

GENETICS OF HEIFER AGE AT PUBERTY IN AUSTRALIAN ANGUS CATTLE

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SUMMARY

Age at puberty has become a key trait in the genetic evaluation of female reproduction for tropically adapted beef breeds in northern Australia. This study aimed to characterise the trait in Australian *Bos taurus* seedstock heifers and determine the degree to which it, and associated traits, were under genetic control. Angus heifers (N = 3093) from nine seedstock herds were serially ultrasound scanned to determine age at puberty, via detection of their first *corpus luteum*, at approximately 4 week intervals from 10.5 to 13.6 months of age, when heifers were synchronised for artificial insemination. Results showed that only 53% of Angus heifers were pubertal at synchronisation for AI and that within this category, age at puberty had a heritability of 0.33. When a penalised record (maximum age at puberty for a contemporary group plus 21 days) was included for heifers that were not pubertal into mating, heritability increased to 0.42. For sires with EBV accuracy greater than 0.7, EBVs for age at puberty ranged from -69 to +70 days. The ability of heifers to conceive early in their first mating season has been linked to lifetime reproductive performance. These results suggest that the proportion of heifers that have reached puberty as they enter their first mating is significantly less than 100% and that opportunities exist to monitor and apply selection to improve age at puberty in Australian Angus 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 the date at first ovulation, was heritable in tropically adapted beef genotypes (Johnston *et al.* 2009). Associated research also demonstrated that lower age at puberty was moderately and 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 (first observed oestrus) in Angus heifers ($h^2 = 0.31$), and a high genetic correlation with first mating pregnancy rate in naturally mated (or AI to observed oestrus) heifers ($r_g = -0.89$), and Wolcott *et al.* (2019) reported a similar heritability ($h^2 = 0.38$) for Hereford heifers in Australia. Continuing from that work, the current study aimed to exploit methods developed in the Beef CRC to characterise age at puberty in Angus heifers, to determine the heritability of the trait and its potential to provide a means to monitor and select to improve age at puberty for the breed.

MATERIALS AND METHODS

Animals and management. Heifers involved in this study were made available by nine Angus seedstock breeders. 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 oestrus. Calving periods for heifers evaluated for the study ranged from 2 – 3 months. The heifers included in the analysis were the progeny of 260 sires, with 78% being the daughters of sires with at least 10 progeny, and 34% of heifers from sires with daughters evaluated in at least two herds.

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Heifers were weaned at an average age of 6.5 months, with a range of weaning ages from 5.3 to 8.0 months. On average, 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 all animals received the same nutritional interventions within herd and year. This also applied to routine management practices (animals' identification and branding, vaccination, parasite control treatments, etc.). Limited culling for conformation related traits between weaning and synchronisation for AI took place though this was assumed to be independent of any understanding of genetic reproduction. 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 were extracted from the Angus Australia 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 (subsequently referred to as their 'post-weaning' record). Subsequent scans took place at 4 - 6 week intervals until the first progesterone-based synchronisation treatment occurred in each herd, prior to artificial insemination (or their 'into-mating' record). All heifers in a cohort were scanned post-weaning) and at synchronization for AI, with interim scans performed on heifers that had not previously displayed a CL. This resulted in most heifers being scanned three times up to synchronisation, with the average number of scans per animal, within herd and year, between 2.2 and 3.9.

Based on ovarian scanning results, the following traits were defined:

- **Age at puberty (AP)** was a trait in females that displayed a CL prior to mating, calculated as the scanning date at which the first CL was detected minus their date of birth.
- **Penalised AP (APP)** generated an age at puberty record for heifers that had failed to display a CL 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 that 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 that identified heifers that 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 display a CL. FC was recorded in this project to investigate its genetic associations with economically important female reproduction traits based on favourable results presented by researchers examining dairy cow performance in New Zealand (Martinez *et al.* 2016).

Growth and body composition traits. At each scan, records of liveweight weight (LWT in kg), hip height (HH in cm) and body condition score (BCS on a 1- to 5+ scale) were collected for each heifer following the protocols for growth and body composition traits described by Johnston *et al.* (2009). P8 fat depth (P8 in mm) was also measured at each scan using the scanner's inbuilt callipers.

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

The contemporary group for BREEDPLAN 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 scanned ovarian traits as the 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 animal 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 being reasonably consistent across herds and years. Additive variances and heritabilities 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 ($h^2 = 0.45$ and 0.57), and with results from this study previously reported by Wolcott *et al.* (2019) for Hereford heifers ($h^2 = 0.55$ and 0.49). The heritability for post-weaning P8 was lower than that reported by Donoghue *et al.* (2018) for Angus females prior to their first calving ($h^2 = 0.44$), but was comparable for BCS ($h^2 = 0.14$), while almost identical results were presented by Wolcott *et al.* (2019) for Hereford heifers ($h^2 = 0.29$ and 0.20 for P8 and BCS respectively). The technicians who collected ultrasound data describing ovarian traits were not accredited BREEDPLAN carcass scanners, and it is possible that a degree of measurement inaccuracy may account for the slightly lower than expected heritability for scanned fat depth.

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 h^2 estimates) for post-weaning growth and body composition and scanned ovarian traits in Angus heifers

Traits	Units	N	Mean	SD	σ_a^2	h^2	s.e.
Post-weaning growth and body composition							
AGE	Days	3093	319.9	46.6	-	-	-
LWT	kg	3085	314.5	48.3	339.2	0.37	0.06
HH	cm	1816	116.9	4.5	7.1	0.57	0.08
P8	mm	3039	5.0	2.9	0.8	0.21	0.06
BCS	Score (1 – 5)	3093	2.8	0.7	0.04	0.29	0.06
Ovarian scanned traits							
AP	Days	1634	345.2	63.2	378.1	0.33	0.08
APP	Days	3078	392.5	71.1	1224.0	0.42	0.06
PUB ^A	1/0	3077	0.53	0.50	0.06	0.32	0.05
FC	Count	2544	21.9	8.9	21.1	0.34	0.06

^A Variance components for PUB estimated on the observed scale.

Ovarian scanned traits. Additive variances and heritabilities (and associated standard errors) for scanned ovarian traits are also presented in Table 1. A key result from this work was the proportion of Angus heifers that were pubertal into mating (PUB = 0.53). This was consistent with the result presented by Wolcott *et al.* (2019) for Hereford heifers involved in the same project (PUB = 0.52), and reinforces the need to understand the genetics of puberty traits in temperate breeds. The phenotypic and additive variance for APP (2882.8 and 1224.0 days respectively) were substantially lower than those reported by Johnston *et al.* (2009) for tropically adapted heifers, consistent with the much shorter scanning period in temperate breeds where maiden matings occur approximately 12 months earlier. The moderate heritability estimated for APP ($h^2 = 0.42$) suggests that the opportunity exists to improve the trait by selection in the Angus 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 evaluation for the breed.

For sires with greater than 70% EBV accuracy, EBVs for APP ranged from -69 to +70 days. These results suggest that sire selection could impact age at puberty in the resulting progeny by at least two months. 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). Antral follicle count was assessed in this project to allow investigation of its genetic association with 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 Angus seedstock heifers. Results showed that the opportunity exists 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 that 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 factors which impact a heifer's capacity to conceive early in their first mating season 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 prime candidate for evaluation in intensively recorded reference populations.

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