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GENETIC ANALYSIS OF BODY CONDITION AND GROWTH TRAITS IN BEEF FEMALES WITHIN AND ACROSS AGES AND PHYSIOLOGICAL STATES

K.L. Moore[1], T.P. Grant[2] and D.J. Johnston[1]

[1]Animal Genetics Breeding Unit*, University of New England, Armidale, NSW, 2350 Australia
[2]Queensland Department of Agriculture and Fisheries, Toowoomba, QLD, 4350 Australia

SUMMARY

This study estimated variance components of body condition and growth traits and the genetic relationships across time and traits for approximately 2,200 females from three tropically adapted northern Australian beef breeds. Body condition score, measured in yearling heifers and subsequently at the commencement of their annual mating seasons (1st and 2nd), was estimated to be heritable (h^2: 0.32to 0.36) and with high genetic correlations (r_g) over time, ranging from 0.76 to 0.85. Hip height was also estimated to be strongly heritable at the three time points (h^2: 0.59 to 0.67) and was genetically the same trait across the time points (r_g: 0.94 to 0.99). Similar results were found for live weight, with heritability estimates ranging between 0.61 and 0.65 and weight being strongly correlated across the different time points (r_g: 0.81 to 0.95). Genetic correlations between traits within the same time point showed that when cows were undergoing the fastest growth (commencement of mating 1) the genetic relationships varied compared to times points with slower growth. As yearling heifers and into mating 2 the genetic relationship between hip height and body condition score was small to moderately negative. However, at commencement of mating 1, a strong negative genetic correlation was observed. Likewise, the genetic correlation between live weight and body condition score was moderately positive, except for the commencement of mating 1, when it was not significantly different from zero. Body composition is moderately heritable but the physiological state impacts on the genetic relationships between traits, so having a clearly defined time of measurement will be essential in the trait definition.

INTRODUCTION

Cow body condition score is an important trait in beef production. It describes body reserves of fat and is potentially an indirect measure of both fertility and survival. Wolcott *et al.* (2014b) demonstrated in Australian Brahman females a positive moderate genetic correlation between body condition score and pregnancy success from the first mating. Overall body condition is affected by both environmental conditions and the physiological state of the cow. A thorough understanding of the genetics of body condition score (reflecting composition) is required to be included into a genetic evaluation programme. This requires evaluating different physiological states and the genetic relationships to other traits.

The aim of this study was to estimate the genetic parameters for body condition score, hip height and live weight, within and across ages in tropically adapted northern Australian beef breeds.

MATERIALS AND METHODS

Female reproduction traits have been extensively recorded as part of the Repronomics™ project in northern Australia (Johnston *et al*. 2017). Briefly, three breeds (Brahman, Droughtmaster and Santa Gertrudis) were managed together at two sites in Queensland (QLD). Approximately 2,200 measurements were considered from females measured as yearling heifers (~14 months) and at the

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commencement of the annual mating seasons1 (~26 months) and 2 (~38 months). Cows not producing a calf were culled and data at mating 2 is censored with only lactating cows included.

Cow body condition score was assessed based on a 1 (poor) to 5 (fat) scoring system, with plus/minus amendments to scores allowed. Where a plus/minus score is recorded the body condition score is adjusted by 0.33 increments, for example 3-, 3 and 3+ are analysed as 2.66, 3.0 and 3.33, respectively. Within each cohort a single experienced assessor scored all animals. Hip height (cm) was recorded in the crush as the distance from the ground to the top of the hip. Live weight (kg) was recorded using electronic scales.

Statistical models were developed for each trait using PROC MIXED in SAS (SAS Institute, 2007), sire was fitted as random and model terms were tested with step-wise elimination until only significant terms remained. All traits were analysed as linear, with breed (Brahman, Droughtmaster and Santa Gertrudis) and cohort fitted as significant fixed effects. A cohort was defined as purebred females born together at the same site in the same year. All breeds at each site were managed together. Mating outcomes were recorded and included the date of birth and sex of calves. Animals with unknown parentage, calf sex, date of birth or dam age were removed from the dataset, as were multiple births and animals that were not purebred.

For body condition score at matings 1 and 2 and all hip height measures, birth month and dam group (a concatenation of dam's project herd, breed type, herd of origin and age group) nested within cohort was also significant. Except formating 2 live weights, age at measurement was a significant linear covariate fitted for all traits, with the quadratic age term also significant for mating 1body condition score. The first order interaction between birth month and measurement age was included in the final model for all body condition score traits and mating 1 hip height. Calf birth month,dam group nested within birth cohort and the interaction between calf birth month and cohort were significant for mating 2 hip height, and calf birth month and age of calf at foot were significant for live weight at the start of mating 2.

To estimate genetic parameters, mixed linear animal models including significant fixed effects were fitted using ASReml (Gilmour *et al*. 2009). Univariate models were fitted to estimate variance components, with genetic relationships estimated fitting tri-variate models that grouped traits by stages (i.e. all mating 1 traits) or by trait type (i.e. all body condition score traits). Fitting a tri-variate model accounts for data censorship at the later time points. A combined breed pedigree was used including up to 3 generations where available.

RESULTS AND DISCUSSION

The number of records by time and trait are presented in Table 1. There are fewer animals at the later time points due to data censoring from culling cows that do not calve from mating 1 and recent cohorts not yet being mated a 2nd time. The largest increase in skeletal size and live weight occurred between the yearling heifer and commencement of mating 1 times. Skeletal structure and live weight still increased (at a slower rate) between matings 1 and 2 as the cows grew, but body condition score decreased as cows were rearing calves and losing condition. Cows were leanest at the commencement of mating 2 and there was more raw variation in body condition score at mating 2 compared to body condition scores at the earlier ages. Averagehip height and live weight increased with each subsequent measurement, but the raw variation increased initially but was then similar for mating 1 and 2.

Estimated variance components (Table 1) showed that all traits were heritable, and that heritability was similar across the different time points considered in this study. Body condition score heritability estimates were moderate (h^2=0.32 to 0.36) with large estimates for hip height (h^2=0.59 to 0.67) and live weight (h^2=0.61 to 0.65). After adjusting for significant fixed effects, including age and reproduction status, the phenotypic variance of body condition score at the commencement of mating 2 was approximately twice the size compared with the variance at the commencement of mating 1 and the variance of live weight also increased over time. The greater variation in body condition score and live weight observed at mating 2 reflects that at this stage cows are meeting the energy demands associated with both lactation and growth. The variance of hip height also increased initially but was then similar for mating 1 and 2.

Table 1. Data summary statistics, estimated additive variance and heritability for body condition score (1 – 5 score), hip height (cm) and live weight (kg) measured in yearling heifers and at the commencement of mating seasons 1 and 2 for pooled breeds (Brahman, Droughtmaster and Santa Gertrudis)

	N	Mean	Standard deviation	Range	Additive Variance	Heritability
				Body condition score		
Yearling Heifer	2,253	3.02	0.41	1.66 – 4.00	0.019	0.32 (0.05)
Mating 1	2,219	3.13	0.41	1.66 – 4.66	0.033	0.36 (0.05)
Mating 2	1,585	2.66	0.59	1.00 – 4.33	0.064	0.36 (0.06)
				Hip height		
Yearling Heifer	2,167	124.4	4.5	109 -141	8.27	0.61 (0.05)
Mating 1	2,213	135.7	5.4	115 - 156	10.5	0.67 (0.05)
Mating 2	1,548	140.3	5.1	121 - 162	9.24	0.59 (0.08)
				Live weight		
Yearling Heifer	2,391	258	37.3	142 - 381	317.7	0.64 (0.05)
Mating 1	1,979	381	60.8	176.5 - 572	612.1	0.61 (0.06)
Mating 2	1,486	431	61.9	244 - 648	1111.6	0.65 (0.06)

Table 2. Genetic (above diagonal) and phenotypic (below diagonal) correlations (standard errors) between body condition score (BCS, 1 – 5 score), hip height (HH, cm) and live weight (LW, kg)measured in yearling heifers and at the commencement of mating season 1 and 2 for pooled breeds (Brahman, Droughtmaster and Santa Gertrudis)

		Yearling heifers			**Mating 1**			**Mating 2**		
		BCS	**HH**	**LW**	**BCS**	**HH**	**LW**	**BCS**	**HH**	**LW**
Yearling heifers	**BCS**		-0.19 (0.09)	0.38 (0.08)	0.79 (0.07)			0.85 (0.08)		
	HH	-0.02 (0.03)		0.66 (0.04)		0.99 (0.01)			0.94 (0.03)	
	LW	0.30 (0.02)	0.62 (0.02)				0.95 (0.02)			0.81 (0.04)
Mating 1	**BCS**	0.39 (0.02)				-0.50 (0.08)	-0.11 (0.10)	0.76 (0.08)		
	HH		0.75 (0.01)		-0.25 (0.02)		0.67 (0.05)		0.98 (0.01)	
	LW			0.79 (0.01)	0.10 (0.03)	0.56 (0.02)				0.91 (0.02)
Mating 2	**BCS**	0.26 (0.03)			0.33 (0.03)				-0.17 (0.12)	0.27 (0.10)
	HH		0.71 (0.02)			0.80 (0.01)		-0.12 (0.03)		0.71 (0.06)
	LW			0.64 (0.02)			0.73 (0.01)	0.36 (0.03)	0.55 (0.02)	

Table 2 presents estimates of genetic correlation between traits recorded at the same time point and for individual traits across time points. All traits were strongly correlated across the different time points. Body condition score was estimated to have very strong genetic correlations (between 0.76 and 0.85) across time points. Likewise, genetic correlations for live weight across time were very strong ranging between 0.81 and 0.95. Genetic correlation estimates for hip height indicated that the trait was genetically the same at each time point with all correlations greater than 0.94. Wolcott *et al*. (2014a) reported similar relationships between pre-calving and mating 2 measurements for all three traits considered in this study. These correlations indicate that selection based on records of younger animals will have a consistent impact on the trait genetically through mating 1 and 2.

Hip height and live weight at all stages were strongly correlated (r_g: 0.66 to 0.71). In contrast, the correlation between hip height and body condition score varied depending on the physiological state. As a growing yearling heifer and at the commencement of mating 2 (i.e. lactating heifer) there were small negative genetic correlations that were not significantly different from zero. At the commencement of mating 1, a moderate negative correlation (r_g=-0.50) was estimated between hip height and body condition score. This suggests that in periods of high growth, genetically taller cattle put energy towards structural growth before laying down body condition. Similarly, genetic correlations between body condition score and live weight varied at the different stages. At the commencement of mating 1, the genetic relationship was not significantly different from zero, but at the other times in the study, a moderate positive genetic correlation was estimated. Wolcott *et al*. (2014a) from Brahman and Tropical Composite animals reported similar results for traits measured pre-calving and at mating 2.

CONCLUSIONS

This study confirms that body condition score, hip height and live weight were heritable when recorded in yearling heifers and at the commencement of mating 1 and 2. Further, within trait estimates of genetic correlations across time showed that selection of animals at one physiological state can be effective when selecting to improve the same trait at another physiological state, however it is not genetically the same trait. The between trait genetic correlations illustrate how animals with more rapid growth (i.e. at the start of mating 1) tend not to lay down body condition whilst they are growing in skeletal size. Once the active growth slows, these animals partition more resources to body condition and there is no longer a significant genetic relationship between body condition score and hip height. Genetic selection of body composition is achievable but having a clearly defined time of measurement will be essential in the trait definition.

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