

Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

**EFFECT OF DIFFERENCES IN LIVE WEIGHT ON FEED
REQUIREMENTS OF PREGNANT NON-LACTATING GRAZING
DAIRY COWS**

A thesis presented in partial fulfilment of the requirements
for the degree of Master of Agricultural
Science in Animal Science at
Massey University,
Palmerston North,
New Zealand

J.G. GARCÍA-MUÑIZ

1994

EFFECT OF DIFFERENCES IN LIVE WEIGHT ON FEED REQUIREMENTS OF
PREGNANT NON-LACTATING COWS.

- (1) I give permission for my thesis to be made available to readers in Massey University Library under conditions determined by the Librarian.
- (2) I agree that my thesis, or a copy, may be sent to another institution under conditions determined by the Librarian.
- (3) I agree that my thesis may be copied for Library use.

Signed



Date

22nd

1994

The copyright of this thesis belongs to the author. Readers must sign their name in the space below to show that they recognise this. They are asked to add their permanent address

NAME AND ADDRESS

DATE

ABSTRACT

The effect of differences in live weight (LW) on feed requirements of pregnant non-lactating cows was assessed during a 41-day grazing experiment. Thirty eight dry pregnant Friesian and Jersey cows (28 Friesian cows differing in live weight and 10 Jerseys) at similar stages of pregnancy (range 190 to 230 days pregnant) and averaging 5.8 years of age were used. The cows were grouped according to their initial LW in three size-groups, i.e. Big Friesians (BF; n=14, LW = 526 kg), Small Friesians (SF; n=14, LW = 415 kg) and Jerseys (J; n=10, LW = 362 kg). Within each size-group the cows were randomly allocated to one of two levels of daily herbage dry matter (DM) allowance (HA), calculated to meet either maintenance and pregnancy (i.e. HA of 7.7 to 11.0 kg DM/cow/day), or the gain of 1 kg of maternal live weight above maintenance and pregnancy (i.e. HA of 17.1 to 22.5 kg DM/cow/day).

The cows provided individual records of their daily liveweight gain (LWG, kg/cow), total liveweight gain (Δ LW) and total condition score change (Δ CS) achieved during the 41-day experimental period. Group average herbage dry matter intake (DMI) and herbage DM allowance were calculated for each treatment group from herbage mass (HM) assessed by cutting-washing-drying and weighing, and by means of two calibration equations, one for each level of feeding, relating HM to the average of 30 plate meter readings (PMR) taken every day before and after grazing. These two calibration equations were:

- (1) for the *ad libitum* level of feeding:

$$\text{HM (kg DM/ha)} = 764.0 \text{ (s.e. 212.0)} + 158.0 \text{ (s.e. 12.7)} * \text{PMR}$$

($r = 0.98$; CV = 24%; r.s.d. = 548 kg DM), and

- (2) for the maintenance fed cows:

$$\text{HM (kg DM/ha)} = 171.0 \text{ (s.e. 3.5)} * \text{PMR}$$

($r = 0.98$; CV = 21.6%; r.s.d. = 442 kg DM).

The energy content of the herbage (MJ ME/kg DM) apparently grazed by the cows and their metabolizable energy intake (MEI) were calculated from the *in vitro* digestibility analyses of pasture samples plucked randomly from each of the grazing areas. Least squares means were calculated for group average herbage dry matter intake (DMI), herbage DM allowance (HA), metabolizable energy intake (MEI), and for the variables derived from the animals' performance (Δ LW, LWG, Δ CS) and differences between levels of feeding and size-groups were tested for significance using analysis of variance.

Differences in average live weight between the three size-groups were highly significant ($P < 0.001$) throughout the experimental period (i.e. BF = 552 kg; SF = 442 kg; J = 377 kg). Heavier cows had: (1) significantly higher daily herbage DM allowances (BF, 16.7; SF, 14.4; J, 12.4 kg/cow/day); (2) higher daily DMI (BF, 10.2; SF, 8.6; J, 7.5 kg/cow/day); (3) higher MEI (BF, 117; SF, 100; J, 87 MJ/cow/day), and (4) lower stocking densities (BF, 240; SF, 262; J, 305 cows/ha/24 hours). However, when HA, DMI and MEI were expressed on a metabolic weight basis, none of these variables were significantly different between the three size-groups.

From the least squares means of LWG, Δ CS, DMI and MEI calculated for each treatment group, feed requirements for zero Δ CS or maintenance (i.e. ME_m) and feed requirements for Δ CS were calculated by means of linear regression analyses. The ME_m calculated pooling the three size-groups was $0.648 \text{ MJ ME/LW}^{0.75}/\text{day}$ for zero Δ CS; and an average intake of 167 kg DM or 1986 MJ ME/cow above maintenance was required for the gain of one condition score unit/cow during the 41 days of experimental period, which was equivalent to a total liveweight change of 52.7 kg/cow. From these estimates it was calculated that cows heavier by 100 kg required an extra intake for maintenance of 10.5 MJ ME/cow/day or about 0.95 kg herbage dry matter intake/cow/day. The results of the present experiment were used to assess the effect of farming large-size cattle on the productive efficiency of pasture-based dairy systems.

ACKNOWLEDGEMENTS

I would like to thank my supervisors Dr. C. W. Holmes and Dr. G.F. Wilson for their advice and assistance with this project.

My special acknowledgement is given to Dr. C. W. Holmes for all the time and effort he devoted to help me with the experiment. For his invaluable help in the preparation and revision of the manuscript, and for his very nice and special way of encouraging me to get this project finished.

This work would not have been possible without the help of Mr. G. S. Purchas, who collected all the grass cutting data of the experiment; the skilful assistance of Messrs. M. and B. Chesterfield in animal husbandry practices; the help of the members of the Nutrition Laboratory of the Animal Science Department, who analyzed all the grass and faecal samples, and the help of Mr. D. Fountain in running the experiment. All their help was invaluable and very much appreciated.

I would also like to thank the staff members of the Animal Science Department for their help and assistance they gave me during these two years at Massey University. My special thanks to Dr. P. C. H. Morel for his advice and help in statistical analyses, and to Dr. S. W. Peterson for his valuable suggestions to improve the standard of presentation of the final document.

My thanks are also given to Dr. C. Matthew, of the Plant Science Department, for his help in some agronomic aspects of this project.

My special thanks are given to the New Zealand Ministry of external relations and Trade, for awarding me an scholarship to undertake a two-year master programme at Massey University, and for looking after me and my family all this time.

This New Zealand Experience was possible thanks to the Departamento de Zootecnia, Universidad Autónoma Chapingo, México, that proposed me as a candidate and allowed me the time required to undertake this master programme.

Finally, I would like to thank my wife Marcela and my son José Alberto for all their support and for making me so happy during all this time in New Zealand.

TABLE OF CONTENTS

ABSTRACT	i
ACKNOWLEDGEMENTS	iii
LIST OF TABLES	vii
LIST OF FIGURES	xi
LIST OF PLATES	xiii
LIST OF ABBREVIATIONS AND SYMBOLS	xiv
LIST OF APPENDICES	xix
INTRODUCTION	1
LITERATURE REVIEW	3
2.1. The energy content of pasture.	3
2.2. Some conversion factors to assess the energy content of pasture.	4
2.3. Estimation of herbage intake by grazing cattle.	7
2.3.1. Herbage intake assessed from faecal output.	7
2.3.1.1. Methods to estimate daily faecal output.	8
i) Total faeces collection.	8
ii) Use of indigestible markers.	8
2.3.1.2. Accuracy of Cr ₂ O ₃ in estimating faecal output.	10
2.3.1.3. Estimation of herbage digestibility.	11
2.3.2. Herbage intake assessed by sward methods.	12
2.3.2.1. Measurements of sward height and density.	13
2.3.2.2. Measurements of non-vegetative attributes of the sward.	13
2.4. Feed requirements of dairy cows.	14
2.4.1. Maintenance requirements.	14
2.4.1.1. ME _m assessed by energy balance trials (calorimetry).	14
A. ME _m estimated from fasting metabolism data.	14
i) Fasting metabolism.	15
ii) Efficiency of utilization of ME _m (k _m).	16
iii) Calculated ME _m for dry cows of different live weight.	17
B. ME _m estimated by regression analyses.	18
i) ME _m for non-lactating cows.	19
ii) ME _m for lactating cows.	20

2.4.1.2. ME _m calculated by means of stallfeeding trials.	22
2.4.1.3. ME _m assessed by means of grazing trials.	23
2.4.2. ME required for liveweight gain.	27
2.4.2.1. Energy value of the liveweight gain.	27
2.4.2.2. Efficiency of utilization of ME for growth and fattening (k_g)	28
2.4.3. ME requirements for pregnancy.	32
2.5. Efficiency of production of dairy cattle.	36
2.5.1. Some estimates of gross feed efficiency in dairy cattle.	37
2.5.2. Between breed differences in gross feed efficiency.	39
2.5.3. Within breed differences in gross feed efficiency.	40
2.6. Relationships between cow efficiency, intake and body size.	41
2.7. Cow feed efficiency and dairy farm productivity.	45
2.7.1. Ranking cows according to efficiency.	45
2.7.2. Cow size and feed requirements.	46
2.7.3. Large size cows and dairy farm profitability.	48
MATERIALS AND METHODS	50
3.1. Location of the experimental area.	50
3.2. Animals and treatments.	50
3.3. Pastures.	51
3.4. Experimental design.	51
3.5. Calculation of herbage allowances.	52
3.6. Grazing management.	53
3.7. Variables measured and generated in the experiment.	55
3.7.1. Live weight and condition score.	55
3.7.2. Cow age, previous calving date and days since conception.	55
3.7.3. Pre-grazing and post-grazing herbage mass.	55
3.7.3.1. Herbage mass assessed by cutting.	55
3.7.3.2. Herbage mass assessed by plate meter.	56
3.7.4. Daily herbage allowance.	57
3.7.5. Daily herbage intake.	57
3.7.6. Efficiency of grazing.	57
3.7.7. Stocking density.	57
3.7.8. Herbage sampling and analysis.	58
3.8. Estimation of intake by individual cows from daily faecal output.	58
3.9. Statistical analysis.	59
RESULTS	61
4.1. Introduction.	61
4.2. Estimation of herbage dry matter intake.	61
4.2.1. Estimation of daily faecal output using chromium oxide (Cr_2O_3).	62
4.2.2. Estimation of daily herbage DM intake by the plate meter.	62
4.2.2.1. Pre-grazing and post-grazing herbage mass.	64
4.2.2.2. Herbage dry matter allowance.	65
4.2.2.3. Apparent herbage dry matter intake (average for each treatment group).	66
4.2.2.4. Efficiency of grazing, daily area and stocking density.	67

4.3. Estimation of metabolizable energy allowance and ME intake.	68
4.3.1. Herbage digestibility and ME content.	68
4.3.2. Metabolizable energy allowance.	69
4.3.3. Metabolizable energy intake.	70
4.4. Variables derived from the animals' performance.	71
4.4.1. Cow age and stage of pregnancy.	71
4.4.2. Liveweight change.	71
4.4.3. Condition score change.	73
4.5. Relationship between Δ CS and liveweight change.	74
4.6. Feed requirements for zero Δ CS calculated separately for each size- group.	76
4.7. Feed requirements for the average Δ LW or the average Δ CS calculated separately for each size-group.	78
4.7.1. Feed intake requirements.	79
4.7.2. Herbage allowance requirements.	81
4.8. Feed requirements for zero Δ CS and CS gain pooled for the three size-groups.	84
4.9. Effect of large cow size on daily feed requirements.	85
4.10. Photographs.	88
DISCUSSION	92
5.1. Relationship between Δ LW and Δ CS.	92
5.2. Calculation of feed requirements.	94
5.2.1. Feed requirements for zero Δ CS calculated separately for each size-group.	94
5.2.2. Feed requirements for the average Δ LW or the average Δ CS calculated separately for each size-group	95
5.2.3. Feed requirements for zero Δ CS and CS gain pooled for the three size-groups.	96
5.2.3.1. Dry matter requirements.	97
5.2.3.2. Metabolizable energy requirements.	99
5.3. Effect of large cow size.	101
5.3.1. Effect of large cow size on daily feed requirements.	102
5.3.2. Effect of large cow size on farm management requirements.	102
5.5. Limitations of the results obtained.	106
5.5.1. Estimation of individual cow intakes.	106
5.5.2. Estimation of group mean intakes.	107
5.5.3. Calibration of the rising plate meter.	107
CONCLUSIONS	109
REFERENCES.	110
APPENDICES	118

LIST OF TABLES

	<u>Page</u>
Table 2.1 . Some estimates of the concentration of metabolizable energy (MJ/kg) in the feed as reported by several authors in the literature.	6
Table 2.2. Generalised Equations for predicting k_m from attributes of the feed.	17
Table 2.3. ME_m for dry pregnant cows of different body size (live weight) calculated using fasting metabolism equations.	18
Table 2.4. ME_m (MJ ME/LW ^{0.75} /day) for non-lactating dairy cows obtained by means of energy balance trials and using regression analyses.	20
Table 2.5. ME_m (MJ ME/LW ^{0.75} /day) for lactating dairy cows obtained by means ² of EB trials and using regression analyses.	21
Table 2.6. ME_m (MJ ME/LW ^{0.75}) of lactating and dry cows assessed by means of stall-feeding trials.	23
Table 2.7. Energy costs above maintenance associated with the grazing activities	24
Table 2.8. ME_m (MJ ME/LW ^{0.75} /day) of grazing dairy cattle assessed by multiple regression analyses.	25
Table 2.9. Estimates of the ME_m (MJ ME/LW ^{0.75} /day) of lactating and non-lactating dairy cows assessed by different methods (mean±S.D.)	26
Table 2.10. Equations for predicting the efficiency of utilization of metabolizable energy for growth an fattening (k_g) in adult sheep and cattle.	29
Table 2.11. Efficiency of utilization of ME for growth and fattening (k_g) in non-lactating dairy cows as reported in experiments from the literature.	29

Table 2.12. ME required for liveweight gain (MJ ME /kg liveweight gain) by lactating and non-lactating dairy cattle calculated by means of multiple regression analyses.	31
Table 2.13. Average values of k_p for ewes, dairy and beef cows	32
Table 2.14. Relationships of some components of foetus, conceptus or gravid uterus to day of gestation, and their corresponding efficiencies of utilization of ME for energy retention (After Ferrell <i>et al.</i> , 1976 a, 1976 b)	33
Table 2.15. Estimates of gross feed efficiency of dairy cattle as reported by several authors in the literature.	38
Table 2.16. Heritability (h^2 S.E.) and repeatability (r) estimates for feed efficiency in dairy cattle.	41
Table 2.17 . Phenotypic correlations among measures of intake, efficiency, yield and body size in dairy cattle.	43
Table 2.18 . Genetic correlations among measures of intake, efficiency, yield and body size in dairy cattle.	44
Table 2.19. Effect of an extra 100 kg live weight on the maintenance requirements of grazing dairy cows.. . . .	47
Table 2.20. Effect of increasing live weight by 100 kg/cow on the energy (MJ ME) or dry matter (kg) required for maintenance of dairy cows, as reported by several authors in the literature.	48
Table 3.1. Mean values (\pm S.E.) for live weight (kg), metabolic weight ($LW^{0.75}$, kg) and days since conception at the start of the experimental period for the different treatment groups	51
Table 3.2. Calculated requirements of ME (MJ/cow/day), DM (kg/cow/day) and HA (kg/cow/day) for each treatment group at the start of the experimental period	52
Table 3.3. Information used to calculate the daily areas required by each treatment group	53
Table 4.1. Least squares means and standard errors for pre-grazing and post-grazing herbage mass (t DM/ha) for each treatment group during the experimental period	64
Table 4.2. Least squares means and standard errors for daily herbage dry matter allowance (HA) for each treatment group during the experimental period (HA expressed either as kg DM/cow/day, kg DM/100 kg live weight or g DM/ $LW^{0.75}$).	65

Table 4.3. Least squares means and standard errors for herbage dry matter intake (DMI) for each treatment group (DMI expressed as kg DM/cow/day, kg DM/100 kg live weight, and as g DM/LW ^{0.75} /day).	66
Table 4.4. Least squares means and standard errors for daily area (m ² /cow), stocking density (cows/ha/24 hours) and efficiency of grazing (%).	67
Table 4.5. Herbage organic matter content (OM, %), nitrogen content (N, %), predicted <i>in vivo</i> digestibility of the dry matter (DMD, %), predicted <i>in vivo</i> digestibility of the organic matter expressed as a proportion of the dry matter (DOMD, %) and predicted <i>in vivo</i> digestibility of the organic matter (OMD, %).	68
Table 4.6. Least squares means and standard errors for metabolizable energy allowance (MEA) for each treatment group (MEA expressed as MJ/cow/day, MJ/100 kg LW or MJ/LW ^{0.75}).	69
Table 4.7. Least squares means and standard errors for metabolizable energy intake (MEI) (MEI given as MJ/cow/day, MJ/100 kg LW or MJ/LW ^{0.75}).	70
Table 4.8. Least squares means and standard errors for cow age and days since conception for each group of cows during the experimental period.	71
Table 4.9. Least squares means and standard errors for initial live weight, final live weight, total liveweight change, and daily liveweight gain (kg/cow, unadjusted for pregnancy) during the experimental period.	72
Table 4.10. Least squares means and standard errors for initial condition score, final condition score, total condition score change and average daily condition score gain during the experimental period.	73
Table 4.11. Least squares means for average days pregnant and total daily LWG (i.e. maternal + gravid uterus weight gain); gravid uterus and maternal liveweight gain estimated from regression equations relating ΔLW to ΔCS or predicted as by Ferrell <i>et al.</i> (1976 b).	76
Table 4.12. Estimated daily intake of dry matter or metabolizable energy required for maintenance	78
Table 4.13. Estimated daily amount of dry matter intake or metabolizable energy intake required to achieve (a) the mean change in liveweight or (b) the average change in total condition score.	79
Table 4.14. Estimated daily amount of either dry matter allowance or metabolizable energy allowance required to achieve (a) the mean change in liveweight or (b) the mean change in total condition score.	82

Table 4.15. Effect of an extra 100 kg cow live weight on increasing the intake of metabolizable energy or dry matter required for maintenance, or for the average condition score gain.	87
Table 5.1. Pasture dry matter requirement for maintenance of body condition score and for gain in condition score by dry pregnant dairy cows.	98
Table 5.2. Metabolizable energy (MJ/LW ^{0.75} /day) required for maintenance of body condition score and for gain in condition score by dry pregnant dairy cows.	100
Table 5.3. Least squares means (S.E) for herbage DM allowance (kg/cow/day), herbage DMI (kg/cow/day), residual herbage mass (kg DM/ha/day), efficiency of grazing (%) and stocking density (cows/ha/24 hr.).	101
Table 5.4. Effect of an extra 100 kg live weight/cow (in the range 350 to 550) on the cow's daily energy (MJ ME) or dry matter (kg) required for maintenance, and on the extra growth of pasture annually required on the farm (t DM/ha).	103
Table 5.5. Annual feed requirements of dairy cows of different live weight and stocking rates required to achieve the same level of pasture utilization . . .	104

LIST OF FIGURES

- | | <u>Page</u> |
|---|-------------|
| Fig. 1. Diagram of the paddocks being grazed by the herds in each treatment group; double lines represent boundary fences, broken lines represent temporary electric fences; first subdivision represent the area of pasture already utilized; second subdivision represent the area being grazed by the treatment groups [J= Jersey (5 cows); SF= Small Friesian (7 cows); BF = Big Friesian (7 cows)]. The shaded area corresponds to the area to be grazed the following day, and the following subdivision is an extra strip of pasture set up ahead of the cows. | 54 |
| Fig. 2. Relationship between plate meter reading (cm) and herbage mass (kg DM/ha) pre and post-grazing assessed by cutting. Each symbol represents a daily observation of a treatment group for Big Friesians: □,■; Small Friesians: ◇,◆, or Jersey cows: ✨,★, fed at maintenance or <i>ad libitum</i> , respectively. The dotted regression line corresponds to the maintenance level of feeding and the continuous regression line to the <i>ad libitum</i> level of feeding. | 63 |
| Fig. 3. Relationship between total liveweight gain (kg/cow/41 days experimental period) and total condition score change. Each symbol represents either an observation for an individual cow (a) or the mean of a treatment group (b) of Big Friesians: □,■; Small Friesians: ◇,◆, or Jersey cows: ✨,★, fed at maintenance or <i>ad libitum</i> , respectively. | 75 |
| Fig. 4. Relationship between daily liveweight gain (kg/cow) and MEI (MJ ME/LW ^{0.75} /day) using group means for Big Friesians:□,■; Small Friesians:◇,◆, or Jersey cows:✨,★, fed at maintenance or <i>ad libitum</i> , respectively. Vertical bars at the top and at the bottom of each symbol represent the standard error of the mean, and the horizontal dotted lines represent the estimated (a) and the predicted (b) daily weight gain of the gravid uterus for each size-group (J= ; SF=---.---.;BF = - - -). . . . | 77 |

- Fig. 5. Relationship between daily liveweight gain (kg/cow) and daily MEI (MJ ME/LW^{0.75}/day). Each symbol represents the average of the group over the experimental period for Big Friesians:□,■; Small Friesians:◇,◆, or Jersey cows:⊛,★, fed at maintenance or *ad libitum*, respectively. Vertical bars at the top and at the bottom of each symbol represent the standard error of the mean, the horizontal dotted line at the middle of the graph represents the average liveweight gain for all the treatment groups during the experimental period. 80
- Fig. 6. Relationship between total condition score change (CS units/cow/41-day experiment) and MEI (MJ/LW^{0.75}/day). Each symbol represents the average of the group over the experimental period for Big Friesians:□,■; Small Friesians:◇,◆, or Jersey cows:⊛,★, fed at maintenance or *ad libitum*, respectively. Vertical bars at the top and at the bottom of each symbol represent the standard error of the mean, the horizontal dotted line at the middle of the graph represents the average condition score gain for all the groups during the experimental period. 81
- Fig. 7. Relationship between LWG (kg/cow/day) and (a) HA (kg DM/cow/day) and (b) condition score change, using group means for Big Friesians: □,■; Small Friesians:◇,◆, or Jersey cows:⊛,★, fed at maintenance or *ad libitum*, respectively. Vertical bars at the top and at the bottom represent the standard error of the mean; the horizontal dotted line at the middle of the graph represents the average LWG (a) or the average CS gain (b) for all the groups during the experimental period. 83
- Fig. 8. Relationship between metabolizable energy intake (MEI) (MJ ME/LW^{0.75}/day) and total condition score change (CS units/cow/41-day experiment). Each symbol represents the average of a treatment group of Big Friesians:□,■; Small Friesians:◇,◆ or Jersey:⊛,★ cows fed at maintenance (empty symbols) or *ad libitum* (filled symbols) respectively. 85
- Fig. 9. Relationship between average cow live weight (kg) and daily metabolizable energy intake (MJ/cow/day) for maintenance (ME_m) (solid lines) or for the average condition score change (ME_{CS}) (broken regression line). Each point represents the average of a treatment group. 86

LIST OF PLATES

	<u>Page</u>
Plate 4.1. Allowance layout for the treatment groups fed <i>ad libitum</i> (Herbage allowance, 20 kg DM/cow/day; Residual herbage mass, 1800 kg DM/ha/day).	88
Plate 4.2. Allowance layout for the treatment groups offered an allowance for maintenance (Herbage allowance, 9.5 kg DM/cow/day; Residual herbage mass, 782 kg DM/ha/day).	88
Plate 4.3. Group of Big Friesian cows fed <i>ad libitum</i> (Herbage allowance, 23 kg DM/cow/day; Residual herbage mass, 1835 kg DM/ha/day).	89
Plate 4.4. Group of Big Friesian cows offered an allowance for maintenance (Herbage allowance, 11.0 kg DM/cow/day; Residual herbage mass, 782 kg DM/ha/day).	89
Plate 4.5. Group of Small Friesian cows fed <i>ad libitum</i> (Herbage allowance, 20 kg DM/cow/day; Residual herbage mass, 1830 kg DM/ha/day).	90
Plate 4.6. Group of Small Friesian cows offered an allowance for maintenance (Herbage allowance, 9.6 kg DM/cow/day; Residual herbage mass, 813 kg DM/ha/day).	90
Plate 4.7. Group of Jersey cows fed <i>ad libitum</i> (Herbage allowance, 17.7 kg DM/cow/day; Residual herbage mass, 1844 kg DM/ha/day).	91
Plate 4.8. Group of Jersey cows offered an allowance for maintenance (Herbage allowance: 7.8 kg DM/cow/day; Residual herbage mass, 750 kg DM/ha/day).	91

LIST OF ABBREVIATIONS AND SYMBOLS

□	Group of Big Friesian cows fed at maintenance.
■	Group of Big Friesian cows fed <i>ad libitum</i> .
◇	Group of Small Friesian cows fed at maintenance.
◆	Group of Small Friesian cows fed <i>ad libitum</i> .
⊛	Group of Jersey cows fed at maintenance.
★	Group of Jersey cows fed <i>ad libitum</i> .
>	Greater than.
*	Significant at $P < 0.05$.
**	Significant at $P < 0.01$.
***	Significant at $P < 0.001$.
α	Constant term of simple or multiple regression equations.
4% FCM	4% Fat corrected milk yield (kg).
b	Linear regression coefficient.
BF	Big Friesian cows.
B_i	Partial regression coefficient.
BI	Breeding index.
Δ CS	Total condition score change (CS units/cow/41 days experiment).
Δ LW	Total liveweight change (kg/cow/41 days experiment).
C.V.	Coefficient of variation (%).
CF	Correction factor for the recovery rate of the indigestible marker.
CP	Crude protein (%).
Cr_2O_3	Chromium oxide.
CRC	Controlled release chromium capsule.
CSG	Condition score gain (CS units/cow/day).
D	Herbage digestibility (%).

d	days.
DCP	Digestible crude protein (%).
DE	Digestible energy (MJ/kg DM).
DM	Dry matter (%).
DMD	Dry matter digestibility (%).
DMI	Dry matter intake (kg/cow/day).
DOMD	Digestible organic matter expressed as a proportion of the DM.
<i>e</i>	Base of the natural logarithm.
EB	Energy balance.
EEI	Estimated energy intake (MJ/day).
ENE	Estimated net energy intake (Mcal/day).
EV _g	Energy value of the gain (MJ/kg).
FCS	Final condition score (CS units/cow).
FEI	Feed energy intake (MJ/day).
FHP	Fasting heat production (MJ/day).
FLW	Final live weight (kg/cow).
FM	Fasting metabolism (MJ/cow/day).
FO	Faecal output.
FPCM	Fat and protein corrected milk yield (kg).
FU _m	Feed units for maintenance.
FW	Fasted live weight (kg).
g	Grams.
GE	Gross energy.
GBF	Big Friesians fed <i>ad libitum</i> .
GFE	Gross feed efficiency (%).
GJer	Jersey cows fed <i>ad libitum</i> .
GSF	Small Friesians fed <i>ad libitum</i> .
<i>h</i> ²	Heritability (%).

ha	hectare.
HA	Herbage allowance (kg DM/cow/day).
HM	Herbage mass (kg DM/ha).
HM ^{fe}	Herbage mass measured in enclosure areas (kg DM/ha).
hr	Hour.
I	Intake.
ICS	Initial condition score (CS units/cow).
ILW	Initial live weight (kg/cow).
J	Jersey cows.
kg	kilogram.
k_g	Efficiency of utilization of ME for growth and fattening (%).
$k_{g(1)}$	Efficiency of utilization of ME for body tissue deposition when the cow is lactating (%).
k_1	Efficiency of utilization of ME for milk and tissue energy deposition (%).
km	Kilometre.
k_m	Efficiency of utilization of ME for maintenance (%).
k_p	Efficiency of utilization of ME for pregnancy (%).
k_{p1}	Efficiency of utilization of ME for the synthesis of uterine tissue and uterine contents (%).
k_{p2}	Efficiency of utilization of ME for oxidation due to pregnancy (%).
k_{p3}	Efficiency of utilization of ME for foetal maintenance and increased maternal fasting metabolism due to pregnancy (%).
LW	Live weight.
LW ^{0.75}	Metabolic weight.
LWG	Liveweight gain (kg/cow/day).
M/D	Energy concentration of the pasture (MJ ME/kg DM).
MBF	Big Friesian cows fed at maintenance.
Mcal.	Megacalories.
ME	Metabolizable energy (MJ/kg DM).
MEA	Metabolizable energy allowance (MJ).
ME _g	Metabolizable energy intake for liveweight gain (MJ/day).

MEI	Metabolizable energy intake (MJ/cow/day).
MEI	Metabolizable energy intake (MJ).
ME _m	Metabolizable energy for maintenance (MJ/LW ^{0.75} /day).
ME _p	Metabolizable energy for pregnancy (MJ/day).
ME _y	Metabolizable energy used for milk yield.
MF	Milkfat (kg).
MJ	Megajoules.
MJer	Jersey cows fed at maintenance.
MLWG	Maternal liveweight gain (kg/cow/day).
MSF	Small Friesian cows fed at maintenance.
N	Nitrogen (%).
NE _g	Net energy of the gain made (MJ/kg liveweight gain).
NE _p	Net energy for pregnancy (MJ/day).
N _{p1}	Net energy stored in uterus and the uterine contents (MJ/day).
N _{p2}	Net energy lost as 'Heat increment of gestation' (MJ/day).
N _{p3}	Net energy for foetal maintenance and the increased maternal fasting metabolism due to pregnancy (MJ/day).
OMD	Organic matter digestibility (%).
P	Protein content of the organic matter (g/kg).
PHM	Pre-grazing herbage mass (kg DM/ha).
q	Metabolizability [i.e. (DE/ME)*100].
qL	Metabolizability determined at any level of feeding.
qm	Metabolizability determined at a maintenance level of feeding.
r	Repeatability (%).
r	Correlation coefficient.
r.s.d.	Residual standard deviation.
r ²	Coefficient of determination.
RHM	Post-grazing or residual herbage mass (kg DM/ha).
RR	Recovery rate of the indigestible marker in faeces (%).

S.D.	Standard Deviation.
s.e.	Standard error.
SF	Small Friesian cows.
t	Day of gestation.
t	tonne.
TDN	Total digestible nutrients (%).
TEG	Tissue energy gain (MJ/day).
TEL	Tissue energy loss (MJ/day).
W_0	The amount of component of tissues of pregnancy at day zero of gestation.
W_t	The amount of component of tissues of pregnancy at day t of gestation.
Y_E	Energy deposited as milk (MJ/day).
$Y_{E(C)}$	Energy deposited as milk, adjusted by positive (TEG) or negative (TEL) tissue energy change.

LIST OF APPENDICES

	<u>Page</u>
Appendix I. Analysis of variance table and expected mean squares for the variables generated in the experiment.	118
Appendix II. Pre-grazing herbage mass, post-grazing herbage mass, number of cows per treatment group and average plate meter reading for each paddock used in the experiment.	119
Appendix III. Analyses of variance tables for the regression equations appearing in the body of the text.	121
Appendix IV. Results of the analyses of variance for the variables generated in the experiment.	125
Appendix V. Individual cow values for initial live weight, final live weight, total liveweight change during the 41 days of experimental period, and average daily liveweight gain.	131
Appendix VI. Individual cow values for initial condition score, final condition score and total condition score change during the 41 days of experimental period.	132
Appendix VII. Cow age and days since conception at the beginning and at the end of the experiment	133