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GENETICS OF HEIFER AGE AT PUBERTY IN AUSTRALIAN HEREFORD CATTLE

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SUMMARY

Age at puberty has become a key trait in the genetic evaluation of female reproduction traits for tropically adapted beef breeds in northern Australia. This study aimed to characterise the trait in Australian Hereford seedstock heifers and to determine the degree to which it, and associated traits, were under genetic control. Hereford heifers (n = 922) from three seedstock herds were serially ultrasound scanned to detect their first *corpus luteum* (indicative of age at puberty) at 4 - 6 week intervals from 10.6 to 13.2 months of age, at which time heifers were synchronised for artificial insemination. Results showed that only 52% of heifers were pubertal at synchronisation, and for these heifers, age at puberty had a heritability of 0.26. When a penalised record (equal to the maximum age at puberty for their contemporary group plus 21 days) was included for heifers which were not pubertal into mating, heritability increased to 0.38. For sires with at least 10 progeny, EBVs for age at puberty ranged from -42 to 28 days. The ability of heifers to conceive early in their first mating season is linked to lifetime reproductive performance. These results suggest that the proportion which have reached sexual maturity as they enter their first mating is significantly less than 100% and that opportunities exist, if the trait were included in the genetic evaluation for the breed, to monitor and apply selection to improve age at puberty in Hereford heifers.

INTRODUCTION

Results from the Co-operative Research Centre for Beef Genetic Technologies' Northern Breeding Project (Beef CRC) showed that age at puberty, identified by serial ultrasound scanning to determine date at first ovulation, was heritable in tropically adapted beef genotypes (Johnston *et al*. 2009). These results have been supported by subsequent research in the Repronomics™ project (Johnston *et al*. 2019) (h^2 = 0.32 to 0.56). Associated research also demonstrated that lower age at puberty was favourably genetically correlated with lifetime reproductive outcomes (r_g = -0.29 to -0.40), and that selection to improve (reduce) age at puberty would have favourable consequences for lifetime reproductive performance (Johnston *et al*. 2014). Morris *et al*. (2000) showed moderate heritability for age at puberty in Angus heifers when the trait was based on observed first oestrus (h^2 = 0.31), and a high genetic correlation with first mating pregnancy rate (r_g = -0.89). The current study aimed to exploit methods developed in the Beef CRC to characterise age at puberty in Hereford heifers, to determine the heritability of the trait and its potential to provide a means to improve and monitoring female reproduction in the genetic evaluation for the breed.

MATERIALS AND METHODS

Animals and management. Heifers used for this study were made available by three Hereford seedstock breeders, and represented the entire cohort of females weaned in 2017 and 2018 from each herd. Herds were selected for inclusion based on a history of high quality pedigree and performance recording, and a willingness to endure the significant imposition associated with serial ultrasound scanning required to identify first oestrous. Heifers were managed in accordance with standard practices for the three seedstock herds, one of which was located in the Southeast of New South Wales (n =

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534) and the other two in the New England region (n = 149 and 239).

Heifers were born over a 2-month spring calving period at the Southern New South Wales property and over three months for the New England herds. The animals evaluated for this study were the progeny of 99 sires, with 71% from sires with at least 10 progeny, and 20% of heifers from sires used in at least two herds. Heifers were weaned at an average of 5.4 months, with the two New England properties weaning at 6.6 months and the remaining herd weaning earlier (averaging 4.5 months old). Heifers weaned in 2018 were reared under significantly dryer conditions than those in 2017. This meant that more supplementary feeding was provided for heifers in 2018, but within herd and year, all animals received the same nutritional interventions. This was also the case for routine management practices (animals identification and branding, vaccination, parasite control treatments, etc.) as well as culling for conformation related traits between weaning and syncronisation for artificial insemination. All herds routinely submit data to BREEDPLAN for genetic evaluation. For the heifers involved in this study, this included pedigree information, date of birth and weaning weight, and these data were extracted from the Hereford Australia Ltd. database for these analyses.

Scanning for ovarian function. Ultrasound scanning to detect first oestrous followed the protocols described by Johnston *et al*. (2009) for tropical beef females in the Beef CRC. Within herd and year, scanning was performed by one of three technicians using a Mindray M7Vet real-time ultrasound unit equipped with a variable frequency 6LE5Vs intra-rectal transducer, set at 8MHz. The timing of first scans to detect the presence of a *corpus luteum* (CL), was undertaken when managers at each location observed the first signs of heat in the heifer cohorts examined for this study (post-weaning). Subsequent scans were undertaken at 4 - 6 week intervals, until the first progesterone based synchronisation treatment occurred in each herd, prior to artificial insemination (into-mating). All heifers in the cohort were scanned at post-weaning and at mating synchronization, with interim scans performed on heifers which had not displayed a CL. This resulted in the majority of heifers scanned three times up to synchronisation, with average number of scans per animal, within herd and year, between 2.3 and 2.8. Based on ovarian scanning results, the following traits were defined:

- **Age at puberty (AP)** was a trait in females which displayed a CL prior to mating, calculated as the scanning date at which the first CL was detected minus date of birth.
- **Penalised AP (APP)** generated an age at puberty record for heifers which had failed to display a corpus luteum prior to mating. APP was calculated for these animals as the maximum AP for their contemporary group plus 21 days. For a small number of heifers which failed to display a CL prior to mating and were in small contemporary groups (for which the maximum AP was based on too few records ($N \leq 3$) to be reliable) no APP was analysed (N = 15 heifers).
- **Pubertal into mating (PUB)** was a binary trait which identified heifers which had cycled at any time up to mating (1) or not (0).
- **Antral follicle count (FC)** was the total number of follicles greater than 2mm, visible by ultrasound examination of both ovaries at the first scan in heifers which did not have a CL.

Growth and body composition traits. At each scan, records of liveweight weight (LWT), hip height (HH) and body condition score (BCS) were collected for each heifer following the protocols for growth and body composition traits described by Johnston *et al*. (2009). P8 fat depth (P8) was also measured at each scan using the scanner's inbuilt callipers, with the exception of the first scan for heifers from one herd where the records could not be collected.

Modelling, variance component and EBV estimation. Descriptive statistics were generated using PROC MEANS in SAS. Contemporary group information was extracted from the Hereford Australia Ltd. database, and was built based on information supplied by participating breeders as described by Graser *et al*. (2005).

The contemporary group for 200 day weight was used to analyse heifer growth, body composition and the descriptors of ovarian function evaluated for this study. For growth and body composition traits, dam age and linear animal age were fitted as covariates. Consistent with the protocols established by Johnston *et al*. (2009) heifer age was modelled for ovarian scanned traits as month of birth nested within herd and year. Variance components for each trait were estimated in univariate analyses in ASReml (Gilmour *et al.* 2009), with EBVs for all animals in the three generation pedigree estimated as the solution for the random animals effect. For this study genetic parameters for the binary PUB trait were estimated on the observed scale.

RESULTS AND DISCUSSION

Growth and body composition traits. Summary statistics, additive variances and heritabilities for post-weaning growth and body composition traits are presented in Table 1. On average, heifers were 10.6 months of age at their post-weaning scan, with mean ages at first scan consistent across herds. Additive variances and heirtabilities for post-weaning LWT and HH were consistent with those reported by Donoghue *et al*. (2018) for Angus and Hereford females prior to their first calving (h^2 = 0.45 to 0.57). The heritability for post-weaning P8 was lower than that for Hereford females prior to their first calving reported for that study (h^2 = 0.64), but heritability for BCS was comparable (h^2 = 0.29). The technicians employed to collect ultrasound data describing ovarian traits were not accredited BREEDPLAN carcass scanners, and this may explain the slightly lower than expected heiritability for the scanned fat depth trait.

Table 1. Number of records analysed (N), mean and standard deviation (SD), with additive variance (σ_a^2) and heritability (h^2) (and standard error (s.e.)) for post-weaning growth and body composition and ovarian scanned traits in Hereford heifers

Traits	Units	N	Mean	SD	σ_a^2	h^2	s.e.
Post-weaning growth and body composition							
AGE	Days	922	321.4	27.9	.	.	.
LWT	kg	922	262.9	35.0	460.4	0.55	0.11
HH	cm	921	116.7	4.6	6.8	0.49	0.11
P8	mm	837	3.6	1.8	0.6	0.29	0.10
BCS	Score (1 – 5)	922	2.8	0.6	0.03	0.20	0.08
Ovarian scanned traits							
AP	Days	481	365.8	38.3	363.0	0.26	0.13
APP	Days	902	396.2	44.3	588.7	0.38	0.10
PUB[A]	1/0	917	0.52	0.50	0.05	0.36	0.11
FC	Count	729	23.3	7.1	21.1	0.42	0.13

[A] Variance components for PUB estimated on the observed scale.

Ovarian scanned traits. Summary statistics, additive variances and heritabilities for ovarian scanned traits are also presented in Table 1. A key result from this work was the proportion of heifers which were pubertal into mating (PUB = 0.52). This reinforces the need to investigate the genetics of puberty traits in temperate breeds and for subsequent analyses, which will examine relationships of the trait with first mating outcomes. The phenotypic and additive variance for APP (1549.2 and 588.7 days respectively) were substantially lower than those reported by Johnston *et al*. (2009) for troppically adapted heifers, which was consistent with the much shorter scanning period in temperate breeds where maiden matings occur approximately 12 months earlier. The moderate heritability estimated for APP (h^2 = 0.38) suggested that opportunities exist to improve the trait by selction in the Hereford breed. Both AP and APP were under significantly greater genetic control than days to calving ($h^2 \sim 0.05$) which is currently the key descriptor of female reproductive performance in the BREEDPLAN genetic evaluation for the breed.

For sires with 10 or more progeny, EBVs for APP ranged from -42 to 28 days. The heifers available for this study were a reasonably small sample of the breed, but these results suggest that sire selection could impact age at puberty in the resulting progeny by at least 35 days. With only 52% of females pubertal into their first mating, and mating periods as low as 2 months in commercial beef breeding herds in southern Australia, this could have implications for reproductive outcomes for naturally mated maiden heifers.

Mean and standard deviation for post-weaning FC were consistent with those reported by Walsh *et al*. (2014) for dairy heifers in the US and Ireland, with heritabilities also comparable ($h^2 = 0.25$ and 0.31 respectively). FC was recorded in this project to investigate its genetic associations with economically important female reproduction traits and this will be the subject of future analyses.

CONCLUSIONS

This study presents an initial investigation of the genetics of age at puberty and associated traits in Australian Hereford seedstock heifers. Results showed that there are opportunities to improve (reduce) age at puberty by selection in the breed and, by including the trait in the breed's genetic evaluation, to monitor this aspect of female reproduction as selection is applied to improve other economically important traits. The proportion of heifers which were not pubertal as they entered their first mating was a key result of this study. The increasing prevalence of artificial insemination and the associated treatments to synchronise (and possibly induce) first oestrous, suggest that genetic and environmental factors which impact a heifer's capacity to conceive early in their first mating season may warrant monitoring and inclusion in the genetic evaluation for temperate beef breeds. It is acknowledged that serial ultrasound scanning to detect first oestrous is an expensive and labour intensive operation, making it a candidate for evaluation in intensively recorded reference populations, and for further research to economise the recording regime.

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