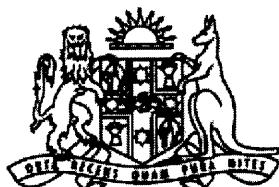


***QUANTITATIVE ANALYSIS OF BEHAVIOUR OF GRAZING  
DAIRY COWS***



**ROBIN CHRISTOPHER DOBOS**

**NSW DEPARTMENT OF PRIMARY INDUSTRIES  
BEEF INDUSTRY CENTRE  
ARMIDALE 2351**



**NSW DEPARTMENT OF  
PRIMARY INDUSTRIES**

**A thesis submitted in fulfilment of the requirements for the degree of Doctor of  
Philosophy**

**February 2007**

**Department of Animal Science**

**University of New England**

## DECLARATION

The studies presented in this dissertation were completed by the author while a part-time postgraduate student in the Department of Animal Science, University of New England and employed with NSW Department of Primary Industries. Assistance given by other persons is indicated in the text or in the list of acknowledgements. All references cited are included in the bibliography. The work is original otherwise.

\* \* \* \*

I certify that the substance of this thesis has not already been submitted for any degree and is not being currently submitted for any other degree. I certify that any help received in preparing this thesis, and all sources used, have been acknowledged in this thesis.

Signed: \_\_\_\_\_ Date: \_\_\_\_\_

## **ACKNOWLEDGEMENTS**

This thesis could not have been without the help of some key people. In particular I wish to acknowledge the friendship and leadership of Professor Bill Fulkerson, whom I have had the privilege of working with for over 20yrs. He has been a great inspiration and friend throughout this time. Also, I would like to acknowledge the friendship of Dr Kuldip Nandra. His charming nature and drive for me to complete this thesis has been extremely helpful.

To my supervisors, Associate professor Geoff Hinch and Professor John Nolan, I say thank you for your patience and perseverance. Your guidance has been inspirational. To Bill as an associate supervisor thank you for your great patience.

I also acknowledge my employer, NSW Department of Primary Industries for allowing me to conduct this research and to submit it as a PhD dissertation. Funding from Dairy Australia for some of this work is also gratefully acknowledged.

Finally, I am extremely grateful for the patience of my family, my wife Kathy and 5 children, Aaron, Caleb, Joshua, Zachary and Emily. Without their understanding and support I may never have finished.

## **DEDICATION**

This thesis is dedicated to my mother Elva Eileen Dawn Dobos (1934 – 2005), who guided, nurtured and encouraged me to pursue science. Unfortunately she died before this thesis was completed.

## LIST OF ABBREVIATIONS

ADF	acid detergent fibre	RDP	rumen degradable protein
BW	body weight (kg)	RPM	rising plate meter
d	day	SH	sward height (cm)
DM	dry matter (kg)	SSH	sward surface height (cm)
DMI	dry matter intake (kg DM/d)	SN	normal distribution
DN	double normal distribution	UDP	rumen undegradable protein
g	grams	VFA	volatile fatty acids
G	gamma distribution	W	Weibull distribution
GD	grazing duration (h)	WSC	water soluble carbohydrate
GT	grazing time (min/24h)		
h	hours		
IR	intake rate (g/min)		
kg	kilograms		
LN	log-normal distribution		
LW	liveweight (kg)		
min	minutes		
MVT	Marginal Value Theorem		
N	nitrogen		
NDF	neutral detergent fibre		
NH <sub>3</sub>	ammonia		
OFT	optimal foraging theory		
OM	organic matter		
RDC	rumen degradable carbohydrate		

## **ABSTRACT**

This research thesis describes the quantitative analysis of behaviour of grazing dairy cows in terms of sward height (SH) in combination with the length of the grazing session (grazing duration, GD), the time of allocation of fresh pasture and the type of carbohydrate supplement offered. A review of the literature (Chapter 2) identified that there was limited information on the combined affects of SH and GD on behaviour, herbage dry matter intake (DMI) and intake rate (IR) of dairy cows grazing sub-tropical pastures and how these interact to influence sward structure. Also, there was limited information on how SH x GD, time of allocation of fresh pasture and type of carbohydrate supplement offered affects the temporal patterns of behaviour and the subsequent time-dependent probabilities.

In this current study, 2 levels of SH (10 and 13cm) and 5 levels of GD (1, 2, 4, 8 and 15h) were used to quantify the effects of SH and GD on dairy cow grazing behaviour, IR and herbage DMI. Sward height significantly ( $P<0.05$ ) influenced total GT such that cows grazing SH13 swards spent an extra 45min grazing than SH10 cows over the 15h grazing period. There was a significant ( $P<0.05$ ) asymptotic relationship between GT and GD such that GT increased by 0.45 h/h GD to a maximum at 4h GD, irrelevant of SH treatment. Intake rate declined more rapidly for SH13 cows than SH10 cows but had stabilised for both SH treatments by 4h GD. Irrespective of SH treatment, cows had consumed >70% of their total herbage DMI within the first 4h GD. Quantification of the sward profiles after each SH x GD combination showed that dairy cows grazing kikuyu using the management described in this current study did not graze at random.

Spectral decomposition of dairy cows grazing behaviour at two different SH (10 and 13cm) did not find any differences in temporal patterns of behaviour. However, dairy cows offered their fresh pasture after the afternoon milking (PM) grazed longer at this

time and exhibited different temporal patterns of grazing behaviour than those cows offered their fresh pasture after the morning milking (AM). There were no differences in temporal patterns of grazing behaviour for grazing dairy cows offered different types of carbohydrate supplements to test rumen synchrony of N and energy (Synch *v.* ASynch).

Dairy cows offered the shorter swards (10cm) had a higher likelihood of being found in the grazing state (21%) than those offered taller swards (13cm; 16%) during the 15h period under the strip-grazing management described in this current study. Cows offered their fresh pasture at either AM or PM were equally likely to be in either the grazing or non-grazing states as were cows offered different types of carbohydrate supplements to either synchronise energy and N in the rumen or otherwise (synchronous *v.* asynchronous).

The results from this current thesis highlight the factors that either encourage or discourage grazing by dairy cows and should also help to improve decision tools used for pasture rotation, supplementary feeding and stocking density.

## TABLE OF CONTENTS

<b>DECLARATION</b>	<i>i</i>
<b>ACKNOWLEDGEMENTS</b>	<i>ii</i>
<b>DEDICATION</b>	<i>iii</i>
<b>LIST OF ABBREVIATIONS</b>	<i>iv</i>
<b>ABSTRACT</b>	<i>v</i>
<b>TABLE OF CONTENTS</b>	<i>vii</i>
<b>LIST OF FIGURES</b>	<i>x</i>
<b>LIST OF TABLES</b>	<i>xiii</i>
<b>CHAPTER 1 GENERAL INTRODUCTION</b>	<i>1</i>
<b>CHAPTER 2 LITERATURE REVIEW</b>	<i>4</i>
<b>2.1. Introduction</b>	<i>4</i>
<b>2.2 Theory of foraging behaviour</b>	<i>6</i>
<b>2.2.1 The patch</b>	<i>7</i>
<b>2.2.2 Diet preference</b>	<i>8</i>
<b>2.3 Measuring herbage DMI and grazing behaviour</b>	<i>10</i>
<b>2.4 Factors affecting intake rate</b>	<i>13</i>
<b>2.5 Factors affecting grazing time and temporal patterns of behaviour</b>	<i>20</i>
<b>2.6 Management factors that maximise herbage DMI</b>	<i>29</i>
<b>2.6.1 Herbage allowance</b>	<i>29</i>
<b>2.6.2 Nutritive value of herbage</b>	<i>35</i>
<b>2.6.3 Supplementation</b>	<i>38</i>
<b>2.6.4 Diet synchrony</b>	<i>39</i>
<b>2.6.5. Integrating information – decision support tools</b>	<i>41</i>
<b>CHAPTER 3 THE EFFECTS OF SWARD HEIGHT AND GRAZING DURATION ON BEHAVIOUR AND INTAKE OF DAIRY COWS GRAZING KIKUYU (<i>Pennisetum clandestinum</i>) GRASS PASTURES.</b>	<i>45</i>
<b>3.1 Introduction</b>	<i>45</i>
<b>3.2 Materials and methods</b>	<i>47</i>
<b>3.2.1 Study location and design</b>	<i>47</i>
<b>3.2.2 Grazing behaviour</b>	<i>48</i>
<b>3.2.3 Herbage intake</b>	<i>49</i>
<b>3.2.4 Sward structure</b>	<i>50</i>
<b>3.2.5 Statistical analysis</b>	<i>50</i>

<b>3.3 Results</b>	<b>51</b>
3.3.1 Effect of SH and GD on behaviour	51
3.3.2 Effect of SH and GD on pasture depletion	53
3.3.4 Effect of SH and GD on DMI and IR	54
3.3.5 Effect of SH and GD on sward structure	56
<b>3.4 Discussion</b>	<b>58</b>
3.4.1. Behaviour and pasture depletion	58
3.4.2 Herbage DMI and IR	59
3.4.3 Sward structure	61
<b>3.5 Conclusions</b>	<b>62</b>
<b>CHAPTER 4 THE EFFECT OF SWARD HEIGHT AND GRAZING DURATION ON THE FREQUENCY DISTRIBUTION OF SWARD HEIGHT OF KIKUYU (<i>Pennisetum clandestinum</i>) GRASS PASTURES GRAZED BY DAIRY COWS.</b> <u>63</u>	
<b>4.1 Introduction</b>	<b>63</b>
<b>4.2 Materials and methods</b>	<b>65</b>
4.2.1 Study location and experimental design	65
4.2.2 Swards and sward height	65
4.2.3 Statistical analysis	66
<b>4.3 Results</b>	<b>68</b>
<b>4.4 Discussion</b>	<b>82</b>
<b>4.5 Conclusions</b>	<b>85</b>
<b>CHAPTER 5 SPECTRAL ANALYSIS OF DAIRY COW GRAZING BEHAVIOUR PATTERNS RELATIVE TO SWARD HEIGHT AND TIME OF ALLOCATION OF PASTURE AND CARBOHYDRATE SUPPLEMENTS.</b> <u>86</u>	
<b>5.1 Introduction</b>	<b>86</b>
<b>5.2 Materials and Methods</b>	<b>88</b>
5.2.1 Behaviour relative to SH and GD (Chapter 3)	88
5.2.2 Grazing behaviour relative to time of fresh pasture and carbohydrate supplements allocation (Trevaskis et al. 2004)	88
5.2.3 Spectral analysis	89
<b>5.3 Results</b>	<b>91</b>
5.3.1 Temporal behaviour patterns – Chapter 3 data	91
5.3.2 Temporal behaviour patterns – Trevaskis et al. (2004)	97
<b>5.4 Discussion</b>	<b>102</b>
<b>5.5 Conclusions</b>	<b>104</b>
<b>CHAPTER 6 TIME-DEPENDENT TRANSITION PROBABILITIES IN BEHAVIOUR OF GRAZING DAIRY COWS.</b> <u>105</u>	
<b>6.1 Introduction</b>	<b>105</b>

<b>6.2 Materials and Methods</b>	<b>106</b>
<b>6.1.1 Grazing behaviour data</b>	<b>106</b>
<b>6.2.2. Time-dependent transition probabilities</b>	<b>106</b>
<b>6.3 Results</b>	<b>109</b>
<b>6.3.1 Time-dependent transition probabilities</b>	<b>109</b>
6.3.1.1 Chapter 3 behaviour data	109
6.3.1.2 Trevaskis <i>et al.</i> (2004) behaviour data	113
<b>6.4 Discussion</b>	<b>116</b>
<b>6.5 Conclusions</b>	<b>118</b>
<b>CHAPTER 7 GENERAL DISCUSSION</b>	<b>120</b>
<b>7.1 Introduction</b>	<b>120</b>
<b>7.2 Quantification of the effects of SH and GD on IR, herbage DMI, grazing behaviour and sward dynamics</b>	<b>121</b>
<b>7.3 Quantification of effects of SH and GD, time of allocation of pasture and type of carbohydrate supplement on temporal patterns of grazing behaviour</b>	<b>124</b>
<b>7.4 Quantification of effects of SH and GD, time of allocation of pasture and type of carbohydrate supplement on the time-dependent probabilities of grazing behaviour</b>	<b>127</b>
<b>7.5 Conclusions and perspectives</b>	<b>128</b>
<b>BIBLIOGRAPHY</b>	<b>131</b>
<b>APPENDIX 1 Data for Chapter 3 analyses</b>	<b>149</b>
<b>APPENDIX 2 GENSTAT code and data for Chapter 4 analyses</b>	<b>154</b>
A2.1 GENSTAT code for fitting the 5 distributions	155
A2.2 GENSTAT code to generate figures in Chapter 4.	157
<b>APPENDIX 3 GENSTAT code and behaviour data for Chapter 5</b>	<b>163</b>
A3.1 GENSTAT code to conduct spectral analysis of behaviour data from Chapter 3	164
A3.2 GENSTAT code to conduct spectral analysis of behaviour data from Trevaskis <i>et al.</i> (2004)	166
<b>APPENDIX 4 Solving steady-state probabilities</b>	<b>168</b>

## LIST OF FIGURES

Figure	Page
<i>Figure 1. Factors influencing herbage DMI and also behaviour by grazing dairy cows.</i>	<hr/> 1
<i>Figure 2. Prediction of diet choices based on dry matter intake rate maximisation: an example on swards containing reproductive patches (dotted curve) in a background of vegetative patches (solid curve) (after Prache et al. 1998).</i>	<hr/> 9
<i>Figure 3. Effect of physiological state (lactating □, non-lactating ■) on the response to sward surface height in bite mass and total grazing time (h/d) by dairy cows (after Gibb et al. 1999).</i>	<hr/> 14
<i>Figure 4. Effect of sward surface height on bite mass of lactating dairy cows (after Gibb 2006).</i>	<hr/> 16
<i>Figure 5. Effect of bite mass on bite rate of lactating dairy cows (after Gibb 2006).</i>	<hr/> 17
<i>Figure 6. Effect of sward surface height on short-term intake rate by lactating dairy cows (after Gibb 2006).</i>	<hr/> 18
<i>Figure 7. Effect of sward surface height on time spent grazing (G), idling (I) and ruminating (R) by lactating dairy cows (after Gibb 2006).</i>	<hr/> 18
<i>Figure 8. Typical temporal pattern of grazing, ruminating and idling activity by a dairy cow under continuous variable stocking management (after Gibb 2006)</i>	<hr/> 25
<i>Figure 9. Typical temporal patterns of grazing, ruminating and idling activity by dairy cows under daily paddock-stocking management provided with the same daily herbage allowance either following morning milking or following afternoon milking (after Gibb 2006).</i>	<hr/> 26
<i>Figure 10. Smoothed periodogram of grazing behaviour by grazing sheep (after Champion et al. 1994)</i>	<hr/> 28
<i>Figure 11. Effect of daily herbage OM allowance on daily herbage OM intake by dairy cows grazing perennial ryegrass swards (Greenhalgh et al. 1966 □ and 1967 ■; Le Du et al. 1979, expts 1 ◇ and 2 ♦; Combellas and Hodgson 1979, high △ and low ▲ herbage mass; Peyraud et al. 1996 × after Gibb 2006). — fitted line (<math>y=a+bx</math>)</i>	<hr/> 30
<i>Figure 12. Effect of daily herbage OM allowance on utilisation (OM intake/OM allowance). Source data as in Figure 11. (after Gibb 2006).</i>	<hr/> 31
<i>Figure 13. Relationship between herbage allowance and herbage DMI for cows grazing irrigated perennial ryegrass-white clover pastures at low mass (○) and medium mass (●) swards (after Wales et al. 1999).</i>	<hr/> 33

Figures continued	Page
<i>Figure 14. Effect of daily herbage OM allowance on (a) overall mean herbage OM intake within groups of cows and heifers □ and (b) mean herbage intake by cows ■ and heifers □ calculated separately (after Gibb 2006).</i>	34
<i>Figure 15. Effect of SH (— 10cm; ----- 13cm SH) and length of grazing session (1, 2, 4, 8 and 15 h) on mean (<math>\pm</math>se) total time (min) spent (a) grazing (●), (b) ruminating (▲) and (c) resting (■) for dairy cows grazing sub-tropical pastures. Vertical bars are <math>\pm</math>se.</i>	52
<i>Figure 16. Effect of SH (10 (●) and 13 (▲) cm) and length of grazing session (1, 2, 4, 8 and 15 h) treatments on post-grazing pasture heights (cm) of kikuyu pastures grazed by dairy cows. Vertical bars are <math>\pm</math>se.</i>	54
<i>Figure 17. Effect of sward height (10 and 13cm) and length of grazing session (1, 2, 4, 8 and 15 h) treatments on intake rate (kg DM/min spent grazing) for dairy cows grazing sub-tropical pastures (SH10 ■ SH13 ▲-----).</i>	56
<i>Figure 18. Frequency histograms of sward height measurements made in (a) 10cm and (b) 13cm swards at the different length of grazing sessions (from bottom 0, 1, 2, 4, 8 and 15h).</i>	57
<i>Figure 19. Frequency histograms of pre- and post-grazing sward height measurements made in 10cm swards at different grazing durations (GD = 1, 2, 4, 8 and 15h).</i>	74
<i>Figure 20. Frequency histograms of pre- and post-grazing sward height measurements made in 13cm swards at different grazing durations (GD = 1, 2, 4, 8 and 15h).</i>	75
<i>Figure 21. Fit of single-normal distribution to post-grazing sward height frequency distributions for SH 10cm and 13cm at different grazing durations.</i>	77
<i>Figure 22. Fit of double-normal distribution to post-grazing sward height frequency distributions for SH of 10cm and 13cm at different grazing durations (SH 13cm x GD 8h – no fit).</i>	78
<i>Figure 23. Fit of gamma distribution to post-grazing sward height frequency distributions for SH of 10cm and 13cm at different grazing durations.</i>	79
<i>Figure 24. Fit of log-normal distribution to post-grazing sward height frequency distributions for SH of 10cm and 13cm at different grazing durations.</i>	80
<i>Figure 25. Fit of Weibull distribution to post-grazing sward height frequency distributions for SH of 10cm and 13cm at different grazing durations.</i>	81

<i>Figures continued</i>	<i>Page</i>
<i>Figure 26. Effect of SH (10 _____ v 13cm ----) on time spent (min/h) (a) grazing, (b) ruminating and (c) resting from 1600h to 0700h by dairy cows grazing kikuyu pastures.</i>	92
<i>Figure 27. Periodograms of grazing behaviour for cows grazing kikuyu pastures at either a SH of 10cm or 13cm (..... approx F at P&lt;0.05).</i>	93
<i>Figure 28. Periodograms of ruminating behaviour for cows grazing kikuyu pastures at either a SH of 10cm or 13cm (..... approx F at P&lt;0.05).</i>	94
<i>Figure 29. Periodograms of resting behaviour for cows grazing kikuyu pastures at either a SH of 10cm or 13cm (..... approx F at P&lt;0.05).</i>	95
<i>Figure 30. Ratio of ordinates at each cycle length for (a) grazing, (b) ruminating and (c) resting activities by dairy cows grazing kikuyu pastures at an initial SH of 10cm and 13cm and associated upper and lower critical F values (...., <math>\alpha = 0.05</math>) from 1600h to 0700h.</i>	96
<i>Figure 31. Effect of time of allocation of fresh grazing area and carbohydrate feeding on time spent (min/h) (a) grazing and (b) not grazing of dairy cows grazing annual ryegrass pastures 0700 to 2400h on the last day of experiment 2 of Trevaskis et al. (2004). _____ PM; ..... Synch; ----- ASynch</i>	98
<i>Figure 32. Periodograms of grazing behaviour for cows grazing annual ryegrass pastures for treatments PM, Synch and ASynch from Trevaskis et al. (2004) (..... approx F at P&lt;0.05).</i>	99
<i>Figure 33. Plot of ratio of ordinates for (a) PM/ASynch, (b) PM/Synch, (c) ASynch/Synch. Where the ratio exceeds the upper or lower critical F (<math>P&lt;0.05</math>) boundaries, differences exist in grazing cyclicity.</i>	101
<i>Figure 34. Transition diagrams for the Markov model of dairy cows grazing (a) SH10 and (b) SH13 treatment swards of kikuyu over a 15h period (G=grazing state, R=ruminating state, I=idling state).</i>	111
<i>Figure 35. Time-dependent transition probabilities of staying in a state (diagonal) and changing of state (off-diagonals) for dairy cows grazing kikuyu pastures at an initial sward height of 10cm (○) and 13cm (●). State 1=grazing; state 2=ruminating; state 3=idling (PSS1=probability of staying in state 1; PCS12=probability of transition from state 1 to state 2).</i>	112
<i>Figure 36. Transition diagrams for the Markov model of (a) PM, (b) Synch and (c) ASynch treatment groups of Trevaskis et al. (2004) over a 17h period (G=grazing state, NG= not grazing state).</i>	114
<i>Figure 37. Time-dependent transition probabilities of staying in a state and changing of state for dairy cows grazing annual ryegrass pastures between 0700 and 2400h on the last day of experiment 2 for treatments PM (●), Synch (■) and ASynch (▲) (calculated from Trevaskis et al. 2004).</i>	115

## LIST OF TABLES

<i>Table 1. Effect of sward height (10 and 13cm) and length of grazing session (1, 2, 4, 8 and 15 h) treatments on herbage dry matter intake (DMI, kg DM/cow) for dairy cows grazing sub-tropical pastures.</i>	55
<i>Table 2 Effect of sward height and grazing duration on mean<math>\pm</math>se pre- and post-grazing heights.</i>	69
<i>Table 3 Parameter estimates for five theoretical distributions fitted to sward height distributions, skewness and coefficients of variation (CV) from swards grazed at different durations with a 10cm target height. p is the proportion that is 'tall'.</i>	70
<i>Table 4 Parameter estimates for five theoretical distributions fitted to sward height distributions, skewness and coefficients of variation (CV) from swards grazed at different durations with a 13cm target height. p is the proportion that is 'tall'.</i>	71
<i>Table 5 Akaike information statistics for five theoretical distributions fitted to sward height frequency distributions measured at sward heights of 10 and 13cm and grazing durations of 1, 2, 4, 8 and 15h.</i>	73