The Genetics of Brahman Cow Weight in Northern Australia and its Relationship with Female Reproductive Performance

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ABSTRACT: Annual weights from 1025 Brahman cows, commencing at their first annual mating (average 2 years of age) were evaluated in a univariate random regression analysis. Results showed that cow weight from 2 to 7 years was heritable (h^2 = 0.31 to 0.53). The analysis was extended to include a second dependent variable describing female reproductive performance (age at puberty (AP), lactation anoestrus interval (LAI) or lifetime annual weaning rate (LAWR)). Genetic correlations of AP with cow weight were low (rg = -0.09 to 0.03), while lower LAI and higher LAWR displayed moderate genetic relationships with higher early cow weight which decreased with cow age (r_g= -0.28 to 0.02 and 0.37 to 0.11 respectively). Results show that if Brahman breeders in northern Australia select to improve female reproductive performance, correlated responses in cow weight would be small and expected to diminish with cow age.
Keywords: cow weight; female reproduction; random regression

Introduction

In northern Australia, low female reproductive performance, particularly in lactating first-calf females, has been identified as an important source of economic loss for beef producers (Schatz and Hearnden 2008). Johnston et al. (2009 and 2014) showed that age at puberty (AP) and lactation anoestrus interval (LAI: measured as days from the start of the second annual mating) were heritable in Brahman cattle (h^2 = 0.57 and 0.51 respectively). Johnston et al. (2009) also reported that lower AP was moderately genetically associated with higher weight in Brahman females at 25 months of age (r_g = -0.20 ± 0.19). Wolcott et al. (2014b), in the same Brahman females however, showed that neither weight measured at 18 months nor in females at the beginning of their second annual mating (at 37 months of age), were significantly genetically associated with LAI (r_g = 0.05 ± 0.22 and -0.05 ± 0.21).

Studies by Arango et al. (2004), Legarra et al. (2004) and Meyer (2004) have applied random regression methods to cow weights measured over time, with the latter concluding that 'substantial benefits could be obtained from the implementation of a random regression model' where multiple weights were available.

Following from the work of Johnston et al. (2009 and 2014), and Wolcott et al. (2014b), and evaluating records from the same Brahman females, this study aimed to examine the genetics of Brahman cow weight when analysed as a trajectory, and to determine the genetic relationships of this with female reproductive performance through up to 6 annual matings.

Materials and Methods

Animals and measurements. Animals evaluated for this study comprised the Brahman female portion of the Co-operative Research Centre for Beef Genetic Technologies Northern Project (Burrow and Bindon, 2005). Breeding and management of heifers up to their first annual mating was described by Barwick et al. (2009), and Johnston et al. (2009) described ultrasound scanning of females to identify age at first *corpus luteum* (CL), interpreted as identifying AP. Females were first mated, to calve as 3 year olds, at an average age of 25 months (Johnston et al. 2009). At the start of the second annual mating period, ultrasound scanning to identify the presence of a CL commenced for lactating cows to identify the onset of cycling and allow the calculation of LAI. Cows remained in the project until the weaning of calves from their sixth annual mating. Cows which failed to successfully wean a calf in consecutive years were removed from the experiment. For all females, lifetime annual weaning rate (LAWR) was calculated as the total number of calves weaned from the first, and up to the sixth mating, divided by the number of annual matings to which the animals were exposed (Johnston et al. 2014). Females were weighed, following the methods described by Wolcott et al. (2014a), at the beginning of their first annual mating, when they averaged 25 months of age (WT2), and again at the start of each subsequent annual mating (WT3, WT4, WT5, WT6 and WT7).

Statistical analysis. Fixed effect modeling for traits describing female reproductive performance was described by Johnston et al. (2009 and 2014). Fixed effects for weights measured at the start of each annual mating period (up to 6) initially contained project design variables and lifetime mating group (formed from previous mating group and all earlier mating groups, which remained the same for most animals from year to year), as well as a term describing lactation status: whether females were lactating (WET) or not (DRY) at the start of each annual mating period. For females which failed to wean a calf in consecutive years and were removed from the experiment, previous lactation status for years in which cows were

[1] AGBU is a joint venture of NSW DPI and the University of New England

actually mated were analyzed as DRY. For random regression analyses of cow weight (described below), previous lactation status in subsequent years for these animals was set as WET.

Random regression of cow weight. For each cow up to 6 (n) weights, measured at the beginning of their first to sixth annual mating period, were analysed in ASReml using a single trait random regression model (Gilmour 2009):

$$Y_{ij} = \text{fixed effects} + \sum_{m=1}^{n} \text{ANIMAL}_{im}\, \varphi_m(\text{AGE}) + \sum_{m=1}^{n} \text{PE}_{im}\, \varphi_m(\text{AGE}) + e_{ij}$$

Where: Y_{ij} is annual cow weight for animal i at measurement time j, ANIMAL_{im} and PE_{im} are random regression coefficients for the additive genetic and animal permanent environmental effects (m = 1 to n). The value $\varphi_m(\text{AGE})$ are orthogonal Legendre polynomials for standardized age (-1 to +1), with e_{ij} representing random error terms for animal i each year. Genetic co-variances between cow weights were estimated as $\varphi K \varphi'$, where K represents the matrix of covariance functions, and φ was a matrix of orthogonal Legendre polynomials. Different orders of fit for the ANIMAL and PE components were examined to identify the model which best described the data, based on optimization of Akaike's Information Criteria (AIC) statistics. Consistent with the methods of Veerkamp and Thompson (1999), different orders of polynomial regression were evaluated for the ANIMAL and PE components of the model.

Genetic covariances of cow weight with reproduction traits (Y_2) were also estimated using ASReml, by extending the random regression model to include a second dependent variable describing a measurement of cow reproductive performance (AP, LAI or LAWR), consistent with the methods described by Veerkamp et al. (2001). The additive and residual variances for reproduction traits were fixed in these analyses, using the results presented by Johnston et al. (2009) for AP, and Johnston et al. (2014) for LAI and LAWR. Covariances between random regression coefficients for cow weights and the reproduction trait (c), were estimated as $\text{cov}(\text{ANIMAL}_i, Y_{2i})$. Genetic covariances of reproduction traits with cow weight at specific ages were estimated as $c\varphi'$.

Results and Discussion

Table 1 describes the cow weight data analysed for this study. Final orders of fit for Legendre polynomials, based on AIC, and the resultant Akaike weights (Wagenmakers and Farrell 2004) were quadratic for the ANIMAL component of the model and linear for the animal permanent environmental effect (order 2 and 1 respectively). These orders of fit were lower than those reported by Arango et al. (2004) (3 for the direct genetic and up to 5 for the animal permanent environmental effect) in a univariate random regression analysis which also examined weight in beef cows. It is proposed that by limiting the weights analysed in the current study to annual measurements, the significant seasonal variation observed in the trait when evaluated more regularly (i.e. monthly, as was the case in the study of Arango et al. (2004)) was absent. This would reduce the complexity of the data, allowing the more simple models reported here to accurately describe cow weight over time.

Table 1. Mean age (age), and descriptive statistics for Brahman cow weight measurements at the start of 6 annual matings (WT2 – WT7)

Cow weight	Age, mths	Number	Mean, kg	s.d
WT2	25	1025	320	59
WT3	37	973	390	49
WT4	49	946	430	57
WT5	61	886	447	72
WT6	73	832	479	78
WT7	85	769	482	67

The genetics of cow weight at mating. Table 2 presents the genetic, animal permanent environment, residual and phenotypic variances, and the resultant heritability estimated from univariate random regression analyses, for annual cow weight. Barwick et al. (2009) and Wolcott et al. (2014a) reported heritabilities for WT2 and for lactating cows at WT3 in the same Brahman females from conventional, univariate, analyses. These ($h^2 = 0.39 \pm 0.11$ and 0.44 ± 0.13 respectively) were consistent with the heritabilities presented here ($h^2 = 0.31$ and 0.39 for WT2 and WT3) from the random regression analysis. Heritabilities of 0.44 – 0.53 for WT4 – WT7 also agreed with those reported by Meyer (1995) ($h^2 = 0.48 – 0.49$) and Regatieri et al. (2012) ($h^2 = 0.43$) for cow weight in tropical genotypes. The trend for additive and animal permanent environment variances and heritability to increase to 5 years of age (WT5), and plateau beyond that point was also consistent with the results of Meyer (1999) for Brahman cross females.

Table 2. Variance components[1] and heritabilities for Brahman cow weight (kg) at the start of 6 annual matings (WT2 – WT7) estimated from random regression analysis

Cow Weight	σ^2_a	σ^2_{pe}	σ^2_r	σ^2_p	h^2
WT2	191	286	132	609	0.31
WT3	438	326	389	1153	0.38
WT4	750	415	243	1408	0.53
WT5	919	551	334	1804	0.51
WT6	937	735	262	1936	0.48
WT7	1007	967	300	2274	0.44

[1] σ^2_a = genetic variance, σ^2_{pe} = animal permanent environmental variance, σ^2_r = residual variance, σ^2_p = phenotypic variance and h^2 = heritability.

Table 3 presents genetic correlations between annual cow weights. Results display a predictable pattern of high correlations between adjacent weights on the trajectory (r_g = 0.81 – 0.99), which diminish as time between measurements increases. This agreed with the pattern observed by Arango et al. (2004) in random regression analyses of monthly cow weight from 19 to 103 months of age. It can also be observed that weights measured in cows before they experience their first breeding season and lactation (WT2) were less strongly genetically related to

WT3 – WT6 (r_g = 0.68 – 0.81) than was the case within weights collected from 3 to 6 years of age (r_g > 0.90).

Table 3. Genetic correlations among Brahman cow weight (kg) at the start of 6 annual matings (WT2 – WT7).

Cow Weight	WT2	WT3	WT4	WT5	WT6
WT3	0.81				
WT4	0.70	0.98			
WT5	0.68	0.97	0.99		
WT6	0.72	0.91	0.93	0.97	
WT7	0.71	0.72	0.73	0.80	0.92

Genetic relationships of cow weight with female reproduction. Table 4 presents the genetic correlations of Brahman female reproduction traits with cow weight. Genetic correlations of cow weight with AP were consistently low (r_g = -0.09 to 0.03). Johnston et al. (2009) reported a genetic correlation of -0.20 ± 0.19 between AP and cow weight at the start of their second annual dry season, which was consistent with the result estimated by random regression at the equivalent time (r_g of AP with WT2 = -0.09). This result suggests that selection pressure could be applied to reduce AP in Brahman cows without significant consequences for cow weight at any age.

Table 4. Genetic correlations of Brahman cow weight at the start of 6 annual matings (WT2 – WT7) with age at puberty (AP), lactation anoestrus interval (LAI) and lifetime annual weaning rate (LAWR)

Cow Weight	AP	LAI	LAWR
WT2	-0.09	-0.23	0.37
WT3	-0.01	-0.28	0.21
WT4	0.02	-0.27	0.15
WT5	0.03	-0.22	0.13
WT6	0.03	-0.11	0.12
WT7	0.02	0.08	0.11

The genetic relationship of LAI with cow WT2 to WT5 were moderate and negative (r_g = -0.22 to -0.28), but the magnitude of these estimates declined beyond 5 years of age. Wolcott et al. (2014b) reported that for the subset of these females which were lactating when WT3 measurements were collected, the genetic relationship of cow weight with LAI was lower (r_g = -0.05 ± 0.21) than that estimated here when both lactating and non-lactating cows were included in a random regression analysis. These results suggest that cows with lower LAI tended to be genetically heavier up to mating as 5 year olds, but that this relationship diminished with cow age.

Higher cow weight at WT2 was genetically associated with higher LAWR (r_g = 0.37), with correlations remaining positive but declining from WT3 to WT7 (r_g = 0.21 to 0.11). Wolcott et al. (2014b) reported a positive genetic relationship of cow weight at mating 2 (equivalent to WT3 here) and LAWR (r_g = 0.40 ± 0.27) which was consistent with the trend observed here when cow weight was analysed as a trajectory. As observed for LAI, these results describe a moderate genetic relationship of higher early weight with female reproduction, which tended to decline with age.

The results of this study showed that breeders of Brahman cattle in northern Australia could select to improve AP with the expectation that genetic cow weight would not be changed as a consequence. Similarly, selection to reduce LAI and increase LAWR would only produce small and positive correlated responses in cow weight which would be expected to diminish with age.

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