	17.2^{a}	1.10	0.2653^{a}	0.0300	-0.0297^{a}	0.0035	10.7	1.44	25.5^{a}	0.71	4.51^{a}	0.065
1b	25	19.2^{b}	1.10	0.2399^{b}	0.0300	-0.0250^{b}	0.0035	9.9	1.43	28.4^{b}	0.71	4.65^{b}	0.065
2	14	32.0^{c}	1.43	0.0860^{c}	0.3870	-0.0276^{ab}	0.0045	7.8	1.86	35.1^{c}	0.92	4.00^{c}	0.083
3	12	29.1^{d}	1.53	0.2674^{a}	0.4160	-0.0497^{c}	0.0049	4.9	1.09	37.7^{d}	0.99	3.89^{d}	0.090
All	75	22.6	0.65	0.2231	0.0177	-0.0311	0.0021	8.9	0.85	30.3	0.42	4.35	0.038
Level of significance		**		**		*		NS		***		**	

abcd Different superscripts in column indicate significant difference P < 0.05

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

NS = not significant

Means and standard deviations (SD) of energy and nitrogen utilization traits per stage of lactation for Trials 1 and 2

	TRIALS			
	1		2	
	Mean	SD	Mean	SD
yield (MJ/day)				
	103.2	18.3	84.4	20.2
	98.9	16.9	84.3	14.6
	86.4	15.3	78.0	13.4
	77.1	15.3	72.4	13.4
	91.3	14.2	79.9	13.7
E required (%)				
	91.3	14.8	104.4	12.8
	106.9	15.6	114.5	11.3
	114.3	15.9	120.7	12.2
	114.5	16.2	119.7	14.1
	106.1	12.0	114.5	9.6
ove maintenance ME requirements/FCM (MJ/kg)				
	4.62	1.03	5.48	0.93
	5.73	1.12	6.20	0.85
	6.30	1.19	6.66	0.98
	6.35	1.36	6.65	1.21
	5.66	0.87	6.20	0.74
intake/milk yield (kg/kg)				
	0.33	0.080	0.40	0.081
	0.38	0.088	0.44	0.066
	0.44	0.105	0.45	0.096
	0.41	0.106	0.41	0.101
	0.39	0.077	0.43	0.068
ke (g/day)				
	482	68.8	453	32.2
	550	67.7	504	42.2
	534	67.6	495	38.0
	495	59.7	467	39.1
	515	54.0	480	31.7
ke - undegraded in rumen (g/day)				
	140	45.0	149	28.8
	169	38.8	165	38.9
	155	57.0	165	24.7
	141	34.2	144	24.2
	150	38.4	156	24.4
ke - degraded in rumen (g/day)				
	342	42.2	303	43.3
	381	49.1	338	43.5
	379	57.1	329	46.1
	354	53.4	322	41.5
	365	44.0	323	39.7
no acid N supplied to tissues (EAA-N, g/day)				
	118	23.0	121	16.7
	140	20.9	134	20.0
	134	25.1	133	13.9
	123	17.6	122	14.1
	129	10.9	128	14.1
ed (g/day)				
	1.8	18.6	25.7	10.2
	27.4	18.8	37.2	13.6
	30.6	22.1	40.4	10.6
	28.6	14.9	34.5	11.1
	22.6	15.1	34.7	8.2
N required (%)				
	101.7	16.0	128.9	14.1
	125.2	17.6	139.3	15.0
	130.1	22.3	144.7	14.3
	131.6	18.5	140.5	15.9
	121.6	14.6	138.2	11.0

Table A.25 Correlation coefficients between the same nutrient utilization variables in different periods of lactation for both Trials 1 and 2.

Periods of lactation (wk)	**2–6 x 7–12**	**2–6 x 13–18**	**2–6 x 19–24**	**2–6 x 2–24**	**7–12 x 13–18**	**7–12 x 19–24**	**7–12 x 2–24**	**13–18 x 19–24**	**13–18 x 2–24**	**19–24 x 2–24**
TRAIT										
TRIAL 1										
ME intake	0.777	0.501	0.425	0.781	0.686	0.594	0.905	0.753	0.874	0.816
Energy balance	0.662	0.252	0.282	0.716	0.569	0.471	0.879	0.638	0.771	0.741
Gross efficiency	0.666	0.324	0.307	0.722	0.657	0.544	0.891	0.729	0.818	0.776
Net efficiency	0.680	0.247	0.217	0.718	0.555	0.442	0.878	0.610	0.746	0.708
Nitrogen efficiency	0.620	0.351	0.284	0.681	0.651	0.422	0.846	0.668	0.843	0.753
TRIAL 2										
ME intake	0.849	0.703	0.552	0.860	0.842	0.702	0.949	0.867	0.944	0.846
Energy balance	0.600	0.315	0.211	0.680	0.713	0.621	0.853	0.831	0.880	0.795
Gross efficiency	0.613	0.428	0.284	0.704	0.775	0.639	0.903	0.876	0.910	0.823
Net efficiency	0.526	0.321	0.183	0.637	0.712	0.571	0.875	0.840	0.887	0.797
Nitrogen efficiency	0.534	0.521	0.314	0.722	0.723	0.557	0.853	0.802	0.921	0.798

Trial 1 = correlation coefficients > 0.254 $P < 0.01$

Trial 2 = correlation coefficients > 0.302 $P < 0.01$

Table A.26 Correlation coefficients between energy balance (MJ ME) or net efficiency (%) in consecutive lactations of the same cow and regression coefficients (b) of 2nd parity cows on 1st parity cows of the same cow

WEEKS OF LACTATION	2-6	7-12	13-18	19-24	2-24
			ENERGY BALANCE		
2nd parity and older cows (n=30)*	0.053	0.271	0.350	0.443	0.177
1st parity cows vs 2nd parity cows (n=14)**	0.164	0.079	0.102	0.229	0.066
b±SE	-0.012±0.314	0.857±0.238	0.863±0.176	0.772±0.148	0.761±0.180
All cows (n=44)***	0.165	0.354	0.461	0.486	0.390
			NET EFFICIENCY		
2nd parity and older cows*	0.021	0.183	0.205	0.338	0.130
1st parity cows vs 2nd parity cows**	0.184	0.004	0.048	0.394	0.067
b±SE	1.123±0.0600	1.011±0.0472	0.986±0.0518	1.008±0.0415	1.050±0.0429
All cows***	0.172	0.224	0.227	0.374	0.249

* correlation coefficients > 0.355 $P < 0.05$

** correlation coefficients > 0.514 $P < 0.05$

*** correlation coefficients > 0.304 $P < 0.05$

Table A.27 Least squares means, standard errors (SE) and the variance (R^2%) explained by each factor for daily estimated energy intake (MJ ME) per stage of lactation - TRIAL 1

STAGE OF LACTATION		1		2		3		4		1-4	
WEEKS OF LACTATION		2-6		7-12		13-18		19-24		2-24	
Factors	Number of records	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Year of calving											
1	33	185^a	4.8	215^a	6.1	211	6.5	213^a	5.5	207^a	4.7
2	35	211^b	4.2	238^b	5.3	226	5.7	199^b	4.8	220^b	4.1
3	35	181^a	3.9	211^a	4.9	222	5.3	200^b	4.5	205^a	3.9
4	12	201^c	6.1	233	7.5	227	8.2	222^c	6.9	219^b	6.1
R^2		15.3		8.4		5.9		7.6		5.7	
Month of calving											
1	47	197	3.7	228	4.6	233^a	5.1	220^a	4.2	219	3.7
2	46	192	3.5	226	4.4	219^b	4.7	208^b	4.1	213	3.4
3	12	195	5.8	219	7.3	212^b	7.9	199^c	6.7	207	5.7
R^2		0.8		0.2		7.0		6.9		3.8	
Milk yield groups											
1	16	170^a	7.4	212^a	9.1	220^a	9.8	206^a	8.3	204^a	6.1
2	45	199^b	3.5	222^b	4.3	215^a	4.7	202^a	3.9	209^a	3.4
3	4	215^c	3.0	238^c	3.7	231^b	4.0	218^b	3.4	226^b	2.9
R^2		16.3		12.0		8.6		12.0		14.6	

abcd Different superscripts in column indicate significant difference $P < 0.05$

Table A.28 Least squares means, standard errors (SE) and the variance (R^2%) explained by each factor for daily estimated energy balance (MJ ME) per stage of lactation - TRIAL 1

STAGE OF LACTATION		1		2		3		4		1-4	
WEEKS OF LACTATION		2-6		7-12		13-18		19-24		2-24	
Factors	Number of records	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Year of calving											
1	33	-22.9^{a}	5.46	-3.4^{a}	7.35	1.5^{a}	6.52	24.6^{a}	5.82	-0.3^{a}	4.54
2	35	-16.2^{ba}	4.78	25.7^{b}	6.51	32.1^{b}	5.83	20.0^{a}	5.19	18.2^{b}	4.04
3	35	-48.2^{c}	4.57	-3.6^{a}	6.07	29.1^{b}	5.46	12.0^{b}	4.88	0.2^{a}	3.81
4	12	-13.2^{b}	7.13	18.2^{b}	9.37	30.7^{b}	8.57	37.9^{c}	7.58	12.0^{c}	6.08
R^2		12.5		6.3		9.8		7.2		6.9	
Month of calving											
1	47	-21.6	4.32	13.8	5.67	32.7^{a}	5.23	32.6^{a}	4.60	12.2	3.67
2	46	-27.4	4.10	6.5	5.42	18.9^{b}	4.86	24.2^{b}	4.38	7.4	3.39
3	12	-26.4	6.72	7.4	8.94	18.5^{b}	8.01	14.1^{c}	7.20	3.0	5.58
R^2		0.5		1.6		6.6		4.7		4.5	
Milk yield groups											
1	16	-31.9^{a}	8.55	4.7	11.26	25.6	10.14	23.5	9.06	5.2	7.06
2	45	-15.9^{b}	4.02	14.7	5.34	23.6	4.86	22.1	4.30	9.1	3.40
3	54	-27.6^{a}	3.55	8.4	4.66	20.8	4.21	25.4	3.71	8.3	2.91
R^2		5.7		5.1		5.1		2.6		5.3	

abcd Different superscripts in column indicate significant difference $P < 0.05$

Table A.29 Least squares means, standard errors (SE) and the variance (R^2%) explained by each factor for gross efficiency (%) per stage of lactation - TRIAL 1

STAGE OF LACTATION		1		2		3		4		1-4	
WEEKS OF LACTATION		2-6		7-12		13-18		19-24		2-24	
Factors	Number of records	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Year of calving											
1	33	51.1[a]	1.56	45.4[a]	1.70	42.2[a]	1.47	36.7[a]	1.55	43.8[a]	1.12
2	35	49.7[ac]	1.37	39.8[b]	1.47	37.0[b]	1.28	37.0[a]	1.36	40.1[b]	0.98
3	35	57.9[b]	1.27	45.8[a]	1.36	37.6[b]	1.19	39.3[b]	1.26	43.8[a]	0.91
4	12	48.2[c]	1.98	41.3[b]	2.10	37.0[b]	1.88	33.8[c]	1.97	41.6[b]	1.46
R^2		11.3		4.8		5.7		5.0		5.0	
Month of calving											
1	47	50.8	1.22	42.3	1.29	37.2	1.16	35.4	1.21	41.8	0.89
2	46	52.0	1.14	43.9	1.22	39.2	1.06	36.7	1.14	42.3	0.81
3	12	52.3	1.87	43.0	2.01	38.9	1.75	38.0	1.88	42.9	1.34
R^2		0.3		2.0		3.5		1.5		2.7	
Milk yield groups											
1	16	53.4[a]	2.38	43.6	2.53	37.8	2.2	36.5	2.35	42.5	1.69
2	45	48.9[b]	1.12	41.5	1.20	37.7	1.06	36.2	1.12	41.4	0.81
3	54	52.9[a]	1.01	44.1	1.07	39.9	0.97	37.4	1.00	43.1	0.71
R^2		7.7		9.3		11.1		7.8		11.7	

[abcd] Different superscripts in column indicate significant difference $P < 0.05$

Table A.30 Least squares means, standard errors (SE) and the variance (R^2%) explained by each factor for net efficiency (%) per stage of lactation - TRIAL 1

STAGE OF LACTATION		1		2		3		4		1-4	
WEEKS OF LACTATION		2-6		7-12		13-18		19-24		2-24	
Factors	Number of records	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Year of calving											
1	33	74.4^a	2.61	61.3^a	2.40	58.3^a	2.14	50.6^a	2.12	60.3^a	1.58
2	35	68.8^b	2.30	52.1^b	2.09	49.7^c	1.87	51.9^a	1.86	54.1^b	1.38
3	35	84.4^c	2.13	62.2^a	1.92	50.4^c	1.73	54.9^b	1.72	60.2^a	1.28
4	12	68.1^b	3.32	54.9^b	2.97	50.1^c	2.73	46.2^c	2.69	56.1^b	2.05
R^2		12.9		7.1		7.6		6.9		7.2	
Month of calving											
1	47	72.5	2.04	56.6	1.82	49.6	1.69	48.3	1.63	56.4	1.26
2	46	74.5	1.92	58.6	1.72	53.3	1.55	50.7	1.56	57.6	1.14
3	12	74.8	3.14	57.7	2.85	53.5	2.55	53.6	2.56	59.0	1.89
R^2		0.3		1.6		5.5		2.9		3.5	
Milk yield groups											
1	16	80.2^a	4.00	59.1	3.58	51.5	3.23	50.5	3.22	58.3	2.39
2	45	68.8^b	1.88	55.9	1.69	51.8	1.54	51.4	1.53	57.1	1.15
3	54	72.8^c	1.69	57.9	1.51	53.1	1.38	50.7	1.37	57.6	1.01
R^2		6.1		7.0		6.1				7.5	

abcd Different superscripts in column indicate significant difference $P < 0.05$

Table A.31 Least squares means, standard errors (SE) and the variance (R^2%) explained by each factor for nitrogen efficiency (%) per stage of lactation - TRIAL 1

STAGE OF LACTATION		1		2		3		4		1-4	
WEEKS OF LACTATION		2-6		7-12		13-18		19-24		2-24	
Factors	Number of records	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Year of calving											
1	33	37.7^{a}	1.00	32.9^{a}	1.11	29.5	0.98	25.1^{a}	1.03	31.1	0.78
2	35	35.1^{b}	0.88	29.1^{b}	0.96	26.7	0.86	26.6^{a}	0.91	29.0	0.68
3	35	37.8^{a}	0.82	29.8^{b}	0.89	27.2	0.80	28.0^{b}	0.84	30.0	0.63
4	12	33.1^{c}	1.28	30.5^{b}	1.37	30.2	1.26	28.1^{b}	1.31	31.6	1.01
R^2		8.2		4.7		6.2		5.5		1.2	
Month of calving											
1	47	36.0	0.78	30.0	0.84	28.2	0.78	26.9	0.80	30.4	0.62
2	46	36.2	0.74	31.0	0.79	28.5	0.71	27.2	0.76	30.5	0.56
3	12	35.6	1.21	30.8	1.31	28.4	1.17	26.8	1.25	30.4	0.93
R^2		0.1		1.3		1.4		0.3		1.1	
Milk yield groups											
1	16	34.9^{a}	1.54	30.0	1.65	27.7	1.48	27.0	1.58	29.9	1.17
2	45	35.4^{b}	0.72	29.8	0.78	28.2	0.71	26.4	0.74	30.1	0.56
3	54	37.5^{c}	0.65	32.0	0.70	29.3	0.64	27.8	0.67	31.3	0.49
R^2		14.5		8.9		4.0		8.6		13.9	

abcd Different superscripts in column indicate significant difference $P < 0.05$

Table A.32 Least squares means, standard errors (SE) and estimates of the effects of daily milk yield in lactation week 2 - kg (regression coefficients (b)) and the variance (R^2%) explained by each factor for daily estimated energy intake (MJ ME) per stage of lactation - TRIAL 2

STAGE OF LACTATION		1		2		3		4		1-4	
WEEKS OF LACTATION		2-6		7-12		13-18		19-24		2-24	
Factors	Number of records	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
All	75	198	2.0	220	2.3	217	2.2	203	2.3	210	1.9
Month of calving											
1	27	196	2.9	221	3.3	219	3.8	207	3.4	211	2.9
2	24	198	3.1	223	3.6	221	3.5	206	3.7	212	3.0
3	24	202	3.4	218	4.1	210	3.9	109	4.4	207	3.3
R^2		0.8		0.3		5.8		7.5		1.4	
Parity groups											
1a	24	184^a	4.1	204^a	4.7	215	4.5	210^a	4.7	204^a	3.9
1b	25	194^b	3.3	214^b	3.7	219	3.6	206^a	3.7	209^b	3.2
2	14	207^c	5.6	223^c	6.4	209	6.2	186^b	6.4	206^a	5.3
3	12	209^c	6.2	241^d	6.7	224	6.5	212^c	6.8	221^c	5.8
R^2		4.5		8.8		5.2		10.9		6.0	
Milk yield (b,SE)	75	1.127	0.4591*	0.5692	0.5020	1.495	0.4811*	1.694	0.5033**	1.272	0.4261**
R^2		2.1		0.8		3.4		4.8		2.4	

abcd Different superscripts in column indicate significant difference $P < 0.05$

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

Table A.33 Least squares means, standard errors (SE) and estimates of the effects of daily milk yield in lactation week 2 - kg (regression coefficients (b)) and the variance (R^2%) explained by each factor for daily estimated energy balance (MJ ME) per stage of lactation - TRIAL 2

STAGE OF LACTATION		1		2		3		4		1-4	
WEEKS OF LACTATION		2-6		7-12		13-18		19-24		2-24	
Factors	Number of records	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
All	75	5.7	2.40	27.1	2.37	37.3	2.22	34.0	2.46	25.7	1.83
Month of calving											
1	27	2.7	3.56	28.0	3.48	41.9	3.24	37.8	3.60	26.2	2.74
2	24	3.0	3.77	31.0	3.78	39.7	3.52	35.6	3.90	26.5	2.91
3	24	11.5	4.12	22.1	4.27	30.3	3.93	28.7	4.60	24.1	3.21
R^2		2.6		1.3		6.9		8.8		2.1	
Parity groups											
1a	24	1.2	4.91	25.3	4.87	34.2	4.51	33.4^a	4.97	25.8	3.71
1b	25	8.1	4.01	23.5	3.90	29.2	3.60	22.5^b	3.95	23.8	3.07
2	14	8.4	6.81	30.6	6.77	44.9	6.20	35.3^a	6.84	28.1	5.14
3	12	5.2	7.42	28.8	7.03	40.7	6.46	45.0^c	7.15	24.7	5.53
R^2		1.4		2.2		6.6				3.3	
Milk yield (b,SE)	75	-1.772	0.5622**	-0.7960	0.5310	-0.5510	0.4862	-0.1567	0.5360	-0.4593	0.4121
R^2		7.3		3.6		0.8		0.1		3.3	

abcd Different superscripts in column indicate significant difference $P < 0.05$

** $P < 0.01$

Table A.34 Least squares means, standard errors (SE) and estimates of the effects of daily milk yield in lactation week 2 - kg (regression coefficients (b)) and the variance (R^2%) explained by each factor for gross efficiency (%) per stage of lactation - TRIAL 2

STAGE OF LACTATION		1		2		3		4		1-4	
WEEKS OF LACTATION		2-6		7-12		13-18		19-24		2-24	
Factors	Number of records	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
All	75	43.1	0.64	39.1	0.54	35.6	0.56	34.6	0.64	38.3	0.44
Month of calving											
1	27	43.7	0.95	38.7	0.78	34.6	0.82	33.7	0.93	38.2	0.66
2	24	44.1	0.90	38.3	0.84	35.3	0.89	34.6	1.00	38.3	0.70
3	24	41.5	1.08	40.5	0.95	36.9	0.99	35.6	1.18	38.4	0.77
R^2		2.2		1.0		3.2		4.2		1.0	
Parity groups											
1a	24	42.8	1.32	37.3	1.16	36.0^a	1.16	35.4^a	1.30	37.8	0.90
1b	25	42.5	1.06	39.8	0.91	38.5^b	0.91	39.0^b	1.02	38.9	0.73
2	14	43.2	1.81	38.5	1.57	32.9^c	1.57	32.2^c	1.77	37.8	1.24
3	12	43.8	1.99	39.0	1.58	35.0^c	1.65	31.9^c	1.86	39.8	1.34
R^2		0.2		4.9		9.5		10.4		5.8	
Milk yield (b,SE)	75	0.6105	0.1481**	0.2762	0.1118*	0.3610	0.1231**	0.3221	0.1380*	0.2633	0.0993**
R^2		9.3		4.6		3.8		2.6		6.4	

abcd Different superscripts in column indicate significant difference $P < 0.05$

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

Table A.35 Least squares means, standard errors (SE) and estimates of the effects of daily milk yield in lactation week 2 - kg (regression coefficients (b)) and the variance (R^2%) explained by each factor for net efficiency (%) per stage of lactation - TRIAL 2

STAGE OF LACTATION		1		2		3		4		1-4	
WEEKS OF LACTATION		2-6		7-12		13-18		19-24		2-24	
Factors	Number of records	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
All	75	58.3	1.02	51.4	0.76	47.3	0.76	47.4	0.84	51.2	0.62
Month of calving											
1	27	59.5	1.51	51.0	1.10	45.9	1.11	46.0	1.23	51.0	0.93
2	24	59.9	1.59	50.1	1.19	46.6	1.20	47.1	1.32	51.0	0.99
3	24	55.4	1.73	53.2	1.34	49.5	1.33	49.2	1.55	51.6	1.09
R^2		3.6		1.6		5.6		8.1		1.9	
Parity groups											
1a	24	59.6	2.11	49.8	1.56	47.6	1.55	47.4	1.71	49.5	1.28
1b	25	57.8	1.70	52.2	1.23	50.4	1.22	52.6	1.34	51.8	1.04
2	14	57.5	2.89	51.4	2.11	44.6	2.11	45.8	2.33	50.9	1.75
3	12	58.1	3.18	52.4	2.24	46.7	2.22	43.8	2.45	52.5	1.90
R^2		0.5		2.8		8.5		10.8		4.8	
Milk yield (b,SE)	75	0.7161	0.2360**	0.2710	0.1618	0.3018	0.1652	0.2310	0.1811	0.2223	0.1402
R^2		6.8		3.5		2.0		1.1		4.4	

abcd Different superscripts in column indicate significant difference $P < 0.05$, * $P < 0.05$, ** $P < 0.01$

Table A.36 Least squares means, standard errors (SE) and estimates of the effects of daily milk yield in lactation week 2 - kg (regression coefficients (b)) and the variance (R^2%) explained by each factor for nitrogen efficiency (%) per stage of lactation - TRIAL 2

STAGE OF LACTATION		1		2		3		4		1-4	
WEEKS OF LACTATION		2-6		7-12		13-18		19-24		2-24	
Factors	Number of records	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
All	75	30.4	0.42	28.2	0.37	26.5	0.43	25.6	0.46	27.9	0.37
Month of calving											
1	27	30.7	0.62	27.2	0.54	26.4	0.62	25.1	0.72	27.8	0.44
2	24	30.2	0.65	28.5	0.58	26.0	0.68	25.9	0.77	27.9	0.47
3	24	30.2	0.71	28.9	0.65	27.3	0.75	25.9	0.90	27.9	0.52
R^2		0.3		3.0		1.1		1.3		0.8	
Parity groups											
1a	24	30.4^a	0.87	27.7^a	0.77	28.2^a	0.88	27.3^a	1.00	27.9	0.61
1b	25	28.3^b	0.70	26.1^b	0.64	25.8^b	0.69	26.4^a	0.78	25.9	0.49
2	14	29.4^c	1.18	26.9^b	1.04	22.8^c	1.21	22.2^b	1.36	25.9	0.83
3	12	33.4^d	1.30	31.9^c	1.09	29.6^d	1.26	26.5^a	1.43	31.7	0.49
R^2		10.6		18.1		24.8		12.8		23.8	
Milk yield (b,SE)	75	0.3310	0.0972**	0.1422	0.0813	0.2563	0.0912**	0.2311	0.1060**	0.1653	0.0672**
R^2		6.9		3.5		3.5		2.4		5.5	

abcd Different superscripts in column indicate significant difference P < 0.05, * P < 0.05, ** P < 0.01

Table A.37 Least squares means and standard errors (SE) of energy and nitrogen utilization variables on milk yield groups and calving condition score groups per stage 1 of lactation - TRIAL 1

CALVING CONDITION SCORE	MILK YIELD GROUPS 1			2			3		
TRAIT	Mean	SE	N *	Mean	SE	N	Mean	SE	N
ME intake (MJ/day)									
1	192	5.7	10	212	5.2	24	217	3.7	31
2	197	9.2	3	195	5.5	14	217	5.8	9
3	124	19.4	3	193	7.0	7	212	5.7	14
Energy balance (MJ/day)									
1	-2.9	6.6	10	-10.8	6.0	24	-28.3	4.2	31
2	-17.2	10.4	3	-15.4	6.3	14	-15.2	6.6	9
3	-75.8	22.4	3	-21.1	8.0	7	-39.1	6.5	14
Gross efficiency (%)									
1	43.7	1.92	10	47.4	1.69	24	52.6	1.19	31
2	48.6	2.95	3	48.4	1.76	14	49.6	1.86	9
3	67.9	6.27	3	50.9	2.26	7	56.4	1.96	14
Net efficiency (%)									
1	62.0	3.22	10	64.6	2.83	24	71.8	1.98	31
2	68.2	4.95	3	68.8	2.95	14	68.0	3.12	9
3	110.2	10.52	3	73.8	3.80	7	78.4	3.29	14
Nitrogen efficiency (%)									
1	31.1	1.24	10	34.8	1.09	24	37.4	0.76	31
2	35.0	1.91	3	36.2	1.14	14	34.7	1.20	9
3	38.7	4.05	3	35.2	1.46	7	40.4	1.27	14

* Number of animals

Table A.38 Least squares means and standard errors (SE) and estimates of the effects of liveweight at calving (kg) and liveweight change – kg/week (regression coefficients (b)) for nitrogen intake (g/day) per stage of lactation – TRIAL 1

STAGE OF LACTATION		1		2		3		4		1-4	
WEEKS OF LACTATION		2-6		7-12		13-18		19-24		2-24	
Factors	Number of records	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
All	115	452	7.8	524	10.0	511	10.0	482	8.3	494	7.3
Year of calving											
1	33	426^{a}	11.9	503^{a}	15.5	490^{a}	15.3	504	12.6	482	11.2
2	35	493^{b}	10.5	560^{b}	13.5	548^{b}	13.4	479	11.0	525	9.7
3	35	411^{a}	9.7	508^{a}	12.4	528^{c}	12.4	469	10.2	485	9.1
4	12	476^{c}	15.1	524^{d}	19.2	481^{a}	19.6	476	16.0	507	14.5
R^2		18.8		4.2		7.3		3.8		5.1	
Month of calving											
1	47	445	9.3	536	11.8	537^{a}	17.2	513^{a}	9.8	507	8.9
2	56	448	8.7	532	11.2	512^{b}	13.2	478^{b}	9.2	497	8.1
3	12	461	14.3	503	18.4	486^{c}	14.2	455^{c}	15.2	478	13.4
R^2		0.3		0.5		5.3		9.7		3.1	
Parity											
2	26	446	13.3	495^{a}	17.1	486	14.2	484	14.3	478	12.6
3	34	441	10.4	516^{b}	13.4	514	23.1	483	10.9	488	9.8
4	25	462	11.0	547^{c}	14.2	525	11.0	483	11.7	506	10.3
5	30	457	11.1	538^{c}	14.2	520	9.9	478	11.7	503	10.4
R^2(%)											
Milk yield potential groups											
1	16	392^{a}	18.2	497^{a}	23.2	307^{a}	23.1	473^{a}	19.1	473^{a}	16.9
2	45	461^{b}	8.5	518^{b}	11.0	496^{a}	11.0	465^{b}	9.0	483^{b}	8.1
3	54	502^{c}	7.7	555^{c}	9.8	530^{b}	9.9	507^{c}	8.1	525^{c}	7.1
R^2(%)^{e}		16.1		10.4		8.0		11.8		14.6	
Calving condition score groups											
1	65	483^{a}	8.8	552	11.4	528	11.3	507	9.3	511	8.2
2	26	471^{a}	10.3	535	13,3	515	13.2	480	10.9	504	9.7
3	24	400^{b}	19.2	483	24.7	482	21.9	488	20.3	466	17.9
R^2(%)		6.6		6.5		3.0		1.2		4.1	
Weekly liveweight change (b,SE)	115	5.353	0.803**	4.693	1.668**	2.808	1.914	1.851	1.501	0.806	0.0224**
R^2		15.3		4.6		1.2		0.8		6.3	
Calving liveweight (b,SE)	115	0.283	0.1053**	0.0967	0.1312	0.293	0.1319*	0.360	0.1082**	0.298	0.0982**
R^2		2.4		1.7		3.7		6.2		4.9	

abcd Different superscripts in column indicate significant difference $P < 0.05$

R^2 = percentage of variance accounted for by the factor

e = includes 5.4, 2.2, 1.7, 0.7 and 1.8% units due to milk yield potential by calving condition score interaction for stages 1, 2, 3, 4 and 5 respectively

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

Table A.39 *Least squares means and unadjusted parity groups means, standard errors (SE) of nitrogen intake (g/day) and estimates of the effects of certain variables (regression coefficients (b)) per stage of lactation - TRIAL 2*

STAGE OF LACTATION		1		2		3		4		1-4	
WEEKS OF LACTATION		2-6		7-12		13-18		19-24		2-24	
Factors	Number of records	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
All	75	463	4.6	511	5.7	494	5.1	464	5.3	584	4.3
Month of calving											
1	27	453	6.9	519	8.3	500	7.5	472	7.7	488	6.5
2	24	463	7.2	517	9.0	504	8.1	467	8.4	488	6.9
3	24	473	7.9	498	10.1	478	9.0	453	9.8	458	7.5
R^2*		1.4		0.5		3.7		5.7		1.5	
Parity groups											
1a	24	420^{a}	9.6	461^{a}	1.7	461^{a}	10.5	455^{ac}	10.8	450^{a}	8.9
1b	25	448^{b}	7.7	514^{b}	9.3	529^{b}	8.3	492^{b}	8.5	499^{b}	7.2
2	14	487^{c}	13.1	532^{c}	16.2	514^{c}	14.3	449^{c}	14.7	496^{b}	12.2
3	12	495^{d}	14.1	537^{c}	16.9	473^{d}	15.0	460^{a}	15.5	491^{b}	13.2
R^2		5.4		8.5		18.7		9.9		10.6	
Weight change (b,SE)		1.105	1.199	2.078	2.283	4.213	2.170	6.219	2.717*	3.241	2.969
R^2		0.3		0.4		1.9		3.9		0.7	
Liveweight at calving (b,SE)		0.282	0.111*	0.517	0.140*	0.267	0.123*	0.193	0.101	0.326	0.122*
R^2(%)		2.3		4.5		1.5		1.9		2.9	
Milk yield (b,SE)		2.216	1.074*	1.530	1.266*	2.948	1.118*	3.514	1.311*	2.62	0.996*
R^2(%)		1.5		0.2		2.0		4.4		1.6	
Calving condition score		-42.34	19.28*	-96.89	24.86*	-10.65	22.18	-28.99	22.75	-42.79	18.42*
R^2(%)		1.7		6.1		0.2		1.5		2.2	
						UNADJUSTED MEANS					
Parity groups											
1a		397^{a}	7.1	432^{a}	9.4	434^{a}	8.3	427^{a}	8.8	423^{a}	6.9
1b	24	437^{b}	7.0	503^{b}	9.2	515^{b}	8.2	481^{b}	8.6	486^{b}	6.8
2	25	519^{c}	9.6	569^{c}	12.5	546^{c}	11.2	486^{b}	11.8	531^{c}	9.3
3	14	525^{c}	9.9	577^{c}	13.0	518^{b}	11.6	499^{c}	12.2	531^{c}	9.6
All	12	453	4.3	505	5.6	495	5.0	468	5.2	482	4.1
Level of significance		***		***		***		***		***	

abcd Different superscripts in column indicate significant difference $P < 0.05$

* R^2 = percentage of variance accounted for by the factor

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

Table A.40 Means and standard deviations (SD) of backfat area change, estimated body fat, energy and protein change and parameters of liveweight and condition score curves - Trials 1 and 2

TRAIT	TRIAL 1 Mean	TRIAL 1 SD	TRIAL 2 Mean	TRIAL 2 SD
Backfat area change (cm^2)				
Lactation weeks 1-6	-1.77	1.52	-	-
1-12	-1.92	1.87	-	-
1-18	-1.17	1.85	-	-
Parameters of liveweight curves				
A (intercept)	634.3	72.3	544.7	63.3
B (linear coefficient)	1.229	1.536	1.618	4.254
C (quadratic coefficients)	0.6901	0.1716	0.0501	0.147
Parameters of condition score curves				
A (intercept)	3.10	0.826	2.29	0.345
B (linear coefficient)	-0.0497	0.0878	-0.0384	0.0425
C (quadratic coefficient)	0.0021	0.0026	0.0014	0.0015
Estimated body fat change (g/day)				
Lactation weeks 1-6	-841.0	833.1		
6-12	77.1	522.0		
12-18	309.3	535.1		
1-18	109.5	301.3		
Estimated body protein change (g/day)				
Lactation weeks 1-6	-3.6	112.0		
6-12	20.6	74.9		
12-18	7.7	74.8		
1-18	9.5	39.6		
Estimated body energy change (MJ/day)				
Lactation weeks 1-6	-33.1	34.3		
6-12	3.5	21.4		
12-18	12.3	22.2		
1-18	-4.1	12.4		

Table A.41 Least squares means and standard errors (SE) of average liveweight (kg) per stage of lactation - TRIAL 1

STAGE OF LACTATION		1		2		3		4		1-4	
WEEKS OF LACTATION		2-6		7-12		13-18		19-24		2-24	
Factors	Number of records	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Year of calving											
1	33	652.5[a]	10.03	640.3	10.92	668.6[a]	11.94	682.7[a]	11.95	660.1[a]	10.18
2	35	644.7[a]	9.01	646.3	9.77	648.8[b]	10.83	651.2[b]	10.80	650.6[a]	9.21
3	35	625.9[c]	8.46	618.5	9.10	627.4[c]	10.10	633.6[c]	10.10	628.5[b]	8.65
4	12	618.1[c]	13.22	627.6	14.10	645.2[b]	15.94	669.0[a]	15.81	626.8[b]	13.8
Month of calving											
1	47	632.6	8.10	633.8	8.62	649.6	9.87	667.9	9.77	638.8	8.45
2	56	637.4	7.51	637.4	8.10	645.2	8.93	652.2	9.03	644.5	7.64
3	12	635.9	12.48	628.3	13.46	647.7	14.87	657.3	15.01	641.1	12.71
Milk yield groups											
1	16	623.2	15.84	621.1	15.92	638.1	18.79	643.8	18.85	627.7	16.06
2	45	635.4	7.46	639.5	8.03	657.1	9.00	671.8	8.96	646.4	7.74
3	54	647.2	6.64	638.9	7.03	647.4	7.87	661.8	7.85	650.3	6.66

[abcd] Different superscripts in column indicate significant difference $P < 0.05$

Table A.42 Least squares means and standard errors (SE) of average condition score (1-5 units) per stage of lactation - TRIAL 1

STAGE OF LACTATION		1		2		3		4		1-4	
WEEKS OF LACTATION		2-6		7-12		13-18		19-24		2-24	
Factors	Number of records	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Year of calving											
1	33	2.64^{a}	0.077	2.67^{a}	0.082	2.72^{a}	0.085	2.89^{a}	0.084	2.64^{a}	0.064
2	35	3.26^{b}	0.083	3.26^{a}	0.086	3.38^{b}	0.092	3.45^{b}	0.091	3.35^{b}	0.069
3	35	3.11^{c}	0.073	3.09^{c}	0.073	2.83^{c}	0.080	2.92^{a}	0.079	2.94^{c}	0.066
4	12	3.00^{c}	0.128	3.06^{c}	0.129	2.71^{a}	0.142	2.89^{a}	0.140	2.70^{a}	0.109
Month of calving											
1	47	2.92	0.065	2.95	0.065	2.86	0.072	3.01	0.071	2.81	0.056
2	56	2.93	0.061	2.94	0.061	2.80	0.066	2.92	0.067	2.87	0.050
3	12	3.16	0.120	3.17	0.122	3.08	0.132	3.19	0.132	3.04	0.099
Milk yield groups											
1	16	2.98	0.103	3.03^{ab}	0.103	3.06^{a}	0.112	3.17^{a}	0.111	2.95^{a}	0.086
2	45	3.11	0.073	3.13^{a}	0.074	3.04^{a}	0.081	3.17^{a}	0.080	3.06^{b}	0.059
3	54	2.92	0.060	2.90^{b}	0.060	2.65^{b}	0.066	2.78^{b}	0.065	2.76^{c}	0.049

[abcd] Different superscripts in column indicate significant difference $P < 0.05$

Table A.43 Least squares means and standard errors (SE) of condition score change between calving and different weeks of lactation - TRIAL 1

STAGE OF LACTATION		1		2		3	
WEEKS OF LACTATION		1-6		1-12		1-18	
Factors	Number of records	Mean	SE	Mean	SE	Mean	SE
Year of calving							
1	33	-0.11[a]	0.099	-0.09[a]	0.110	0.090[a]	0.110
2	35	-0.22[a]	0.085	0.03[a]	0.098	0.12[a]	0.095
3	35	-0.41[b]	0.086	-0.26[b]	0.099	-0.28[b]	0.096
4	12	-0.42[b]	0.122	-0.44[c]	0.141	-0.37[c]	0.136
Month of calving							
1	47	-0.46[a]	0.075	-0.32[a]	0.086	-0.25	0.08
2	56	-0.29[b]	0.073	-0.11[b]	0.084	-0.19	0.081
3	12	-0.13[c]	0.120	-0.01[c]	0.138	0.11	0.133
Milk yield groups							
1	16	-0.25	0.147	-0.08	0.169	-0.13	0.163
2	45	-0.28	0.070	-0.15	0.082	-0.06	0.078
3	54	-0.34	0.062	-0.21	0.072	-0.14	0.070

[abcd] Different superscripts in column indicate significant difference $P < 0.05$

Table A.44 Least squares means and standard errors (SE) of liveweight change (kg/week) per stage of lactation - TRIAL 1

STAGE OF LACTATION		1		2		3		4		1-4	
WEEKS OF LACTATION		2-6		7-12		13-18		19-24		2-24	
Factors	Number of records	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Year of calving											
1	33	-2.93	1.400	2.94[a]	0.865	2.86[a]	0.769	1.20	0.786	1.18[a]	0.467
2	35	-1.02	1.216	-0.09[b]	0.752	1.17[b]	0.668	0.45	0.683	0.20[b]	0.406
3	35	-3.03	1.140	0.68[b]	0.705	1.60[b]	0.627	1.42	0.640	0.20[b]	0.381
4	12	0.46	1.742	2.32[a]	1.077	4.08[c]	0.958	2.70	0.979	2.30[c]	0.581
Month of calving											
1	47	-0.72	1.063	1.48	0.657	3.45[a]	0.584	1.83[a]	0.597	1.59[a]	0.360
2	56	-1.24	1.019	0.66	0.630	1.96[b]	0.560	0.27[b]	0.572	0.44[b]	0.341
3	12	-2.93	1.693	2.25	1.047	1.87[b]	0.931	2.23[a]	0.951	0.89[b]	0.565
Milk yield groups											
1	16	0.44	2.121	1.79	1.311	1.48	1.165	0.94	1.191	1.17	0.708
2	45	-1.51	0.999	1.91	0.618	3.10	0.549	1.86	0.561	1.33	0.334
3	54	-3.82	0.861	0.69	0.532	2.71	0.473	1.53	0.484	0.41	0.287

[abcd] Different superscripts in column indicate significant difference $P < 0.05$

Table A.45 Least squares means and standard errors (SE) of average backfat area (cm^2) and estimates of the effects of certain variables (regression coefficients (b)) for different weeks of lactation - TRIAL 1

WEEKS OF LACTATION		1		6		12		18	
Factors	Number of records	Mean	SE	Mean	SE	Mean	SE	Mean	SE
All	115	6.76	0.305	5.39	0.202	5.03	0.180	5.64	0.198
Year of calving									
1	33	8.16^a	0.481	5.53^a	0.319	4.81^a	0.285	5.93^a	0.306
2	35	6.95^b	0.413	5.15^a	0.274	5.64^b	0.244	6.47^b	0.268
3	35	6.90^b	0.418	6.28^b	0.278	5.56^b	0.243	5.39^c	0.272
4	12	5.02^c	0.593	4.61^c	0.394	4.09^c	0.345	4.78^d	0.389
Month of calving									
1	47	6.91	0.363	5.57^a	0.241	4.58^a	0.209	5.48	0.236
2	56	6.98	0.353	5.55^a	0.234	5.07^b	0.209	5.44	0.227
3	12	6.38	0.581	5.08^b	0.386	5.43^b	0.346	6.00	0.374
Parity									
2	26	6.36	0.519	5.07^a	0.344	5.12	0.303	5.56^a	0.338
3	34	7.30	0.421	5.96^b	0.279	5.33	0.249	6.25^b	0.270
4	25	6.66	0.441	5.19^a	0.294	4.79	0.258	5.50^a	0.284
5	30	6.71	0.418	5.35^a	0.277	4.86	0.244	5.25^a	0.269
Milk yield groups									
1	16	7.05	0.711	6.15	0.472	4.93	0.420	5.33	0.460
2	45	6.47	0.341	4.97	0.227	5.33	0.203	6.09	0.228
3	54	6.76	0.303	5.05	0.201	4.81	0.178	5.50	0.197
Calving condition score group									
1	65	5.73^a	0.340	4.39^a	0.226	4.54^a	0.203	5.30^a	0.219
2	26	6.91^b	0.407	5.60^b	0.270	5.42^b	0.241	6.31^b	0.261
3	24	7.64^c	0.731	6.18^c	0.485	5.12^b	0.429	5.31^c	0.475
Weight change (b,SE)	115	-	-	-0.0131	0.0223	0.0873	0.0333	0.0028	0.00038
Calving liveweight (b,SE)	115	0.00265	0.00218	0.00113	0.00141	0.00089	0.00121	0.00075	0.00133
Day of recording (b,SE) x10	115	-0.75	0.389	-0.389	0.258	-0.101	1.874	0.222	0.242

[abcd] Different superscripts in column indicate significant difference $P < 0.05$

Table A.46 Least squares means and standard errors (SE) of backfat area change (cm^2) and estimates of the effects of certain variables (regression coefficients (b)) between calving and different stages of lactation - TRIAL 1

WEEKS OF LACTATION		1-6		1-12		1-18	
Factors	Number of records	Mean	SE	Mean	SE	Mean	SE
All	115	-1.38	0.225	-1.73	0.271	-1.10	0.272
Year of calving							
1	33	-2.60[a]	0.355	-3.12[a]	0.426	-2.28[a]	0.429
2	35	-1.88[b]	0.305	-1.57[b]	0.367	-0.57[b]	0.368
3	35	-0.64[c]	0.309	-1.28[b]	0.372	-1.46[c]	0.372
4	12	-0.40[c]	0.438	-0.95[c]	0.527	-0.10[b]	0.529
Month of calving							
1	47	-1.35	0.268	-2.42[a]	0.322	-1.52	0.323
2	56	-1.47	0.261	-2.05[a]	0.313	-1.51	0.314
3	12	-1.32	0.429	-0.72[b]	0.516	-0.28	0.517
Parity							
2	26	-2.26	0.383	-1.26	0.460	-0.74	0.462
3	34	-1.36	0.311	-2.00	0.373	-1.00	0.375
4	25	-1.52	0.327	-1.87	0.393	-1.35	0.390
5	30	-1.37	0.308	-2.15	0.631	-1.32	0.370
Milk yield groups							
1	16	-0.78	0.525	-1.78	0.370	-1.64[a]	0.633
2	45	-1.58	0.252	-1.14	0.303	-0.40[b]	0.304
3	54	-1.69	0.224	-1.90	0.269	-1.27[a]	0.271
Calving condition score groups							
1	65	-1.32	0.251	-1.04	0.302	-0.38[a]	0.303
2	26	-1.39	0.301	-1.54	0.361	-0.59[a]	0.363
3	26	-1.42	0.539	-2.61	0.648	-2.24[b]	0.650
Weight change (b,SE)	115	0.0299	0.0248	0.0978	0.0297	0.0547	0.0299
Calving liveweight (b,SE)	115	-0.00126	0.00156	-0.00087	0.00188	-0.00134	0.00189
Day of recording (b,SE) x10	115	0.326	0.287	0.606	0.345	0.572	0.346

Table A.47 Correlation coefficients between liveweight change (kg/week) or condition score change in consecutive lactations of the same cow and regression coefficients (b)) of 2nd parity cows on 1st parity cows of the same cow

WEEKS OF LACTATION	2-6	7-12	13-18	19-24	2-24
			LIVEWEIGHT CHANGE		
2nd parity and older cows[a] (n=30)	0.011	0.393	0.413	-0.049	0.0164
1st parity cows vs 2nd parity cows[b] (n=14)	0.030	0.043	0.023	0.164	-0.087
b ± SE	-0.158 ± 0.700	0.562 ± 0.169	0.698 ± 0.215	0.962 ± 0.183	0.584 ± 0.185
All cows (n=44)[c]	0.090	0.331	0.362	0.030	0.267
			CONDITION SCORE CHANGE		
WEEKS OF LACTATION	**Calving condition score**	**1-6**	**1-12**	**1-18**	
2nd parity and older cows[a]	0.118	0.114	0.195	0.283	
1st parity cows vs 2nd parity cows[b]	0.40	0.619	-0.016	-0.251	
b ± SE	0.916 ± 0.027	2.160 ± 0.593	0.518 ± 0.339	0.132 ± 0.412	
All cows[c]	0.129	0.189	0.177	0.207	

[a] correlation coefficients > 0.355 $P < 0.05$
[b] correlation coefficients > 0.514 $P < 0.05$
[c] correlation coefficients > 0.304 $P < 0.05$

stages of lactation for years 1-4 of experiment

WEEKS OF LACTATION		1-6		6-12		12-18		1-18	
Factors	Number of records	Mean	SE	Mean	SE	Mean	SE	Mean	SE
				FAT					
Year of calving									
1	33	-1070.1	26.35	222.5	13.98	425.0	16.62	-61.1	6.95
2	35	-909.7	22.49	122.0	13.86	344.0	14.18	-86.8	7.76
3	35	-841.0	21.92	76.7	13.74	309.0	14.18	-109.0	7.92
4	12	-308.9	32.58	293.2	24.62	354.1	19.88	130.2	14.9
Heifers	24	-291.9	14.54	297.9	13.222	364.3	11.59	133.0	6.66
]Condition score groups									
1	65	-856.0	13.24	217.2	6.47	288.0	9.06	52.6	4.04
2	26	-799.3	26.84	186.0	14.58	300.5	18.61	-67.0	8.68
3	26	-841.5	30.81	76.7	19.33	309.1	19.81	-109.2	11.15
Milk yield groups									
1	16	-776.8	76.69	119.0	29.75	343.7	39.81	-47.4	23.50
2	45	-717.1	19.77	196.8	12.74	342.5	10.30	-1.80	6.78
3	54	-841.9	15.43	76.7	0.67	309.0	9.91	-109.0	5.58
				PROTEIN					
Year of calving									
1	33	13.6	2.75	48.8	2.00	8.3	1.91	25.7	0.84
2	35	16.7	2.85	20.7	1.90	-4.1	1.73	11.6	1.06
3	35	-3.6	2.95	20.7	1.97	7.7	1.97	9.5	1.04
4	12	-7.5	4.16	36.3	3.22	42.1	2.58	25.3	1.64
Heifers	24	-8.7	2.13	32.6	1.67	46.0	1.29	20.3	0.81
Condition score groups									
1	65	9.9	1.44	34.5	1.04	-1.2	1.15	16.8	0.54
2	26	0.4	3.16	32.2	2.31	3.6	2.54	12.9	1.17
3	26	-3.6	4.15	20.6	2.77	7.7	2.77	-9.5	1.47
Milk yield groups									
1	16	-17.0	7.75	46.0	6.25	11.1	5.14	16.6	2.51
2	45	11.1	2.73	25.0	1.69	11.6	1.38	17.6	0.92
3	54	-3.6	2.07	20.6	1.39	7.7	1.39	9.5	0.73
				ENERGY					
Year of calving									
1	33	-41.7	1.08	10.0	0.57	16.9	0.67	-1.8	2.80
2	35	-35.3	0.93	5.3	0.57	13.3	0.58	-3.1	0.32
3	35	-33.1	0.90	3.5	0.56	12.3	0.58	-4.1	0.33
4	12	-12.3	1.25	12.4	1.00	14.9	0.88	5.7	0.58
Heifers	24	-11.7	0.61	12.5	0.54	15.4	0.47	5.8	0.28
Condition score groups									
1	65	-35.4	0.54	9.3	0.29	11.3	0.38	-1.8	0.17
2	26	-31.4	1.09	8.1	0.59	11.9	0.77	-2.3	0.31
3	26	-33.1	1.27	3.5	0.79	12.3	0.82	-4.1	0.46
Milk yield groups									
1	16	-30.9	3.15	5.8	1.20	13.8	1.65	-1.5	9.68
2	45	-27.9	0.82	8.3	0.52	13.7	0.42	-0.3	2.82
3	54	-33.1	0.64	2.5	0.40	12.3	4.11	-4.1	2.30

Equation	Model	Stage[c]	Constant	SE	b	SE	RSD	R^2 (%)
1	BSC = a + bCS	1	0.0424	0.0056	-0.0184**	0.0021	0.0094	42.6
2	BSC = a + bCS	2	0.0060	0.0057	-0.0004	0.0021	0.0096	1.0
3	BSC = a + bCS	3	-0.0122	0.0057	0.0052*	0.0021	0.0094	4.6
4	BSC = a + bCS	4	0.0113	0.0022	-0.0042**	0.0008	0.0037	19.6
5	BFAC = a + bBFA	1	0.0479	0.0135	-0.0144**	0.0018	0.0379	35.9
6	BFAC = a + bBFA	2	0.0495	0.0111	-0.0074**	0.0015	0.0311	17.5
7	BFAC = a + bBFA	3	0.0099	0.0103	0.0010	0.0014	0.090	0.1
8	BFAC = a + bBFA	4	0.0345	0.0036	-0.0064**	0.0005	0.105	60.7
9	LWC = a + bCS	1	0.502	0.619	-0.368	0.228	1.045	1.5
10	LWC = a + bCS	2	1.257	0.337	-0.398	0.124*	0.407	8.0
11	LWC = a + bCS	3	0.404	0.369	-0.058	0.136	0.623	0.1
12	LWC = a + bCS	4	0.666	0.241	-0.246	0.089*	0.407	5.8
13	BFA = a + bCS	Year 1	11.052	0.6617	6.504	0.8239	-	-
14	BFA = a + bCS	" 2	5.819	0.3672	1.267	0.2698	-	-
15	BFA = a + bCS	" 3	5.831	0.4260	1.283	0.408	-	-
16	BFA = a + bCS	" 4	6.598	0.6537	2.049	0.811	-	-
17	BFA = a + bCS	All	7.324	0.187	2.7768***	0.3138	1.438	53.0
18	LW = a + bCS	Year 1	729.306	14.529	177.315	38.1497	-	-
19	LW = a + bCS	" 2	615.091	17.004	63.100	12.493	-	-
20	LW = a + bCS	" 3	634.456	19.925	82.465	18.867	-	-
21	LW = a + bCS	" 4	650.444	30.267	98.454	37.550	-	-
22	LW = a + bCS	All	657.324	8.662	105.334***	14.529	66.605	41.3
23	LW = a + bBFA	All	646.745	10.297	22.000**	4.406	29.6	72.932
24	CS = a + bBFA	Year 1	2.962	0.0359	0.0799	0.0302	-	-
25	CS = a + bBFA	" 2	3.256	0.0448	0.3741	0.0485	-	-
26	CS = a + bBFA	" 3	3.070	0.0465	0.1877	0.0562	-	-
27	CS = a + bBFA	" 4	3.090	0.0670	0.2079	0.0855	-	-
28	CS = a + bBFA	All	3.094	0.0670	0.2124**	0.0288	0.476	60.3
HEIFERS AND COWS								
29	LW = a + bCS	All	566.411	4.541	148.683**	16.611	36.29	69.8
30	BFA = a + bCS	All	4.517	0.0347	1.583*	0.711	0.381	35.4
31	LW = a + BFA	All	573.525	7.305	27.278***	6.186	42.53	66.1
32	CS = a + BFA	All	2.842	0.0471	0.1407**	0.0399	0.274	35.4
HEIFERS ONLY								
33	BSC = a + bCS	1	0.0372	0.0182	-0.0165*	0.0067	0.0078	17.2
34	BSC = a + bCS	2	0.0024	0.0251	0.0001	0.0094	0.101	0.1
35	BSC + a = bCS	3	-0.0109	0.0168	0.0047	0.0062	0.007	0.1
36	BSC = a + bCS	4	0.0013	0.0053	-0.0052*	0.0019	0.00001	20.0
37	BFAC = a + bBFA	1	0.0217	0.0275	-0.0077	0.0061	0.027	2.5
38	BFAC = a + bBFA	2	0.0048	0.0192	-0.0005	0.0042	0.018	0.2
39	BFAC = a + bBFA	3	0.0306	0.0256	-0.0043	0.0057	0.025	0.1
40	BFAC = a + bBFA	4	0.0151	0.0126	-0.0032	0.0028	0.012	1.2
41	LWC = a + bCS	1	2.071	1.293	-0.777	0.476	0.535	0.3
42	LWC = a + bCS	2	-0.282	1.051	0.294	0.389	0.437	0.1
43	LWC = a + bCS	3	0.090	0.726	0.131	0.269	0.302	0.1
44	LWC = a + bCS	4	0.781	0.636	-0.174	0.236	0.265	0.2

* $P < 0.05$ ** $P < 0.01$ [c] Stage 1, weeks 1-6; Stage 2, weeks 6-12; Stage 3, weeks 12-18; Stage 4, weeks 1-18

Table A.50 Least squares means and standard errors (SE) and estimates of the effects of daily milk yield in lactation week 2 (kg) (regression coefficients (b)) for average liveweight (kg) per stage of lactation - TRIAL 2

STAGE OF LACTATION		1		2		3		4		1-4	
WEEKS OF LACTATION		2-6		7-12		13-18		19-24		2-24	
Factors	Number of records	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
All	75	561.2	4.88	574.4	5.01	592.8	5.19	561.9	4.73	582.8	4.69
Month of calving											
1	27	564.1	7.30	581.2	7.38	599.2	7.68	563.7	7.06	585.7	7.48
2	24	557.6	7.81	570.3	8.04	588.9	8.38	557.4	7.67	577.2	7.60
3	24	562.1	8.46	570.9	8.84	590.4	9.15	564.6	8.72	585.6	8.30
Parity groups											
1a	24	519.8	9.60	521.8^{a}	9.85	537.3^{a}	10.27	519.1^{a}	9.31	537.3	9.20
1b	25	536.3	8.18	538.5^{a}	8.18	553.4^{a}	8.47	534.7^{a}	7.68	556.4	7.89
2	14	584.6	13.65	605.5^{b}	13.99	630.7^{b}	14.44	586.4^{b}	13.10	609.5	13.05
3	12	604.3	14.12	630.6^{c}	13.90	649.9^{b}	14.45	607.3^{c}	13.13	638.1	13.37
Milk yield (b,SE)	75	-0.629	1.165	-1.104	1.124	-1.829	1.139	-2.616	0.898	0.0776	1.074

abcd Different superscripts in column indicate significant difference $P < 0.05$

Table A.51 Least squares means and standard errors (SE) and estimates of the effects of daily milk yield in lactation week 2 (kg) (regression coefficients (b)) for liveweight change (kg/week) per stage of lactation - TRIAL 2

STAGE OF LACTATION		1		2		3		4		1-4	
WEEKS OF LACTATION		2-6		7-12		13-18		19-24		2-24	
Factors	Number of records	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
All	75	0.48	0.449	3.06	0.310	3.21	0.289	2.74	0.235	2.14	0.154
Month of calving											
1	27	1.28	0.654	2.85	0.466	3.44	0.429	3.38^{a}	0.349	2.33	0.228
2	24	0.72	0.710	2.82	0.484	3.22	0.452	3.24^{a}	0.368	2.24	0.246
3	24	-0.55	0.710	3.52	0.527	2.99	0.492	1.60^{b}	0.368	1.86	0.262
Parity groups											
1a	24	-2.829	0.918	2.32	0.642	3.00	0.599	2.73	0.488	2.02	0.319
1b	25	-2.89^{a}	0.719	2.33	0.517	2.28	0.428	2.83	0.392	1.76	0.257
2	14	2.93^{b}	1.251	3.85	0.879	3.06	0.820	2.80	0.668	2.25	0.436
3	12	4.70^{c}	1.307	3.73	0.967	4.52	0.902	2.60	0.734	2.53	0.480
Milk yield (b,SE)	75	-0.3811	0.0977**	-0.0715	0.0719	-0.0100	0.0670	-0.0278	0.0546	-0.0204	0.0357

abcd Different superscripts in column indicate significant difference $P < 0.05$, ** $P < 0.01$

Table A.52 Least squares means and standard errors (SE) and estimates of the effects of daily milk yield in lactation week 2 (kg) (regression coefficients (b)) for average condition score (1-5 units) per stage of lactation - TRIAL 2

STAGE OF LACTATION		1		2		3		4		1-4	
WEEKS OF LACTATION		2-6		7-12		13-18		19-24		2-24	
Factors	Number of records	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
All	75	2.70	0.026	2.55	0.027	2.58	0.033	2.65	0.035	2.69	0.025
Month of calving											
1	27	2.66	0.038	2.61^{a}	0.039	2.58	0.048	2.68	0.051	2.60	0.037
2	24	2.74	0.045	2.59^{a}	0.043	2.59	0.053	2.68	0.056	2.63	0.040
3	24	2.69	0.045	2.46^{b}	0.049	2.58	0.058	2.60	0.066	2.60	0.044
Parity groups											
1a	24	2.84	0.054	2.63	0.055	2.60	0.066	2.60	0.070	2.68	0.051
1b	25	2.72	0.044	2.60	0.045	2.58	0.053	2.65	0.057	2.68	0.042
2	14	2.59	0.074	2.52	0.076	2.65	0.091	2.74	0.097	2.59	0.070
3	12	2.63	0.083	2.48	0.080	2.51	0.097	2.61	0.104	2.48	0.077
Milk yield (b,SE)	75	-0.0161	0.0061**	-0.0192	0.0060**	-0.0230	0.0071**	-0.0235	0.0076**	-0.0162	0.0056**

abcd Different superscripts in column indicate significant difference P < 0.05, ** P < 0.01, * P < 0.05

Table A.53 Simple correlations* between milk production traits, live body measurements and nutrient utilization traits

STAGE OF LACTATION	1		2		3		4		1-4	
TRIAL	1	2	1	2	1	2	1	2	1	2
VARIABLE					MILK YIELD					
Liveweight	0.277	0.458	0.089	0.325	-0.001	0.0497	-0.095	-0.150	0.060	0.243
Condition score	0.206	0.132	-0.124	-0.078	-0.195	-0.385	-0.201	-0.390	-0.100	-0.331
Liveweight change	-0.260	-0.297	-0.231	-0.312	-0.224	-0.081	-0.037	-0.100	-0.432	-0.388
Condition score change	-0.240	-0.156	-0.038	-0.074	-0.031	-0.031	-	-	-	-
ME balance	-0.455	-0.634	-0.523	-0.273	-0.428	-0.447	-0.511	-0.509	-0.552	-0.447
Gross energy efficiency	0.498	0.750	0.670	0.606	0.684	0.746	0.769	0.803	0.729	0.738
Net energy efficiency	0.360	0.589	0.561	0.518	0.490	0.626	0.630	0.687	0.604	0.610
Milk nitrogen efficiency	0.499	0.731	0.680	0.473	0.640	0.575	0.740	0.602	0.698	0.661
Calving condition score	0.238	-0.085	0.079	-0.062	0.074	-0.091	0.105	-0.191	0.148	-0.109
Calving liveweight	0.248	0.496	0.167	0.442	0.148	0.301	0.410	0.097	0.204	0.404
Calving backfat area	0.014	0.102	-0.098	0.009	0.025	0.090	0.101	0.088	0.022	0.078
					LIVEWEIGHT					
FCM	0.277	0.485	0.061	0.294	-0.018	0.049	-0.123	-0.095	-0.081	0.232
ME balance	-0.098	0.523	0.162	0.220	0.231	0.322	0.351	0.357	0.220	0.218
Gross energy efficiency	0.054	0.227	-0.194	-0.197	-0.277	-0.342	-0.405	-0.433	-0.270	-0.206
Net energy efficiency	0.098	0.223	-0.151	-0.186	-0.224	-0.286	-0.372	-0.364	-0.215	-0.174
Milk nitrogen efficiency	0.021	0.261	-0.163	-0.002	-0.276	-0.118	-0.357	-0.221	-0.265	-0.001
					CONDITION SCORE					
FCM	0.064	-0.138	-0.130	-0.261	-0.199	-0.402	-0.160	-0.377	-0.290	-0.328
Milk fat content	0.249	0.156	0.153	-0.080	0.040	-0.159	-0.052	-0.125	0.034	-0.092
Milk protein content	-0.100	0.167	0.011	0.149	0.160	-0.002	0.133	0.047	0.085	0.117
ME balance	-0.250	-0.001	0.065	0.109	0.158	0.183	0.098	0.229	0.112	0.263
Gross energy efficiency	0.231	-0.091	-0.112	-0.291	-0.233	-0.378	-0.243	-0.420	-0.175	-0.428
Net energy efficiency	0.259	-0.039	-0.056	-0.180	-0.166	-0.253	-0.151	-0.306	-0.238	-0.244
Milk nitrogen efficiency	0.079	-0.094	-0.170	-0.054	-0.303	-0.333	-0.216	-0.384	-0.186	-0.273
					LIVEWEIGHT CHANGE					
FCM	-0.417	-0.391	-0.268	-0.336	-0.158	-0.086	-0.019	-0.017	-0.424	-0.393
Milk fat content	-0.353	-0.328	-0.101	-0.067	-0.016	-0.047	0.004	0.096	-0.059	-0.101
Milk protein content	0.339	-0.041	0.420	0.047	0.211	0.265	0.113	0.244	0.435	-0.191
ME balance	0.662	0.523	0.363	0.415	0.251	0.430	0.150	0.361	0.537	0.562
Gross energy efficiency	-0.636	-0.533	-0.370	-0.471	-0.255	-0.322	-0.106	-0.287	-0.549	-0.588
Net energy efficiency	-0.652	-0.538	-0.376	-0.458	-0.274	-0.386	-0.135	-0.349	-0.555	-0.591
Milk nitrogen efficiency	-0.458	-0.365	-0.141	-0.269	-0.054	-0.077	-0.036	-0.216	-0.315	-0.378

* TRIAL 1 $P < 0.05$ $r > 0.195$ and $P < 0.01$ $r > 0.254$

TRIAL 2 $P < 0.05$ $r > 0.232$ and $P < 0.01$ $r > 0.302$

Table A.54 Best relationships between gross, net and nitrogen efficiencies (%) and milk yield - kg/day (b_1), metabolizable energy intake - MJ/day (b_2) selected from Appendix Tables A.57, A.58, A.59.

Equation number	Weeks of lactation	Constant ± SE	b_1 ± SE	b_2 ± SE
		TRIAL 1 - GROSS EFFICIENCY		
1	2-6	55.87 ± 4.26	1.725 ± 0.0961	-0.2897 ± 0.0172
2	7-12	48.79 ± 2.66	1.286 ± 0.0553	-0.1713 ± 0.0101
3	13-18	43.95 ± 2.30	1.271 ± 0.0541	-0.1412 ± 0.0088
4	19-24	42.69 ± 2.13	1.481 ± 0.0534	-0.1411 ± 0.0090
5	2-24	47.67 ± 2.96	1.349 ± 0.0510	-0.1537 ± 0.0093
		TRIAL 2 - GROSS EFFICIENCY		
6	2-6	41.99 ± 3.41	1.599 ± 0.0901	-0.2119 ± 0.0204
7	7-12	36.82 ± 2.43	1.401 ± 0.0764	-0.1694 ± 0.0124
8	13-18	33.04 ± 6.21	1.473 ± 0.0692	-0.1384 ± 0.0109
9	19-24	34.23 ± 7.23	1.557 ± 0.0687	-0.1277 ± 0.0110
10	2-24	37.15 ± 4.99	1.511 ± 0.0717	-0.1613 ± 0.0126
		TRIAL 1 - NET EFFICIENCY		
11	2-6	98.96 ± 7.08	2.516 ± 0.1598	-0.5282 ± 0.02852
12	7-12	68.78 ± 9.92	1.700 ± 0.0747	-0.2879 ± 0.0137
13	13-18	67.36 ± 10.52	1.617 ± 0.0817	-0.2602 ± 0.0132
14	19-24	62.84 ± 12.87	1.937 ± 0.0722	-0.2583 ± 0.0122
15	2-24	69.52 ± 10.25	1.769 ± 0.0668	-0.2679 ± 0.0121
		TRIAL 2 - NET EFFICIENCY		
16	2-6	75.45 ± 8.52	2.241 ± 0.1365	-0.3793 ± 0.0309
17	7-12	60.62 ± 7.31	1.805 ± 0.0956	-0.2653 ± 0.0156
18	13-18	53.72 ± 7.38	1.869 ± 0.0883	-0.2247 ± 0.0140
19	19-24	49.15 ± 8.93	1.962 ± 0.0929	-0.2206 ± 0.0148
20	2-24	50.23 ± 9.94	1.929 ± 0.0905	-0.2544 ± 0.0158
		TRIAL 1 - NITROGEN EFFICIENCY		
21	2-6	30.14 ± 9.34	0.8398 ± 0.0546	-0.1351 ± 0.0097
22	7-12	29.40 ± 10.19	0.7335 ± 0.0414	-0.0841 ± 0.0076
23	13-18	25.07 ± 11.23	0.7380 ± 0.0488	-0.0748 ± 0.0079
24	19-24	20.41 ± 8.65	0.9110 ± 0.0519	-0.0732 ± 0.0088
25	2-24	26.77 ± 9.56	0.7405 ± 0.0452	-0.0772 ± 0.0075
		TRIAL 2 - NITROGEN EFFICIENCY		
26	2-6	29.01 ± 7.85	0.9870 ± 0.0620	-0.1316 ± 0.0141
27	7-12	27.53 ± 8.77	0.7956 ± 0.0911	-0.0966 ± 0.0148
28	13-18	23.71 ± 10.21	0.8208 ± 0.1043	-0.0673 ± 0.0165
29	19-24	14.29 ± 6.51	0.8673 ± 0.0856	-0.0377 ± 0.0137
30	2-24	22.66 ± 7.98	0.8228 ± 0.0897	-0.0751 ± 0.0157

Table A.55 Precision of some prediction equations of dry matter intake (DMI) from milk yield (MY), liveweight (LW), condition score (BS) and liveweight change (LWC) per stage of lactation

Stage of Lactation EQUATION	INDEPENDENT VARIABLES	R^2 (%)		RSD		ORIGINAL SD	
		TRIAL					
		1	2	1	2	1	2
Weeks 2-6							
1	MY, LW, BS, LWC	62.6	70.7	1.49	1.29	2.35	2.30
2	MY, BS, LWC	55.2	67.0	1.62	1.36		
3	LW, BS, LWC	47.3	55.0	1.76	1.58		
4	MY, LW, LWC	58.7	70.2	1.56	1.29		
5	MY, LW, BS	44.6	68.2	1.81	1.33		
6	MY, LW	41.3	66.0	1.87	1.37		
Weeks 7-12							
7	MY, LW, BS, LWC	46.3	68.0	1.85	1.39	2.44	2.37
8	MY, BS, LWC	38.6	57.6	1.97	1.59		
9	LW, BS, LWC	36.6	51.5	2.01	1.70		
10	MY, LW, LWC	44.0	65.6	1.88	1.43		
11	MY, LW, BS	41.9	65.9	1.92	1.42		
12	MY, LW	40.2	62.5	1.96	1.48		
Weeks 13-18							
13	MY, LW, BS, LWC	43.1	59.4	1.92	1.35	2.46	2.05
14	MY, BS, LWC	33.5	44.6	2.07	1.57		
15	LW, BS, LWC	30.7	45.2	2.11	1.56		
16	MY, LW, LWC	41.3	57.0	1.94	1.38		
17	MY, LW, BS	42.6	55.0	1.92	1.46		
18	MY, LW	40.8	49.2	1.95	1.49		
Weeks 19-24							
19	MY, LW, BS, LWC	52.6	52.7	1.65	1.38	2.31	1.95
20	MY, BS, LWC	43.6	42.4	1.79	1.52		
21	LW, BS, LWC	31.4	32.2	1.97	1.65		
22	MY, LW, LWC	50.6	51.6	1.67	1.39		
23	MY, LW, BS	51.6	43.5	1.66	1.50		
24	MY, LW	49.7	40.8	1.69	1.53		

Table A.56 *Precision of some prediction equations of ME balance (MEB) from milk yield (MY), liveweight (LW), condition score (BS) and liveweight change (LWC) per stage of lactation*

Stage of Lactation EQUATION	INDEPENDENT VARIABLES	R^2(%)		RSD		ORIGINAL SD	
		TRIAL					
		1	2	1	2	1	2
Weeks 2-6							
1	MY, LW, BS, LWC	71.0	54.5	20.1	16.2	36.0	23.2
2	MY, BS, LWC	69.4	53.6	20.5	16.2		
3	LW, BS, LWC	59.9	37.6	23.5	18.8		
4	MY, LW, LWC	68.2	53.8	20.9	16.1		
5	MY, LW, BS	51.0	45.8	26.0	17.6		
Weeks 7-12							
6	MY, LW, BS, LWC	48.4	29.7	24.2	17.1	32.5	19.7
7	MY, BS, LWC	44.1	19.7	25.1	18.0		
8	LW, BS, LWC	24.1	20.6	29.3	18.1		
9	MY, LW, LWC	45.6	26.2	24.8	17.4		
10	MY, LW, BS	45.1	23.7	24.9	17.6		
Weeks 13-18							
11	MY, LW, BS, LWC	42.5	47.0	23.0	14.2	29.2	18.9
12	MY, BS, LWC	36.2	36.8	24.1	15.4		
13	LW, BS, LWC	26.2	28.4	25.9	16.4		
14	MY, LW, LWC	41.0	45.0	23.2	14.4		
15	MY, LW, BS	41.4	39.3	23.1	15.1		
Weeks 19-24							
16	MY, LW, BS, LWC	48.3	44.9	19.1	15.8	25.6	20.6
17	MY, BS, LWC	39.4	39.7	20.6	16.4		
18	LW, BS, LWC	24.9	28.8	22.9	17.9		
19	MY, LW, LWC	45.2	43.7	19.5	15.9		
20	MY, LW, BS	47.7	38.4	19.1	16.5		
Weeks 2-24							
21	MY, LW, BS, LWC	58.4	43.8	15.9	12.3	23.8	15.8
22	MY, BS, LWC	52.3	39.2	17.0	12.7		
23	LW, BS, LWC	40.6	35.2	18.9	13.1		
24	MY, LW, LWC	55.7	42.9	16.3	12.3		
25	MY, LW, BS	53.4	35.1	16.8	13.1		

Table A.57 Precision of some prediction equations of gross energy efficiency (GE) from ME intake (MEI), milk yield (MY), liveweight (LW), condition score (BS) and liveweight change (LWC) per stage of lactation

Stage of Lactation EQUATION	INDEPENDENT VARIABLES	R^2(%) TRIAL 1	R^2(%) TRIAL 2	RSD TRIAL 1	RSD TRIAL 2	ORIGINAL SD 1	ORIGINAL SD 2
Weeks 2-6							
1	MY, LW, LWC, MEI, BS	80.4	85.7	4.51	2.73	10.00	6.98
2	MY, LW, LWC, MEI	79.1	85.7	4.65	2.73		
3	MY*3, LW*3, LWC*3, BS*	58.8	69.4	6.52	3.97		
4	MY, LW, MEI, BS	78.6	82.7	4.70	2.985		
	MY, MEI, LWC, BS	80.2	85.7	4.52	2.71		
6	LW, MEI, LWC, BS	49.0	42.3	7.26	5.45		
7	MY, MEI	76.8	82.0	4.86	3.01		
Weeks 7-12							
8	MY, LW, LWC, MEI, BS	84.4	83.7	2.96	2.05	7.33	4.91
9	MY, LW, LWC, MEI	83.6	83.7	3.01	2.05		
10	MY*3, LW*3, LWC, BS*3	55.1	57.8	4.99	3.28		
11	MY, LW, MEI, BS	84.3	83.3	2.95	2.06		
12	MY, MEI, LWC, BS	83.6	86.8	3.02	1.84		
13	LW, MEI, LWC, BS	13.2	11.4	6.93	4.75		
14	MY, MEI	83.1	81.8	3.03	2.12		
Weeks 13-18							
15	MY, LW, LWC, MEI, BS	83.0	87.8	2.61	1.79	6.21	4.93
16	MY, LW, LWC, MEI	82.9	87.7	2.61	1.77		
17	MY*3, LW*3, LWC3, BS	56.6	76.0	4.16	2.48		
18	MY, LW, MEI, BS	82.9	87.4	2.61	1.80		
19	MY, MEI, LWC, BS	82.6	86.8	2.63	1.84		
20	LW, MEI, LWC, BS	17.3	30.7	5.74	4.21		
21	MY, MEI	82.5	85.9	2.62	1.86		
Weeks 19-24							
22	MY, LW, LWC, MEI, BS	87.7	88.3	2.30	1.93	6.40	5.48
23	MY, LW, LWC, MEI	87.6	88.3	2.31	1.93		
24	MY*3, LW*3, LWC3, BS*	73.3	77.4	3.40	2.68		
25	MY, LW, MEI, BS	87.7	88.3	2.30	1.93		
26	MY, MEI, LWC, BS	86.4	87.7	2.41	1.98		
27	LW, MEI, LWC, BS	17.6	27.9	5.93	4.79		
28	MY, MEI	86.0	87.3	2.42	1.98		
29	LW, MEI, LWC, BS, MEIxCS	26.7		5.74			
Weeks 2-24							
30	MY, LW, LWC, MEI, BS	86.9	88.1	2.30	1.64	6.40	4.60
31	MY, LW, LWC, MEI	86.7	88.0	2.13	1.64		
32	MY*3, LW*3, LWC*3, BS*	70.2	75.9	3.19	2.31		
33	MY, LW, MEI, BS	86.5	87.7	2.15	1.65		
34	MY, MEI, LWC, BS	85.7	87.0	2.21	1.71		
35	LW, MEI, LWC, BS	37.5	48.5	4.63	3.39		
36	MY, MEI	85.2	85.8	2.23	1.76		

* = P < 0.05 Significant predictor variables for Trial 1

3 = P < 0.05 Significant predictor variables for Trial 2

Table A.58 Precision of some prediction equations of net energy efficiency (NE) from ME intake (MEI), milk yield (MY), liveweight (LW), condition score (BS) and liveweight change (LWC) per stage of lactation

Stage of Lactation EQUATION	INDEPENDENT VARIABLES	R^2(%) TRIAL 1	R^2(%) TRIAL 2	RSD TRIAL 1	RSD TRIAL 2	ORIGINAL SD TRIAL 1	ORIGINAL SD TRIAL 2
Weeks 2-6							
1	MY, LW, LWC, MEI, BS	82.1	85.0	7.12	3.85	16.51	9.62
2	MY, LW, LWC, MEI	81.2	85.0	7.27	3.83		
3	MY^{*3}, LW*, LWC^{*3}, BS*	51.7	51.6	11.66	6.87		
4	MY, LW, MEI, BS	80.6	82.0	7.39	4.20		
5	MY, MEI, LWC, BS	81.9	84.0	7.13	3.93		
6	LW, MEI, LWC, BS	59.2	40.9	10.71	6.60		
7	MY, MEI	76.5	78.3	8.07	4.55		
Weeks 7-12							
8	MY, LW, LWC, MEI, BS	86.1	84.2	3.97	2.66	10.44	6.48
9	MY, LW, LWC, MEI	85.5	84.2	4.03	2.65		
10	MY^{*3}, LW^{*3}, LWC, BS^{*3}	39.6	39.0	8.24	5.20		
11	MY, LW, MEI, BS	86.0	83.7	3.97	2.69		
12	MY, MEI, LWC, BS	86.1	84.2	3.96	2.65		
13	LW, MEI, LWC, BS	24.1	13.8	9.24	6.18		
14	MY, MEI	84.8	83.7	4.10	2.66		
Weeks 13-18							
15	MY, LW, LWC, MEI, BS	81.8	86.9	3.94	2.41	9.05	6.42
16	MY, LW, LWC, MEI	81.8	86.9	3.93	2.39		
17	MY^{*3}, LW^{*3}, LWC^{*3}, BS	32.7	59.9	7.55	4.18		
18	MY, LW, MEI, BS	81.6	86.5	3.95	2.42		
19	MY, MEI, LWC, BS	81.5	86.9	3.96	2.39		
20	LW, MEI, LWC, BS	30.8	27.4	7.65	6.65		
21	MY, MEI	81.2	86.4	3.95	2.40		
Weeks 19-24							
22	MY, LW, LWC, MEI, BS	86.8	86.8	3.30	2.71	8.91	7.20
23	MY, LW, LWC, MEI	86.8	86.8	3.29	2.69		
24	MY^{*3}, LW^{*3}, LWC^{3}, BS*	55.0	61.3	6.07	4.61		
25	MY, LW, MEI, BS	86.8	86.8	3.29	2.69		
26	MY, MEI, LWC, BS	86.7	86.8	3.30	2.69		
27	LW, MEI, LWC, BS	19.9	24.5	8.10	6.44		
28	MY, MEI	86.7	86.6	3.27	2.68		
29	LW, MEI, LWC, CS, MEIxCS	28.4		7.85			
Weeks 2-24							
30	MY, LW, LWC, MEI, BS	87.8	86.7	2.86	2.20	8.01	5.82
31	MY, LW, LWC, MEI	87.6	86.6	2.86	2.19		
32	MY^{*3}, LW^{*3}, LWC^{*3}, BS	54.1	58.5	5.51	3.85		
33	MY, LW, MEI, BS	87.2	86.2	2.91	2.22		
34	MY, MEI, LWC, BS	87.8	86.7	2.85	2.18		
35	LW, MEI, LWC, BS	42.7	43.6	6.15	4.48		
36	MY, MEI	86.9	85.9	2.92	2.22		

* = $P < 0.05$ Significant predictor variables for Trial 1

3 = $P < 0.05$ Significant predictor variables for Trial 2

Table A.59 *Precision of some prediction equations of nitrogen efficiency (MNE) from ME intake (MEI), milk yield (MY), liveweight (LW), condition score (BS) and liveweight change (LWC) per stage of lactation*

Stage of Lactation EQUATION	INDEPENDENT VARIABLES	R^2(%) Trial 1	R^2(%) Trial 2	RSD Trial 1	RSD Trial 2	ORIGINAL SD Trial 1	ORIGINAL SD Trial 2
Weeks 2-6							
1	MY, LW, LWC, MEI, BS	71.6	79.3	2.71	2.07	4.99	4.40
2	MY, LW, LWC, MEI	71.2	79.3	2.72	2.06		
3	MY*3, LW*3, LWC*, BS	38.5	57.7	3.97	2.94		
4	MY, LW, MEI, BS	71.1	79.3	2.73	2.06		
5	MY, MEI, LWC, BS	71.0	79.0	2.73	2.07		
6	LW, MEI, LWC, BS	26.4	30.0	4.35	3.78		
7	MY, MEI	70.6	78.5	2.73	2.06		
Weeks 7-12							
8	MY, LW, LWC, MEI, BS	76.0	52.1	2.16	2.54	3.32	3.55
9	MY, LW, LWC, MEI	75.6	51.6	2.17	2.54		
10	MY*3, LW*3, LWC3, BS*3	52.1	34.8	3.04	2.94		
11	MY, LW, MEI, BS	73.0	51.8	2.28	2.53		
12	MY, MEI, LWC, BS	75.4	52.1	2.18	2.52		
13	LW, MEI, LWC, BS	8.6	8.1	4.20	3.50		
14	MY, MEI	72.8	50.5	2.27	2.53		
Weeks 13-18							
15	MY, LW, LWC, MEI, BS	69.0	48.6	2.26	2.81	3.98	3.79
16	MY, LW, LWC, MEI	68.7	46.9	2.26	2.84		
17	MY*3, LW*, LWC, BS	49.1	35.5	2.89	3.13		
18	MY, LW, MEI, BS	66.9	47.9	2.33	2.81		
19	MY, MEI, LWC, BS	68.8	47.1	2.26	2.83		
20	LW, MEI, LWC, BS	12.4	14.5	3.79	3.60		
21	MY, MEI	65.4	45.3	2.36	2.84		
Weeks 19-24							
22	MY, LW, LWC, MEI, BS	73.0	60.3	2.29	2.47	4.32	3.80
23	MY, LW, LWC, MEI	72.8	59.6	2.29	2.48		
24	MY*3, LW*, LWC, BS*	65.2	59.9	2.59	2.50		
25	MY, LW, MEI, BS	72.7	59.7	2.29	2.48		
26	MY, MEI, LWC, BS	71.4	60.2	2.35	2.46		
27	LW, MEI, LWC, BS	14.1	23.7	4.07	3.41		
28	MY, MEI	70.9	59.0	2.35	2.46		
29	LW, MEI, LWC, CS, MEIxCS	28.6		3.80			
Weeks 2-24							
30	MY, LW, LWC, MEI, BS	75.9	54.8	1.71	2.23	3.40	3.22
31	MY, LW, LWC, MEI	75.9	54.8	1.71	2.23		
32	MY*3, LW, LWC*3, BS	58.7	44.5	2.22	2.46		
33	MY, LW, MEI, BS	73.5	54.7	1.78	2.23		
34	MY, MEI, LWC, BS	75.1	54.8	1.73	2.23		
35	LW, MEI, LWC, BS	17.6	25.1	3.14	2.85		
36	MY, MEI	72.0	54.6	1.81	2.19		

* = $P < 0.05$ Significant predictor variables for Trial 1

3 = $P < 0.05$ Significant predictor variables for Trial 2

Table A.60 Effect of parity on feeding behavioural traits means and variance ratios (VR) before (B) and after (A) adjustments[d] - Investigation 1

	PARITY			VARIANCE RATIO			
				Parity		Parity/Cow*	
TRAIT	1	2	SE of difference	B	A	B	A
Meal duration (min)	30.1	29.6	1.25	1.10	0.020	6.87	6.77
Rate of eating (kg/5 min)	0.48	0.55	0.016	43.28[c]	8.50[c]	12.97	12.45
Time spent eating (min)	99.8	83.7	2.26	28.47[c]	5.71[a]	12.53	11.41
Number of meals	3.7	3.2	0.114	14.38[c]	2.33	3.32	3.14
Daytime dry matter intake (DDMI, kg)	8.60	8.27	0.172	3.78	0.138	11.43	7.72
Night dry matter intake (NDMI, kg)	6.50	6.30	0.174	2.77	1.70	5.97	6.16
Total dry matter intake (TDMI, kg/day)	15.10	14.57	0.232	0.121	1.49	20.83	12.15
DDMI/TDMI (%)	56.7	56.8	1.08	1.57	0.48	5.42	5.15
NDMI/TDMI (%)	43.3	43.2	1.08	1.57	0.48	5.42	5.15
Meal size (kg)	2.32	2.58	0.112	7.53[b]	0.68	5.36	4.65
First inter-meal interval (min)	94.0	110.8	7.28	2.54	2.97	2.26	2.26
All inter-meal intervals (min)	89.3	102.0	6.88	17.54[c]	2.91	4.71	4.17
Milk yield (kg/day)	21.6	20.4	0.38	17.46[c]		54.1	
Liveweight (kg)	590	636	6.7	1802.6[c]		293.4	
Condition score (1-5 units)	2.75	2.73	0.046	2.61		5.31	
Stage of lactation (weeks)	28.7	28.1	0.34	0.98			

[d] adjusted for milk yield and liveweight, [a] $P < 0.05$, [b] $P < 0.01$, [c] $P < 0.001$

* parity/cow (cows within parities) $P < 0.01$ $VR > 1.67$

Table A.61 Effect of parity on feeding behavioural traits means and variance ratios (VR) before (B) and after (A) adjustments[d] - Investigation 2

				VARIANCE RATIO			
	PARITY		SE of	Parity		Parity/Cow	
TRAIT	1	2	difference	B	A	B	A
Meal duration (min)	25.0	24.3	1.50	1.85	130.53[c]	2.51[c]	7.17[c]
Rate of eating (kg/5 min)	0.45	0.49	0.037	6.70[b]	33.79[c]	7.95[c]	8.92[c]
Time spent eating (min)	106.8	99.2	1.75	16.75[c]	170.77[c]	4.50[c]	10.45[c]
Number of meals	4.6	4.1	0.105	10.69[c]	1.00	2.39[c]	2.07[c]
Daytime dry matter intake (DDMI, kg)	9.23	8.98	0.291	0.76	72.31[c]	5.07[c]	7.09[c]
Night dry matter intake (NDMI, kg)	3.96	3.99	0.165	0.10	0.13	3.49[c]	3.38[c]
Total dry matter intake (TDMI, kg)	13.2	13.0	0.231	0.46	72.42[c]	6.23[c]	7.55[c]
DDMI/TDMI (%)	70.1	69.2	2.39	1.41	25.16[c]	3.37[c]	4.30[c]
NDMI/TDMI (%)	29.9	30.8	2.39	1.41	25.16[c]	3.37[c]	4.30[c]
Meal size (kg)	2.06	2.25	0.064	4.65[a]	4.58[a]	2.75[c]	4.78[c]
First inter-meal interval (min)	146.0	153.8	7.78	0.79	10.66[c]	1.42[b]	1.63[b]
All inter-meal intervals (min)	117.2	138.4	4.75	15.17[c]	2.08	3.59[c]	2.86[c]
Milk yield (kg/day)	18.5	17.1	0.28	103.8[c]		67.42[c]	
Liveweight (kg)	591	635	6.1	1041.7[c]		227.4[c]	
Condition score (1-5 units)	2.78	2.85	0.010	12.61[c]		205.9[c]	
Stage of lactation (weeks)	32.8	32.1	0.45	1.10			

d adjusted for differences in milk yield and liveweight a $P < 0.05$; b $P < 0.01$; c $P < 0.001$

Table A.62 Effect of parity on feeding behavioural traits means and variance ratios (VR) before (B) and after (A) adjustments[a] - Investigation 3

TRAIT	PARITY 1	PARITY 2	SE of difference	VARIANCE RATIO Parity B	Parity A	Parity/Cow* B	Parity/Cow* A
Meal duration (min)	34.3	31.1	0.217	9.17[c]	2.53	3.62	3.29
Rate of eating (kg/5 min)	0.45	0.48	0.012	11.14[c]	1.79	5.95	4.92
Time spent eating (min)	129.2	108.4	2.40	46.75[c]	14.77[c]	7.10	5.45
Number of meals	3.9	3.6	0.107	9.18[c]	2.42	2.96	2.34
Daytime dry matter intake (DDMI, kg)	11.1	10.3	0.268	5.28[a]	8.47[c]	6.92	5.76
Night dry matter intake (NDMI, kg)	3.87	4.83	0.219	16.60[c]	1.78	3.26	3.31
Total dry matter intake (TDMI, kg)	14.9	15.2	0.252	1.21	3.78	6.88	5.47
DDMI/TDMI (%)	74.0	68.0	1.34	16.07[c]	3.58	3.83	3.70
NDMI/TDMI (%)	26.0	32.0	1.34	16.07[c]	3.58	3.83	3.70
Meal size (kg)	2.85	2.86	0.095	0.48	0.48	2.42	2.10
First inter-meal interval (min)	209.0	234.7	8.69	7.25[b]	2.37	2.57	2.30
All inter-meal intervals (min)	165.9	197.1	7.85	13.92[c]	9.62[c]	2.69	2.15
Milk yield (kg/day)	18.3	15.6		210.0[c]		35.70	
Liveweight (kg)	605	653		1460.8[c]		292.4	
Condition score (1-5 units)	2.80	2.88		12.4[c]		318.7	
Stage of lactation (weeks)	37.9	37.1		0.99			

[a] adjusted for differences in milk yield

* parity/cow (cows within parities) VR > 1.65 P < 0.001; [b] P < 0.01; [c] P < 0.001

Table A.63 Effect of parity (L) and stage of lactation (S) on eating behavioural traits and production traits - Investigation 4

	STAGE OF LACTATION							
	1			2			SE of difference	
PARITY	1	2	3	1	2	3	L	S
TRAIT								
Daytime dry matter intake (DDMI, kg)	8.45	11.51	10.18	9.47	12.92	10.63	0.252[c]	0.246[c]
Night dry matter intake (NDMI, kg)	4.62	5.56	5.48	5.19	5.87	6.12	0.166[c]	0.162[c]
Total dry matter intake (TDMI, kg)	13.07	17.07	15.66	14.67	18.80	16.75	0.249[c]	0.244[c]
DDMI/TDMI (%)	64.8	67.3	65.1	64.6	68.7	63.7	1.03	1.01
NDMI/TDMI (%)	35.2	32.7	34.9	35.4	31.3	36.4	1.03[c]	1.01
Number of meals	4.86	5.27	4.78	4.86	4.86	4.31	0.093[c]	0.091[b]
Time spent eating (min)	93.7	120.0	96.2	96.4	123.3	101.7	2.60[c]	2.54
Meal size (kg)	1.76	2.19	2.14	1.97	2.68	2.48	0.050[c]	0.049[c]
Rate of eating (kg/5 min)	0.47	0.50	0.55	0.51	0.54	0.53	0.011[c]	0.011[a]
First inter-meal interval (min)	126.6	108.5	115.9	140.4	107.8	135.0	5.53[c]	5.41
All inter-meal intervals (min)	124.9	111.4	126.1	147.4	125.1	135.8	3.90[c]	3.81[c]
Meal duration (min)	19.4	22.8	20.2	19.9	25.5	23.9	0.610[c]	0.594[c]
Fat corrected milk yield (kg/day)	22.2	31.7	34.4	23.2	32.1	30.3	0.592[c]	0.579[a]
Milk yield (kg/day)	21.0	30.1	32.9	23.0	33.3	32.0	0.547[c]	0.535
Liveweight (kg)	526.2	582.6	602.7	531.7	586.4	600.3	2.17[c]	2.12
Condition score (1-5 units)	2.68	2.65	2.78	2.65	2.60	2.75	0.011[c]	0.011[c]

[a] $P < 0.05$, [b] $P < 0.01$, [c] $P < 0.001$

Table A.64 Regression of dry matter intake (kg) on various feeding behavioural variables per period of day and by investigation

	PERIOD OF DAY							
	1		2		3		4	
VARIABLES	b ± SE	r	b ± SE	r	b ± SE	r	b ± SE	r
				INVESTIGATION 1				
Meal size	1.180 ± 0.0338	0.652	1.136 ± 0.0358	0.727	1.137 ± 0.0258	0.879		
Rate of eating	6.755 ± 0.323	0.074	5.032 ± 0.300	0.176	3.000 ± 0.162	0.623		
Meal duration	0.467 ± 0.0173	0.497	0.434 ± 0.0219	0.467	0.756 ± 0.0452	0.169		
Meals	2.298 ± 0.0884	0.246	1.923 ± 0.0994	0.221	2.775 ± 0.0154	0.079		
Time spent eating	0.389 ± 0.0093	0.735	0.377 ± 0.0147	0.720	0.592 ± 0.032	0.648		
				INVESTIGATION 2				
Meal size	1.086 ± 0.0197	0.800	1.117 ± 0.0237	0.681	1.058 ± 0.0147	0.932	1.129 ± 0.0180	0.857
Rate of eating	4.292 ± 0.1831	0.309	4.815 ± 0.2040	0.144	3.975 ± 0.163	0.594	2.960 ± 0.1151	0.610
Meal duration	0.4622 ± 0.0164	0.357	0.414 ± 0.0140	0.372	0.628 ± 0.0300	0.241	0.541 ± 0.0258	0.057
Meals	2.155 ± 0.0754	0.096	1.940 ± 0.061	0.309	3.143 ± 0.1551	0.058	2.367 ± 0.0901	0.202
Time spent eating	0.4356 ± 0.0121	0.473	0.361 ± 0.0096	0.585	0.5717 ± 0.0258	0.278	0.457 ± 0.0200	0.169
				INVESTIGATION 3				
Meal size	1.061 ± 0.0192	0.793	1.017 ± 0.0256	0.891	1.194 ± 0.0264	0.735	1.103 ± 0.0217	0.760
Rate of eating	7.099 ± 0.2320	0.346	4.927 ± 0.293	0.449	6.169 ± 0.282	0.407	4.860 ± 0.1756	0.309
Meal duration	0.476 ± 0.0148	0.378	0.470 ± 0.0247	0.534	0.606 ± 0.0258	0.070	0.445 ± 0.0141	0.433
Meals	3.269 ± 0.0960	0.388	2.484 ± 0.151	0.246	3.573 ± 0.1280	0.157	2.020 ± 0.0607	0.370
Time spent eating	0.459 ± 0.0104	0.651	0.471 ± 0.0207	0.651	0.491 ± 0.0170	0.264	0.405 ± 0.0097	0.642
				INVESTIGATION 4				
Meal size	1.327 ± 0.0261	0.740	1.201 ± 0.0296	0.736	0.987 ± 0.0327	0.659	1.227 ± 0.0275	0.652
Rate of eating	6.834 ± 0.224	0.258	4.930 ± 0.191	0.251	2.379 ± 0.186	0.074	3.046 ± 0.273	-0.528
Meal duration	0.625 ± 0.0205	0.454	0.591 ± 0.0181	0.569	0.480 ± 0.0205	0.448	0.638 ± 0.0171	0.548
Meals	2.596 ± 0.0709	0.354	2.093 ± 0.0614	0.605	1.7260 ± 0.0524	0.717	2.044 ± 0.0496	0.554
Time spent eating	0.474 ± 0.0109	0.685	0.481 ± 0.0106	0.807	0.478 ± 0.0137	0.781	0.498 ± 0.0111	0.672

Table A.65 Correlations between feeding behavioural variables and production variables per investigation

VARIABLES	Code	INVESTIGATIONS 1	2	3	4
DAYTIME DRY MATTER INTAKE					
Number of meals	1	-0.031	0.188	0.690	0.475
Time spent eating	2	0.419	0.360	0.504	0.543
Rate of eating	3	0.444	0.461	0.423	0.278
Meal size	4	0.776	0.768	0.764	0.696
Night intake	5	-0.335	-0.084	-0.364	0.042
Total dry matter intake	6	0.419	0.896	0.828	0.846
Liveweight	7	-0.016	-0.035	-0.105	0.392
Condition score	8	-0.301	-0.231	-0.347	-0.207
Milk yield	9	0.557	0.419	0.455	0.552
FCM yield	10				0.577
Calving liveweight	11				0.295
Calving condition score	12				-0.445
Wither height	13				0.407
Heart girth	14				0.389
Body length	15				0.240
TIME SPENT EATING					
Number of meals	16	0.050	0.118	0.565	0.257
Rate of eating	17	-0.595	-0.634	-0.554	-0.635
Meal size	18	0.296	0.009	0.325	0.152
Night dry matter intake	19	-0.216	-0.505	-0.765	-0.392
Total dry matter intake	20	0.258	0.111	0.066	0.238
Liveweight	21	-0.187	-0.238	-0.211	0.094
Condition score	22	-0.201	-0.270	-0.283	-0.272
Milk yield	23	0.216	0.002	0.195	0.194
FCM yield	24				0.136
Calving liveweight	25				-0.065
Calving condition score	26				-0.265
Wither height	27				0.253
Heart girth	28				0.024
Body length	29				0.117

For $r > 0.315$ $P < 0.05$; $r > 0.418$ $P < 0.01$

Continued/...

Table A.65 continued/...

VARIABLES	Code	INVESTIGATIONS 1	2	3	4
NUMBER OF MEALS					
Rate of eating	30	-0.595	0.011	0.059	-0.218
Meal size	31	-0.522	0.594	0.225	-0.292
Night dry matter intake	32	-0.134	-0.158	-0.507	-0.268
Total dry matter intake	33	-0.126	0.105	0.418	0.248
Liveweight	34	-0.057	-0.019	0.197	-0.076
Condition score	35	-0.021	0.096	0.204	-0.358
Milk yield	36	0.510	0.091	0.471	0.081
FCM yield	37				0.015
Calving liveweight	38				-0.225
Calving condition score	39				-0.465
Wither height	40				0.309
Height girth	41				-0.135
Body length	42				0.217
RATE OF EATING					
Meal size		0.360	0.594	0.308	0.457
Night intake		-0.028	0.400	0.423	0.477
Daily DMI		0.415	0.609	0.722	0.484
Liveweight		0.097	0.248	0.096	0.257
Condition score		-0.069	0.072	-0.060	0.113
Milk yield		0.253	0.310	0.241	0.283
FCM yield					0.366
Weight at calving					0.348
Condition score at calving					0.076
Wither height					0.037
Heart girth					0.356
Body length					0.058

Continued/...

Table A.65 continued/...

VARIABLES	Code	INVESTIGATIONS 1	2	3	4
MEAL SIZE					
Night DMI		-0.258	-0.029	-0.247	0.200
Daily DMI		0.776	0.730	0.567	0.680
Liveweight		0.016	0.296	0.131	0.478
Condition score		-0.324	0.085	-0.029	0.123
Milk yield		0.313	0.269	0.174	0.517
FCM yield					0.603
Calving liveweight					0.503
Calving condition score					-0.212
Wither height					0.170
Heart girth					0.501
Body length					0.095
Pre-meal interval		0.210	0.319		0.048
Post-meal interval		-0.051	-0.146		-0.197

Table A.66 Composition of diets fed furing the investigations

	INVESTIGATION		
	1	2 and 3	4
Dry matter (DM) concentration (g/kg)	295	348	364
Composition of DM:			
Crude protein (g/kg)	166	151	165
Modified acid detergent fibre (g/kg)	237	243	188
Ash (g/kg)	89	90	82
In vitro digestible organic matter (g/kg)	752	751	780
Estimated metabolizable energy (MJ/kg)	11.1	10.9	11.7
Ether extract (g/kg)	44	40	39
Silage DM (g/kg)	526	526	415

Table A.67 Average composition of complete diets during experiments

YEAR	1		2		3		4	5
Week of Lactation	**1-18**	**19-30**	**1-18**	**19-29**	**1-19**	**20-30**	**1-30**	**1-30**
Components (g/kg DM)								
Silage	350	580	545	530	497	542	504	429
Concentrate mix	600	370	405	420	453	408	446	521
Brewers' grains	50	50	50	50	50	50	50	50

Table A.68 Composition of grass silages and complete diets fed in years 1 and 2

WEEKS OF LACTATION	1 - 18				19 - 30			
	SILAGE		COMPLETE DIET		SILAGE		COMPLETE DIET	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
YEAR 1								
Dry matter (g/kg)	227	24	405	20	327	23	400	40
pH	4.23	0.43			4.56	0.22		
Composition of Dry Matter								
Crude protein (g/kg)	181	43	172	9	178	18	171	6
Modified acid detergent fibre (MADF, g/kg)	332	28	200	14	316	12	233	16
Ash (g/kg)	89	12	69	6	79	4	76	3
Ammona nitrogen (g/kg Total N)	126	56			125	30		
In vitro digestible organic matter (g/kg)	617	28	701	10	649	14	691	16
Estimated metabolizable energy (MJ/kg)	10.1	0.5	11.9	0.2	10.5	0.2	11.5	0.2
YEAR 2								
Dry matter (g/kg)	290	25	406	18	263	29	368	28
pH	3.99	0.17			3.95	0.51		
Composition of Dry Matter								
Crude protein (g/kg)	155	5	171	6	160	16	165	8
Modified acid detergent fibre (MADF, g/kg)	251	10	186	12	316	31	220	24
Ash (g/kg)	72	6	76	8	88	18	77	3
In vitro digestible organic matter (g/kg)	709	16	723	22	648	47	698	37
Estimated metabolizable energy (MJ/kg)	10.8	0.2	11.7	0.1	10.2	0.7	11.4	0.1
Ammonia nitrogen (g/kg Total N)	72	8			118	83		

SD = Standard deviation

Table A.69 Composition of grass silages and complete diets fed in years 4 and 5

WEEKS OF LACTATION	1 - 30			
	SILAGE		COMPLETE DIET	
	Mean	SD	Mean	SD
	YEAR 4			
Dry matter (g/kg)	268	53	380	37
pH	3.91	0.23		
Composition of Dry Matter				
Crude Protein (g/kg)	136	9	158	13
Modified acid detergent fibre (MADF, g/kg)	291	34	205	26
Ash (g/kg)	76	9	78	10
In vitro digestible organic matter (g/kg)	680	3	790	2
Estimated metabolizable energy (MJ/kg)	10.8	0.5	11.6	0.2
Ammonia nitrogen (g/kg Total N)	68	10		
	YEAR 5			
Dry matter (g/kg)	227	26	366	46
pH	3.84	0.29		
Composition of Dry Matter				
Crude protein (g/kg)	157	18	169	8
Modified acid detergent fibre (MADF, g/kg)	331	17	212	15
Ash (g/kg)	82	9	77	8
In vitro digestible organic matter (g/kg)	662	14	771	14
Estimated metabolizable energy (MJ/kg)	10.4	2.2	11.4	2.2
Ammonia nitrogen (g/kg Total N)	96	4		

SD = Standard deviation

Table A.70 Composition of grass silages and complete diets fed in year 3

WEEKS OF LACTATION	1 - 19				20 - 30			
	SILAGE		COMPLETE DIET		SILAGE		COMPLETE DIET	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Dry matter (g/kg)	238	27	327	38	247	14	340	21
pH	3.94	0.12			3.78	0.14		
Composition of Dry Matter								
Crude protein (g/kg)	166	23	169	17	175	10	168	9
Modified acid detergent fibre (MADF, g/kg)	301	26	227	28	291	20	222	26
Ash (g/kg)	79	4	73	5	73	5	73	3
In vitro digestible organic matter (g/kg)	677	18	776	30	678	27	679	29
Ammonia nitrogen (g/kg Total N)	93	45			83	38		
Estimated metabolisable energy (MJ/kg)	10.7	0.2	11.6	0.3	10.7	0.4	11.4	0.3

SD = standard deviation

Figure A.1: Relationship between dry matter intakes (kg/day) of 2 consecutive lactations of the same animal over weeks 2 to 6 of lactation.
Y=15.51(SE, 3.37)+0.208(SE, 0.203), R^2=3.1, RSD=2.78

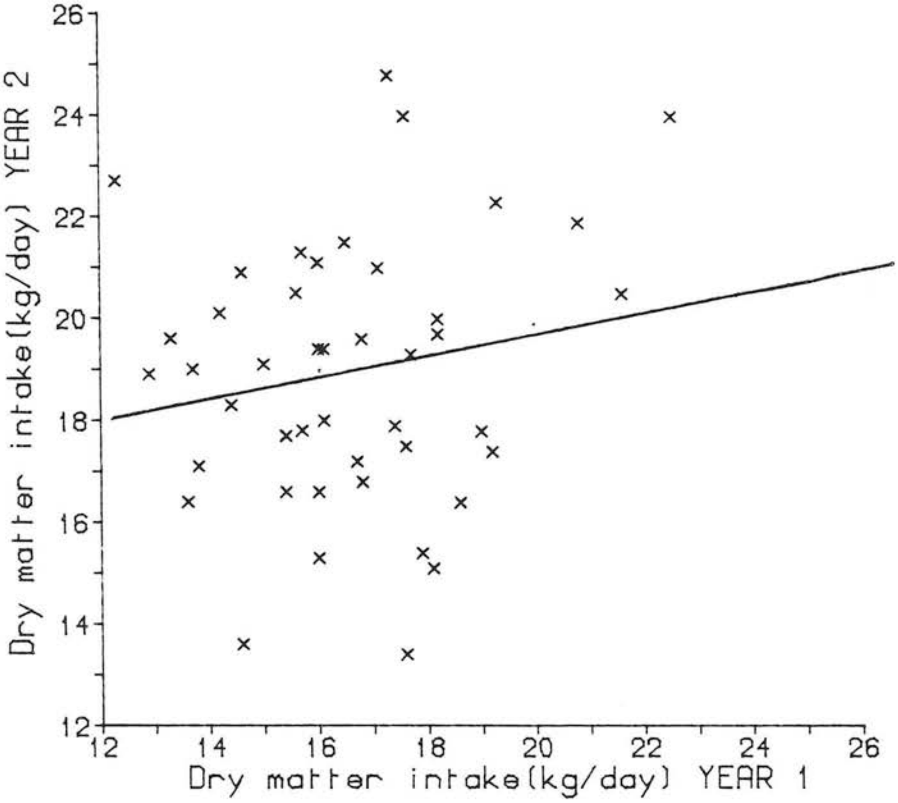


Figure A.2: Relationship between dry matter intakes (kg/day) of 2 consecutive lactations of the same animal over weeks 2 to 24 of lactation.
Y=8.25(SE, 2.43)+0.604(SE, 0.133), R^2=31.9, RSD=1.70

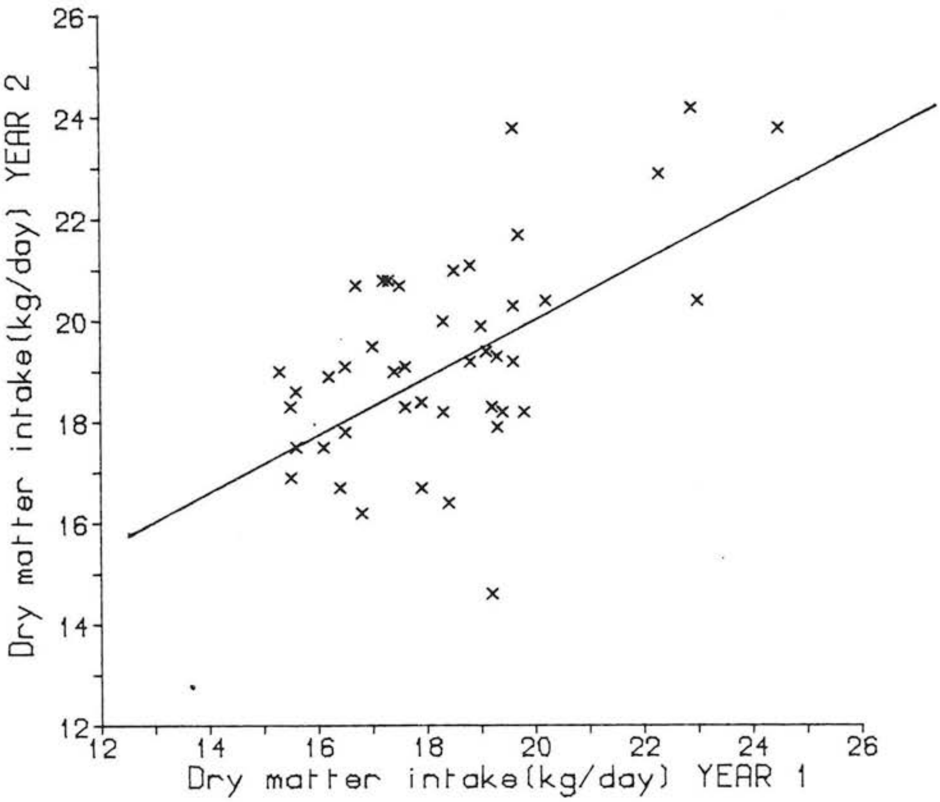


Figure A.3 : Relationship between milk yields(kg/day) of 2 consecutive lactations of the same animal over weeks 2 to 24 of lactation.
$Y=23.06(SE, 3.77)+0.211(SE, 0.145)X$; $R^2=11.1\%$, $RSD=3.94$

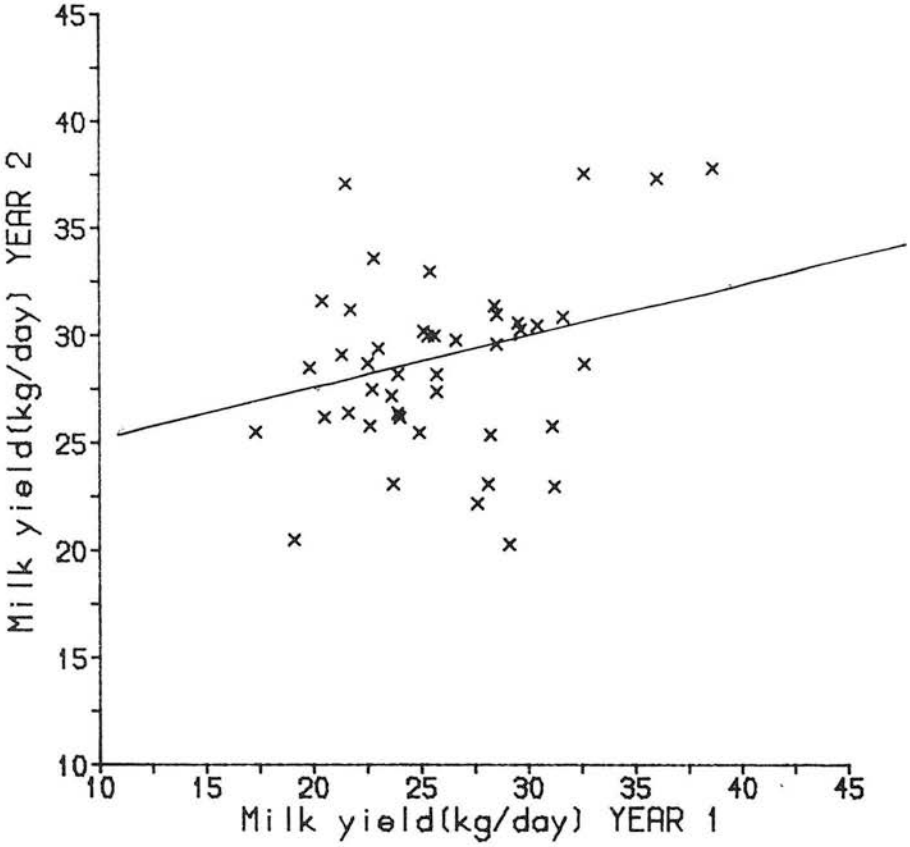
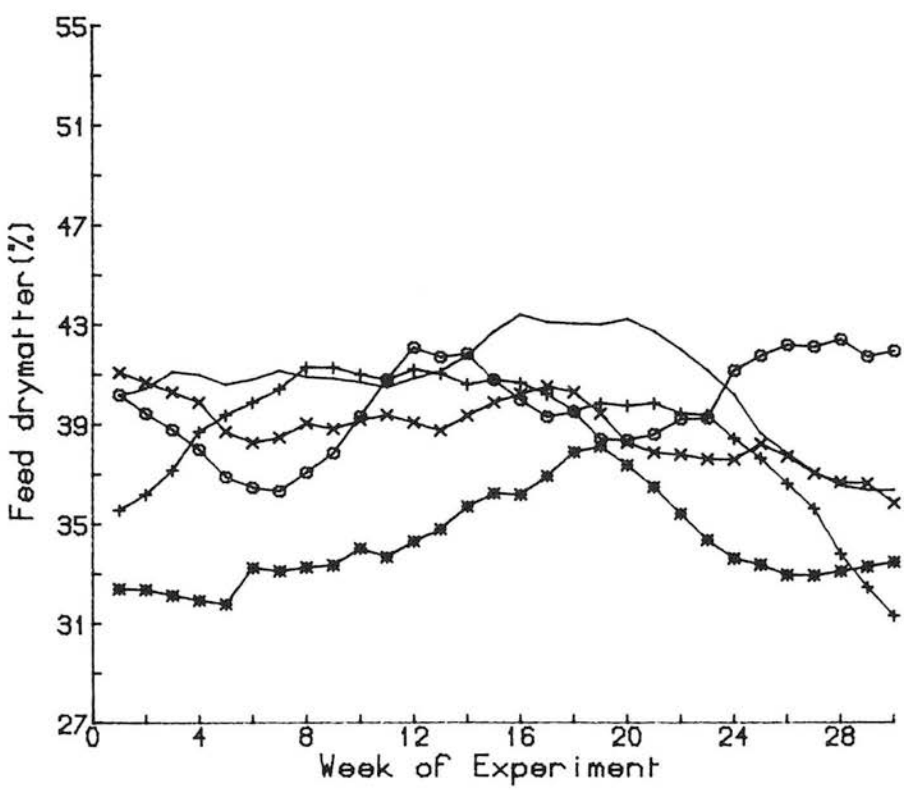


Figure A.4 : Mean drymatters(%) of feed fed during 30 weeks of experiment: Years 1(.), 2(X), 3(*), 4(0) and 5(+)



PUBLICATIONS

KABUGA, J D, NEILSON, D R and BLACK, W J M (1985). Feeding patterns of dairy cattle. Anim Prod, 40, 561 (Abstr).