

Opportunities for selection to improve steer and cow productivity in northern Australia

Matthew L. Wolcott

Bachelor of Applied Science – University of Queensland, February 1991.

Masters in Rural Science – University of New England, March 2004.

A THESIS SUBMITTED FOR THE DEGREE OF DOCTOR OF PHILISOPHY
OF THE UNIVERSITY OF NEW ENGLAND

31ST JULY 2013

I certify that the substance of this thesis has not already been submitted for any degree and is not currently being submitted for any other degree or qualification.

I certify that any help received in preparing this thesis and all sources used have been acknowledged in this thesis.



ACKNOWLEDGEMENTS

The results reported in this thesis are the product of a large progeny test experiment: The Co-operative Research Centre for Beef Genetic Technologies' (Beef CRC) Northern Breeding Project. Each of the experimental chapters of this thesis includes acknowledgements which are relevant to that research. I refer to these and reiterate my appreciation for the massive contributions of funding bodies, co-operating beef cattle breeders, Beef CRC researchers and technical staff to the work undertaken for this thesis. As this thesis is presented as a series of published (or accepted for publication) papers, I particularly acknowledge the co-authors listed for each of these. I extend to them my sincerest thanks for invaluable contributions to the research undertaken for each of these studies. Principal among these was my supervisor, Dr. David Johnston, whose contributions were essential to the successful completion of this thesis, and whose assistance is gratefully acknowledged. I am also grateful for the contribution of Dr. Steve Barwick, to maintaining scientific rigor and quality control in the papers which make up the experimental chapters of this thesis. Finally, I would like to thank my family and friends for their constant encouragement. The motivation to complete this work came from a number of sources, but the support of those beyond the work and study environments was essential and greatly appreciated.

ABSTRACT

This thesis analysed carcass records from 2180 tropically adapted, steers (986 Brahman (BRAH) and 1194 Tropical Composite (TCOMP)) describing weight, eye muscle area, P8 and 12/13th rib fat depth, percent intramuscular fat and retail beef yield, with tenderness assessed as shear force. All steers were feedlot finished with a subset (680 BRAH and 783 TCOMP) recorded for individual feed intake. Female reproductive performance in the half-sib sisters of these steers (1007 BRAH and 1108 TCOMP) was evaluated as outcomes of their first (Mating 1: when females averaged 27 months of age) and second (Mating 2) annual matings, and averaged over up to 6 matings (termed 'lifetime' reproduction traits). Heifer and cow weight, eye muscle area, P8 and 12/13th rib fat depth, body condition score and hip height were recorded at 18 months of age, immediately prior to first calving and at Mating 2. The maternal genetic component of weaning weight (Maternal WWT) was estimated based on weaning weight records available for these steers and females and the progeny of females (N = 12528).

Key results of genetic analysis showed that carcass weight, composition and meat quality traits displayed moderate heritability (h^2) for both genotypes ($h^2 = 0.17$ to 0.64). Genetic correlations (r_g) of steer carcass weight and eye muscle area with female reproductive performance were consistently not different from zero. Lower carcass P8 fat depth was genetically associated with higher Mating 2 weaning rates ($r_g = -0.28$ and -0.76 for BRAH and TCOMP), though for TCOMP, this was reversed for Mating 1 weaning rate ($r_g = 0.43$). Lower residual feed intake in BRAH steers was genetically associated with lower Mating 1 weaning rate ($r_g = 0.76$) and higher days to calving ($r_g = -0.50$), though this did not significantly impact lifetime annual calving or weaning rate ($r_g = 0.10$ and 0.29 respectively). For TCOMP, lower shear force also displayed a significant genetic association with higher Mating 1 days to calving ($r_g = -0.56$) and tended to be unfavourably associated with other

measures of female reproduction. Cow growth and body composition traits measured at pre-calving and mating 2 had moderate to high heritability in BRAH ($h^2 = 0.27$ to 0.67) and TCOMP ($h^2 = 0.25$ to 0.87). Lactating cows of both genotypes lost substantial weight and body condition during this period and, with the exception of hip height, these changes were also moderately heritable ($h^2 = 0.17$ to 0.54). Greater loss of cow liveweight, body condition score and eye muscle area was genetically related to higher Maternal WWT ($r_g = -0.40$ to -0.85) in both genotypes. Higher Maternal WWT was also genetically related to lower lifetime annual weaning rate ($r_g = -0.50$) in BRAH, and with lower mating 2 calving and weaning rate ($r_g = -0.72$ and -0.59) in TCOMP.

Steer growth, carcass composition, meat quality and residual feed intake, and female reproduction could be improved by selection without major antagonisms to female reproductive performance. Important exceptions to this were for tenderness in TCOMP and residual feed intake in BRAH, though these could be managed by recording both traits and included them in the breeding objective. Selection to reduce Maternal WWT in tropically adapted females, particularly in TCOMP, is expected to produce correlated responses of lower fat and muscle mobilization in lactating first calf cows, and higher female reproductive performance.

CONTENTS

Acknowledgements.....	iii
Abstract	iv
List of tables	xii
List of figures	xvi
1 Introduction	1
1.2 Best linear unbiased prediction and the mixed model equation.....	3
1.2.1 The relationship matrix	4
1.2.2 Models for traits with multiple random effects.....	5
1.2.3 Multivariate mixed model equations.....	6
1.2.4 Genetic correlations.....	8
1.2.5 Breeding values estimated by BLUP.....	9
1.3 Estimating variance components by restricted maximum likelihood (REML)	9
1.4 Breeding objectives, selection criteria and selection indices	11
1.4.1 Selection indices using multi-trait derived EBVs.....	12
1.5 Breeding objectives and selection criteria for tropically adapted beef cattle in northern Australia.....	14
1.5.1 Current industry breeding objectives.....	15
1.5.2 Potential new breeding objectives and selection criteria.....	18
1.5.2.1 Residual feed intake	18
1.5.2.2 Tenderness and meat quality traits	19
1.5.2.3 Flight time	19
1.5.2.4 Age at puberty and lactation anoestrus interval.....	19
1.5.2.5 Tropical adaptation traits.....	20

1.5.2.6	Growth and body composition in lactating first calf cows.....	21
1.6	The Co-operative Research Centre for Beef Genetic Technologies Northern Breeding Project	21
1.7	Conclusions	23
1.8	Relationship between experimental chapters and aims of thesis	24
2	Genetics of meat quality and carcass traits and the impact of tender-stretching in two tropical beef genotypes.....	28
2.1	Abstract	28
2.2	Introduction	29
2.3	Materials and methods	31
2.3.1	Animals and live measurements	31
2.3.2	Carcass and meat quality measurements	33
2.3.3	Statistical analysis.....	35
2.3.3.1	Data editing and fixed effect modelling.....	35
2.3.3.2	Variance component estimation.....	36
2.3.3.3	Model predicted means.	37
2.4	Results and discussion.....	37
2.4.1	Effect of tenderstretching on objective tenderness	38
2.4.2	Genotype differences.....	39
2.4.3	Genetic and phenotypic variances and heritabilities for carcass and meat quality traits	40
2.4.4	Relatedness of carcass and meat quality traits.....	41
2.4.4.1	Meat quality and marbling traits.....	42
2.4.4.2	Meat quality and carcass composition traits	43
2.4.4.3	Ossification score and meat quality traits.....	44
2.4.5	Relatedness of carcass and live animal traits.....	44

2.4.6	Relatedness of meat quality and live animal traits	45
2.4.6.1	Live measures of body composition and meat quality traits.....	45
2.4.6.2	Steer and heifer growth rates and meat quality traits.....	47
2.4.6.3	Insulin-like growth factor I and meat quality traits.....	48
2.4.6.4	Residual feed intake and meat quality and carcass traits.....	49
2.4.6.5	Flight time and tenderness traits	50
2.5	Conclusions	50
2.6	Acknowledgements.....	51
3	The genetics of cow growth and body composition at first calving in two tropical beef genotypes	71
3.1	Abstract	71
3.2	Introduction	72
3.3	Materials and methods	74
3.3.1	Animals and measurements.....	74
3.3.2	Weaning weight	76
3.3.3	Statistical analysis.....	76
3.3.3.1	Data editing and fixed effect models	76
3.3.3.2	Model predicted means	78
3.3.3.3	Variance component estimation.....	78
3.4	Results	79
3.4.1	Genotype, pregnancy and lactation status effects	80
3.4.2	Genetic and phenotypic variances and heritabilities for cow growth and body composition traits and weaning weight.....	81
3.4.3	Relationships among cow growth and body composition traits.....	82
3.4.4	Genetic relationships involving change from pre-calving to mating 2 traits	83

3.4.5	Relationships of cow growth and body composition traits with the maternal and direct genetic components of weaning weight	84
3.5	Discussion	86
3.5.1	Genotype differences	86
3.5.2	Differences between pregnant and non-pregnant, and lactating and non-lactating cows..	86
3.5.3	Variances and heritabilities for cow growth and body composition traits	87
3.5.4	Genetic relationships between pre-calving and mating 2 measurements	88
3.5.5	The genetics of tissue mobilization from pre-calving to mating 2	89
3.5.6	The role of maternal WWT in cow growth and body composition and tissue mobilization	91
3.6	Conclusions	92
3.7	Acknowledgements	93
4	Genetic relationships of female reproduction with growth, body composition, maternal weaning weight and tropical adaptation in two tropical beef genotypes	104
4.1	Abstract	104
4.2	Introduction	105
4.3	Materials and methods	107
4.3.1	Animals and management	107
4.3.2	Traits	108
4.3.3	Statistical analysis	110
4.4	Results	112
4.4.1	Female reproduction and heifer growth and body composition	112
4.4.2	Female reproduction and mating 2 growth and body composition	113
4.4.3	Female reproduction and tropical adaptation	114
4.4.4	Heifer and mating 2 growth and body composition	114
4.4.5	Tropical adaptation and mating 2 growth and body composition	115
4.4.6	Maternal WWT and female reproduction, growth, body composition and tropical adaptation	116
4.5	Discussion	117

4.5.1	Female growth, body composition and maternal WWT as genetic indicators of female reproduction.	117
4.5.2	Tropical adaptation traits as genetic indicators of female reproduction.	120
4.5.3	Other consequences of exploiting heifer growth and body composition and tropical adaptation traits as genetic indicators of female reproduction	121
4.6	Conclusions	122
4.7	Acknowledgements.....	122
5	Genetic relationships between steer performance and female reproduction and possible impacts on whole herd productivity in two tropical beef genotypes	137
5.1	Abstract	137
5.2	Introduction	139
5.3	Materials and methods	140
5.3.1	Animals and measurements.....	140
5.3.2	Statistical analysis.....	142
5.4	Results	144
5.4.1	Relationships of male traits with female reproduction in Brahmans	144
5.4.2	Relationships of male traits with female reproduction in Tropical Composite	146
5.5	Discussion.....	148
5.5.1	Genetics relationships of male growth and body composition with female reproduction	148
5.5.2	Genetics relationships of male IGF-I and feed intake with female reproduction.....	150
5.5.3	Genetic relationships of male carcass and meat quality traits with female reproduction .	153
5.6	Conclusions	154
5.7	Acknowledgements.....	155
6	Conclusions	166
6.1	Opportunities for selection to improve steer carcass and meat quality traits in tropically adapted beef cattle and implications of this for steer and heifer body composition, and steer residual feed intake.....	167

6.2	Genetic relationships of steer growth, residual feed intake, carcass composition and meat quality with female reproduction	168
6.3	Genetics of female growth and body composition and relationships with reproductive performance.....	170
6.4	Genetic relationships of tropical adaptation with female reproduction	171
6.5	Opportunities for further research	172
6.6	Final Conclusions.....	173
7	References.....	175

LIST OF TABLES

Table 2.1	Description of carcass and meat quality traits	52
Table 2.2	Number of measurements (N), unadjusted trait means, standard deviations (\pm s.d.) and minimum (Min) and maximum (Max) for Brahman and Tropical composite steer carcass and meat quality traits	53
Table 2.3	Number of observations (N), model predicted means (P.Mean), additive (σ_A^2) and phenotypic (σ_P^2) variances and heritabilities (h^2), (\pm standard errors in parentheses), for meat quality and Δ SF traits, with genetic correlations of meat quality traits with Δ SF	54
Table 2.4	Number of observations (N) and model predicted means (P.Mean) for carcass and meat quality traits in similarly treated BRAH and TCOMP steers with standard errors of difference (s.e.d.).	54
Table 2.5	Phenotypic (σ_A^2) and Additive (σ_P^2) variances and heritabilities (h^2) (\pm standard errors in parentheses) for carcass and meat quality traits in Brahman (BRAH) and Tropical Composite (TCOMP) steers	55
Table 2.6	Genetic (above diagonal) and phenotypic (below diagonal) correlations for carcass and meat quality traits for Brahman and Tropical Composite steers combined (\pm standard errors in parentheses)	56
Table 2.7	Genetic correlations of carcass and meat quality traits with steer feedlot exit (EXIT) and net feed intake test (FEEDTEST) traits, for Brahman and Tropical Composite combined (\pm standard errors in parentheses)	58
Table 2.8	Phenotypic correlations of carcass and meat quality traits with feedlot exit (EXIT) and net feed intake test (FEEDTEST) for Brahman and Tropical Composite combined	60
Table 2.9	Genetic correlations for carcass and meat quality traits with steer feedlot entry (ENTRY), post-weaning (POSTW) and weaning (WEAN) measurements for Brahman and Tropical Composite combined (\pm standard errors in parentheses)	61
Table 2.10	Genetic correlations for carcass and meat quality with traits heifer traits measured at the end of their first wet season following weaning (ENDWET), and at the end of their second dry season after weaning (ENDDRY) for Brahman and Tropical Composite combined	63

Table 2.11	Brahman (BRAH) and Tropical Composite (TCOMP) specific genetic correlations for carcass traits with steer carcass, feedlot exit (EXIT), feed test (FEEDTEST), feedlot entry (ENTRY), and weaning (WEAN) measurements (\pm standard errors in parenthesis)	65
Table 2.12	Brahman (BRAH) and Tropical Composite (TCOMP) specific genetic correlations for carcass traits with heifer measurements from the end of their first wet season following weaning (ENDWET), and end of their second dry season following weaning (ENDDRY) (\pm standard errors in parentheses)	66
Table 2.13	Brahman (BRAH) and Tropical Composite (TCOMP) specific genetic correlations for meat quality traits with steer carcass, feedlot exit (EXIT), net feed intake test (FEEDTEST), feedlot entry (ENTRY), and weaning (WEAN) traits and heifer end of first wet season following weaning (ENDWET) and end of second dry season following weaning (ENDDRY) measurements (\pm standard errors in parentheses)	67
Table 3.1	Description of cow growth and body composition measurement times and traits	93
Table 3.2	Number of measurements (N), unadjusted trait means and standard deviations (\pm s.d.) for Brahman and Tropical composite weaning weight, and pre-calving, mating 2 and change from pre-calving to mating 2 traits	94
Table 3.3	Number of observations (N) and model predicted means (P.Mean) for growth and body composition traits at pre-calving (pregnant and non-pregnant) and mating 2 (lactating and non-lactating) and for the change from pre-calving to mating 2 in BRAH and TCOMP born and managed at the same location and under similar conditions	95
Table 3.4	Additive (σ_A^2) and Phenotypic (σ_P^2) variances and heritabilities (h^2) for growth and body composition traits at pre-calving and mating 2, and for the change from pre-calving to mating 2, in BRAH and TCOMP (\pm standard errors in parentheses)	96
Table 3.5	Genetic (above diagonal) and phenotypic (below diagonal) correlations for growth and body composition traits measured pre-calving and at mating 2, and for the change from pre-calving to mating 2, in BRAH and TCOMP combined (\pm standard errors in parentheses)	97

Table 3.6	Genotype specific genetic correlations for Brahman (BRAH) and Tropical Composite (TCOMP) growth and body composition traits at pre-calving and mating 2, and for the change from pre-calving to mating 2 (\pm s.e.) standard errors in parentheses)	99
Table 3.7	Additive (σ_A^2), phenotypic (σ_P^2), residual (σ_E^2), maternal (σ_M^2) and dam permanent environmental (σ_C^2) variances and heritabilities (h^2) (\pm standard errors in parentheses) for weaning weight in Brahman (BRAH) and Tropical Composite (TCOMP)	100
Table 3.8	Genetic correlations and their standard errors (s.e.) for pre-calving, mating 2 and change from pre-calving to mating 2 growth and body composition traits with the direct (r_{gD}) and maternal (r_{gM}) genetic components of weaning weight in Brahman (BRAH) and Tropical Composite (TCOMP)	100
Table 4.1	Description of traits	123
Table 4.2	Genetic correlations for Brahman and Tropical Composite of female reproduction traits with heifer growth and body composition traits (\pm standard errors in parentheses)	125
Table 4.3	Genetic correlations for Brahman of female reproduction traits with maternal weaning weight (WWT) and mating 2 growth and body composition traits (\pm standard errors in parentheses)	127
Table 4.4	Genetic correlations for Tropical Composite of female reproduction traits with maternal weaning weight (WWT) and mating 2 growth and body composition traits (\pm standard errors in parentheses)	128
Table 4.5	Genetic correlations for Brahman and Tropical Composite of female reproduction traits with tropical adaptation traits (\pm standard errors in parentheses)	129
Table 4.6	Genetic correlations for Brahman and Tropical Composite of heifer growth and body composition traits with maternal weaning weight (WWT) and mating 2 growth and body composition traits (\pm standard errors in parentheses)	130
Table 4.7	Phenotypic correlations for Brahman and Tropical Composite of heifer growth and body composition traits and mating 2 growth and body composition traits (\pm standard errors in parentheses)	131

Table 4.8	Genetic correlations for Brahman and Tropical Composite of female tropical adaptation traits with maternal weaning weight (WWT) and mating 2 growth and body composition traits (\pm standard errors in parentheses)	132
Table 4.9	Phenotypic correlations for Brahman and Tropical Composite of female tropical adaptation traits with mating 2 growth and body composition traits (\pm standard errors in parentheses)	133
Table 5.1	Description of measurement times and traits definitions	155
Table 5.2	Genetic correlations of Brahman male growth, hip height and eye muscle area with female reproduction traits (\pm standard errors in parentheses)	157
Table 5.3	Genetic correlations of Brahman male fat depth, body condition score, blood IGF-I concentration, flight time and feed intake with female reproduction traits (\pm standard errors in parentheses)	158
Table 5.4	Genetic correlations of Brahman steer carcass and meat quality traits with female reproduction (\pm standard errors in parentheses)	159
Table 5.5	Genetic correlations of Tropical Composite male growth, hip height and eye muscle area with female reproduction traits (\pm standard errors in parentheses)	160
Table 5.6	Genetic correlations of Tropical Composite male fat depth, body condition score, blood IGF-I concentration, flight time and feed intake with female reproduction traits (\pm standard errors in parentheses)	161
Table 5.7	Genetic correlations of Tropical Composite steer carcass and meat quality traits with female reproduction (\pm standard errors in parentheses)	162

LIST OF FIGURES

Figure 1.1	Breeding objectives for the Brahman “Jap Ox” selection index	15
Figure 1.2	Weightings applied to BREEDPLAN EBVs for the Brahman “Jap Ox” selection index	16