Ultrasonographic measurements in first trimester concepti identify predictors of birth weight and postnatal development in cattle¹

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ABSTRACT: The placenta is a major driver of prenatal growth and involved in programming of postnatal performance. We therefore determined placental and embryo-fetal ultrasonographic parameters in early pregnancy and their relationships with birth weight and postnatal weights in a *Bos indicus*–*Bos taurus* composite beef cattle population. Pregnancies were generated in 2-yr-old Droughtmaster heifers by artificial insemination after estrus synchronization in 2 consecutive years (2009, $n = 36$ and 2010, $n = 57$), with a subset of 2010 heifers used again as lactating 3-yr-old cows in 2011 ($n = 24$). Each cohort was managed as 1 contemporary group for measurements of *Corpus luteum* diameter, amnion length and width, placentome width and thickness, and embryo-fetal crown-rump length, at 7 and 8 wk of gestation. This was followed by recordings of birth weight, branding weight at 5 to 6 mo of age and weaning weight 2 mo later. At a significance threshold of

$P < 0.05$, placentome thickness at week 7 was negatively correlated with weights at birth ($r = -0.23$), branding ($r = -0.25$), and weaning ($r = -0.35$), whereas placentome width at week 7 ($r = 0.24$) and thickness at week 8 ($r = 0.29$) were positively correlated with birth weight. Thicker placentomes in males at week 7 (7%) difference mirrored sex differences in weights at birth (7%), branding (10%), and weaning (6%). The sex difference trend for birth weight was not consistent across sire-year combinations, ranging from -3.2 to $+4.7$ kg (birth weight of males – females per sire). These results support the hypothesis that placental parameters at the transition from embryo to fetal stage are major predictors of fetal and postnatal growth, albeit with significant environmentally induced plasticity, in stabilized *B. indicus*–*B. taurus* composite populations, and suggest that elements of *B. indicus*–*B. taurus* reciprocal differences in birth weight persist in composite populations.

Key words: *Bos indicus*–*Bos taurus* composite, Droughtmaster, embryo-fetal, placenta, postnatal weights

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J. Anim. Sci. 2018.96:4186–4194
doi: 10.1093/jas/sky290

¹Funding to support this work was provided by the Queensland Department of Agriculture, Fisheries and Forestry. We also acknowledge the assistance of Robert and Donna Rea and family, Lissgar Station, via Home Hill, Queensland, Australia who supplied the cattle for this study. Efforts here contribute to DAFF project “Precision beef cattle production through an alternative genetic

(epigenetics) approach” and USDA-NIFA Hatch project TEX 08937 “Investigation of input variation in economically important beef production traits.” S.H. is a JS Davies Professorial Fellow.

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Received March 29, 2018.

Accepted July 17, 2018.

INTRODUCTION

Embryo-fetal programming and its implications for birth weight and postnatal performance is well documented in human and animal models (e.g., Barker et al. (1993), Fowden et al. (2005), and Sinclair et al. (2016)). However, data on the role of placental parameters during early development as drivers of birth weight in beef cattle are limited, although potential impacts on birth weight have been shown (Stalker et al., 2006; Greenwood and Café, 2007; Martin et al., 2007; Sullivan et al. 2009a). Birth weight is an important factor in beef cattle production that requires optimization to help prevent dystocia due to excessive calf weights and to capitalize on the strong positive correlations with postnatal growth and development (Lubchenco et al., 1963; Holland and Odde, 1992). Increased birth weight of large offspring syndrome has been associated with epigenetic changes that affect gene expression after nuclear transfer cloning (Wilson et al., 1995; Young et al., 1998) and in vitro fertilization (Farin and Farin, 1995; Van Wagendonk-de Leeuw et al., 1998; Jacobsen et al., 2000) in cattle and was later shown to be driven by changes in placental structure and function (Constant et al. 2006). Additionally, significant reciprocal birth weight differences and large sex differences in reciprocal *Bos taurus* × *Bos indicus* crosses (Roberson et al., 1986; Brown et al., 1993; Riley et al., 2007) are driven by the conceptus and not maternal intrauterine effects as demonstrated by embryo transfer experiments (Amen et al., 2007; Dillon et al., 2015). Early gestation placental and embryo-fetal data and their relationships with birth weight in cattle are limited, and, to the best of our knowledge, no such data exist for *B. indicus*–*B. taurus* composites. Thus, objectives of this study were to 1) determine placental and embryo-fetal parameters at a critical phase in conceptus development, the transition from embryo to fetus between weeks 7 and 8 of gestation, and 2) evaluate these traits and their interrelationships with subsequent calf weights, specifically in reference to sex effects in a Droughtmaster herd in northern Queensland, Australia.

MATERIALS AND METHODS

Animals and procedures used in proposal “Precision Beef Cattle Production Through an Alternative Genetic (Epigenetics) Approach” were approved for 2008 to 2014 by the Department of Primary Industries and Fisheries, Department of Employment, Economic Development and Innovation, and Department of Agriculture,

Fisheries and Forestry Animal Ethics Committees (Queensland, Australia) as SA 2008/01/227 and SA 2010/12/339, respectively.

Animals, Management, and Treatments

Animals belonged to a private Droughtmaster cooperater herd located approximately 35 km south-east of Home Hill (latitude 19° 48' S and 147° 36' E) in the dry tropics of north Queensland. The climate is characterized by hot wet summers with 76% of the annual median rainfall of 823 mm typically received in December to March. Average minimum and maximum temperatures vary from 11.9 °C and 25.2 °C in July to 23.1 °C and 32.3 °C in January, respectively. Droughtmaster is a stabilized composite beef breed developed in Queensland and is approximately 50% Shorthorn (*B. taurus*) and 50% Brahman (*B. indicus*).

Two-year-old purebred Droughtmaster virgin heifers were utilized to generate AI pregnancies in 2009 and 2010, with a subset of the 2010 primiparous females used again as 3 years old in 2011. Females of each birth year group were managed as 1 contemporary group from allocation prior to AI through calf weaning annually. During each dry season (which extended to January in 2009 to 2010), all females were supplemented ad libitum with molasses containing urea and protein meal. Heifers averaged 795 d of age (range of 760 to 840 d) and body condition score of 5 (on 9-point scale) when estrous synchronization protocols were initiated; heifer average BW was 376.4 kg (25.57 kg SD) in 2009 and 340.5 kg (31.96 kg SD) in 2010. Primiparous, lactating females utilized in 2011 averaged BW of 475.7 kg (36.09 kg SD) in approximate body condition score of 5 (on 9-point scale) and ranged from 63 to 89 d postcalving at time of AI.

Females were synchronized for estrus utilizing FTAI using a 10-d progesterone-based estrous synchronization program. Intravaginal progesterone-releasing devices (0.78 g P4, Cue-Mate Intravaginal Device, Bioniche Life Sciences Inc.) and estradiol benzoate (1 mg IM, Ciderol, Genetics Australia, Bacchus Marsh, Victoria, Australia) were administered on day 0. Intravaginal devices were removed on day 8, and cloprostenol (250 µg IM, Oviprost, Bayer Animal Health) and PMSG (300 IU IM, Pregnecol, Bayer Animal Health) were administered. Estradiol benzoate (1 mg IM, Ciderol, Genetics Australia, Bacchus Marsh, Victoria, Australia) was administered on day 9; heifers were inseminated on day 10.

In 2011 at day 0, primiparous females were provided a 1.56-g P4 intravaginal device (Cue-Mate Intravaginal Device, Bioniche Life Sciences, Inc.) and 2-mg estradiol benzoate IM (Ciderol, Genetics Australia, Bacchus Marsh, Victoria, Australia). Intravaginal devices were removed on day 8 along with cloprostenol (250 µg IM, Ovuprost, Bayer Animal Health) and PMSG (400 IU IM, Pregnecol, Bayer Animal Health) were administered. Estradiol benzoate (2-mg IM, Ciderol, Genetics Australia, Bacchus Marsh, Victoria, Australia) was administered on day 9; females were inseminated on day 10. Dates for FTAI were January 8, 2009, January 8, 2010, and January 4, 2011, respectively, of these 3 study years. In all 3 years, the same technician administered the synchronization protocols and inseminated the females.

To study potential sire effects on placental measures and fetal and calf growth, 2 purebred Droughtmaster AI sires were utilized in both 2009 and 2010 and were chosen to represent 1 average-growth animal and 1 high-growth animal based on EBV for 400-d weight within the Droughtmaster breed. Females in 2011 were bred to a third purebred Droughtmaster AI sire that was considered high growth based on 400-d weight EBV.

Measurements

Transrectal fetal ultrasonographic scans were performed using a Honda 2100V machine equipped with a 10-MHz 60-mm linear array probe at gestation weeks 7 and 8. Amnion length and width, embryo-fetal crown-rump length, and *Corpus luteum* diameter and width were recorded. Furthermore, as location of the placenta influences its size (Leiser et al., 1997), 2 placentas at the immediate fetal location in the gravid horn were recorded for width and thickness. Pregnant animals were monitored 2 to 3 times daily during calving, and birth weights were determined within 12 to 15 h of birth. Furthermore, calf weights were obtained at branding (5 to 6 mo of age) and at weaning approximately 80 d later. Weighing conditions were similar across times with shrunk calf weights collected.

Statistical Analyses

All placental, fetal, and calf traits were analyzed through mixed model analyses of variance (SAS v 9.3, SAS Institute, Cary, NC, USA). Fixed effects included birth year, calf sex, AI sire nested within birth year, and the potential interaction of

AI sire and calf sex. The regression of birth weight on gestation length was not utilized as a covariate because genetic differences in gestation length have variable relationships with birth weight in *B. indicus*–*B. taurus* crossbred cattle. Similarly, differences among calf age at branding and at weaning within each year are functions of differences in gestation length, and therefore, these weights were also not adjusted for animal age. Variability in average calf age at branding and weaning between years are accounted for by the birth year effects. Least squares means were separated by two-tailed *t*-tests for main effects ($P < 0.05$) and interactions ($P < 0.10$) that showed differences based on *F*-tests. Additionally, linear correlations were computed for traits of interest and considered significant at $P < 0.05$.

RESULTS

Summary statistics for the traits studied are provided in Table 1. Three traits with relatively low variation (based on CV) were embryo-fetal crown-rump length at 7 wk (8%) and 8 wk (6%) and gestation length (2%). Placenta width and thickness had CV of 17% to 18% at 7 wk, and 12% to 13% at 8 wk.

The substantial variation observed in conceptus and calf measures was explained by year, sire, sex, and sire $\times$ sex interaction (Table 2). Differences between years were observed for all traits except week 7 amnion width and week 8 placenta width and thickness while differences in gestation length ($P = 0.066$) and branding weight at 5 mo ($P = 0.102$) approached significance (Table 2). There was no consistent pattern for year differences. For example, the largest week 7 placenta width, the largest week 7 crown-rump length, the smallest week 8 crown-rump length, the smallest week 8 amnion width, and the shortest gestation length were observed in 2011. However, the largest week 7 placenta thickness, lightest birth weight, and lightest branding and weaning weights were observed in 2009. The only trait where the means of measurements obtained in 2010 differed from other years was *Corpus luteum* diameter at weeks 7 and 8, where both measurements were smaller in 2010.

The regression of birth weight on gestation length was not utilized as a covariate in these analyses because gestation length has variable relationships with birth weight among different crosses of *B. indicus*–*B. taurus*. Similarly, differences among calf age at branding and at weaning within each year were functions of differences in gestation length, and therefore, these weights were also not adjusted

Table 1. Summary of animal numbers and study traits

Animals	Study year					
	2009	2010	2011			
Females FTAI (<i>n</i>)	133	137	51			
Pregnancies week 7 (<i>n</i>)	36	57	24			
Pregnancies week 8 (<i>n</i>)	36	54	22			
Calves born (<i>n</i>)	33	47	21			
Calves weaned (<i>n</i>)	33	43	20			
Traits measured	<i>n</i>	Mean	SD	CV	Min.	Max.
<i>Corpus luteum</i> diameter week 7, mm	110	23.5	2.94	12.5	16	32
Average placentome width week 7, mm	110	7.6	1.34	17.5	5	13
Average placentome thickness week 7, mm	110	3.8	0.70	18.3	2.5	7.5
Amnion width week 7, mm	110	24.9	3.97	16.0	15	35
Amnion length week 7, mm	110	38.6	4.32	11.2	27	49
Crown-rump length week 7, mm	110	30.7	2.42	7.9	24	37
<i>Corpus luteum</i> diameter week 8, mm	110	23.5	2.50	10.6	17	30
Average placentome width week 8, mm	109	9.9	1.17	11.9	7.5	13
Average placentome thickness week 8, mm	109	4.2	0.56	13.1	3	6
Amnion width week 8, mm	109	33.2	4.31	13.0	23	47
Crown-rump length week 8, mm	101	51.8	3.06	5.9	43	58
Gestation length, d	102	287.8	5.92	2.1	267	300
Birth weight, kg	101	34.4	5.08	14.8	21	45.5
Branding age, d	98	165	14	8.5	135	195
Branding weight, kg	98	176.1	33.75	19.2	94.5	257
Weaning age, d	95	247	33	13.4	191	286
Weaning weight, kg	95	237.6	39.01	16.4	163	348

Amnion length week 8 was not measured in 2009 and 2010 and excluded from further analysis.

Table 2. Proportion of variation (R^2) accounted for by linear models¹ and least squares means across years

Stage	Age	Dependent variable	R^2	2009	2010	2011
Conceptus	Week 7	Average placentome width, mm	0.54	7.0 ± 0.18 ^a	7.3 ± 0.14 ^a	9.5 ± 0.21 ^b
		Average placentome thickness, mm	0.25	4.1 ± 0.12 ^a	3.6 ± 0.09 ^b	3.8 ± 0.14 ^b
		Fetal crown-rump length, mm	0.11	30.1 ± 0.43 ^a	30.6 ± 0.34 ^a	31.8 ± 0.50 ^b
		Amnion width, mm	0.16	24.6 ± 0.72	25.2 ± 0.58	23.4 ± 0.85
		Corpus luteum diameter, mm	0.20	24.6 ± 0.51 ^a	22.2 ± 0.41 ^b	24.8 ± 0.61 ^a
	Week 8	Average placentome width, mm	0.05	9.8 ± 0.23	9.81 ± 0.18	10.2 ± 0.27
		Average placentome thickness, mm	0.19	4.3 ± 0.10	4.3 ± 0.08	4.1 ± 0.12
		Fetal crown-rump length, mm	0.43	52.6 ± 0.46 ^a	53.1 ± 0.40 ^a	48.2 ± 0.54 ^b
		Amnion width, mm	0.25	33.5 ± 0.74 ^a	34.6 ± 0.59 ^a	29.3 ± 0.87 ^b
Calf	Birth	Corpus luteum diameter, mm	0.21	24.9 ± 0.43 ^a	22.5 ± 0.34 ^b	23.9 ± 0.50 ^a
		Gestation length, d	0.12	288 ± 1.1 ^a	289 ± 0.9 ^a	285 ± 1.3 ^b
		Weight, kg	0.32	31.2 ± 0.82 ^a	35.2 ± 0.67 ^b	36.3 ± 0.97 ^b
		5 to 6 mo	0.47	147.0 ± 4.84 ^a	194.8 ± 4.13 ^b	178.6 ± 5.72 ^c
		7 to 8 mo	0.62	199.1 ± 4.70 ^a	265.5 ± 4.11 ^b	242.0 ± 5.55 ^c

¹Models included year, AI sire nested within year, calf sex, and calf sex × AI sire (within year) interaction.

^{a-c}Means across years with different superscripts are different ($P < 0.05$).

for animal age. The SD for gestation length, age at branding, and age at weaning were almost identical within study year and were 7.6, 4.9, and 4.2 d, respectively, for 2009, 2010, and 2011 calves.

The only traits where measurements were significantly larger in males than in females (Table 3) were week 7 placentome thickness and 5- to 6-mo branding weight (182 ± 3.6 vs. 165 ± 4.4 kg, respectively;

$P = 0.01$). However, there was a tendency for males to be heavier at birth (35.3 ± 0.6 vs. 33.1 ± 0.7 kg, respectively; $P = 0.07$) and weaning (243 ± 3.6 vs. 228 ± 4.3 kg, respectively; $P = 0.06$). For all of these measures, males had 6% to 7% greater values. For some of these traits, the sex comparison alone does not provide a complete description of variation as an interaction between sex and sire nested within

year (Table 4) was observed for placentome thickness at week 7 ($P = 0.017$) and week 8 ($P = 0.013$), and amnion width at week 7 ($P = 0.029$), with a tendency for an effect on birth weight ($P = 0.095$). Of the few significant differences, those with some degree of consistency were higher placentome thickness in males being reflected in higher calf birth weights. At a significance threshold of $P < 0.02$, placentome thickness at week 7 was negatively correlated with birth weight ($r = -0.23$), branding weight ($r = -0.25$), and weaning weight ($r = -0.35$), whereas placentome width at week 7 ($r = 0.24$) and PT8 ($r = 0.29$) was positively correlated with birth weight (Table 4).

DISCUSSION

Our main goal in assessing placental and embryo-fetal measures was to investigate their variation and associations with birth weight and postnatal weight development to better understand programming effects in a *B. taurus*–*B. indicus* composite beef cattle population. The major observations from our data are that calf weights at birth through weaning are influenced by differences in placental morphology, and, presumably function, early in gestation. However, these effects vary considerably between trial years in a production system characterized by highly variable environmental

Table 3. Least squares means and P -values for sire $\times$ year $\times$ calf sex effects on placental traits and birth weight

Combination ¹	<i>n</i>	Placentome thickness ² week 7, mm	Amnion width week 7, mm	Placentome thickness ² week 8, mm	Calf birth weight, kg
KR-2009-F	5	3.5 $\pm$ 0.28 ^a	23.6 $\pm$ 1.72	5.0 $\pm$ 0.24 ^{aw}	33.3 $\pm$ 1.9
KR-2009-M	7	4.9 $\pm$ 0.24 ^b	24.4 $\pm$ 1.45	4.2 $\pm$ 0.20 ^b	30.1 $\pm$ 1.66 ^w
T-2009-F	7	3.9 $\pm$ 0.24	23.7 $\pm$ 1.45	4.0 $\pm$ 0.20	30.1 $\pm$ 1.66 ^y
T-2009-M	14	4.0 $\pm$ 0.17	26.8 $\pm$ 1.03	4.1 $\pm$ 0.14	31.2 $\pm$ 1.18 ^y
KR-2010-F	7	3.5 $\pm$ 0.24	25.0 $\pm$ 1.45	4.4 $\pm$ 0.20 ^x	31.9 $\pm$ 1.66 ^a
KR-2010-M	15	3.6 $\pm$ 0.16	25.3 $\pm$ 0.99	4.2 $\pm$ 0.14	36.6 $\pm$ 1.14 ^{bx}
T-2010-F	14	3.6 $\pm$ 0.17	25.6 $\pm$ 1.03	4.2 $\pm$ 0.14	35.6 $\pm$ 1.18 ^z
T-2010-M	11	3.7 $\pm$ 0.17	24.8 $\pm$ 1.07	4.5 $\pm$ 0.15	36.8 $\pm$ 1.33 ^z
G-2011-F	9	3.8 $\pm$ 0.21	25.9 $\pm$ 1.23 ^a	3.8 $\pm$ 0.18 ^a	33.9 $\pm$ 1.47 ^a
G-2011-M	12	3.7 $\pm$ 0.18	21.0 $\pm$ 1.11 ^b	4.4 $\pm$ 0.15 ^b	38.6 $\pm$ 1.27 ^b
		$P = 0.017$	$P = 0.029$	$P = 0.013$	$P = 0.095$

¹KR, T, and G represent designations for individual sires; F = females, M = males.

²Average of 2 placentomes evaluated at each time point.

^{a,b}Difference ($P < 0.05$) between sexes within sire-year combination.

^{w,x}Difference ($P < 0.05$) between years within calf sex for sire KR.

^{y,z}Difference ($P < 0.05$) between years within calf sex for sire T.

Table 4. Correlations ($P < 0.02$) between conceptus traits, gestation measures, and calf weights

Pair of traits	Correlation (<i>r</i>)
Among conceptus measures	
Average placentome width week 7—amnion width week 7	−0.25
Average placentome width week 7—fetal crown-rump length week 8	−0.45
Average placentome width week 7—amnion width week 8	−0.43
Fetal crown-rump length week 7—amnion width week 7	0.30
Amnion width week 7—amnion width week 8	0.30
CL diameter week 7—CL diameter week 8	0.64
Amnion width week 8—fetal crown-rump length week 8	0.30
Among calf weight measures	
Birth weight—Average placentome width week 7	0.24
Birth weight—Average placentome width week 8	0.29
Birth weight—Average placentome thickness week 8	−0.23
Birth weight—gestation length	0.38
Calf branding weight (5 to 6 mo age)—Average placentome thickness week 7	−0.25
Calf weaning weight (7 to 8 mo age)—Average placentome thickness week 7	−0.35

Other correlations among these traits were not significant.

conditions. This is consistent with differences in environmental prenatal programming effects and phenotypic plasticity (Gluckman and Hanson, 2004), and the following discussion focuses on placental and calf (epi)genetic effects relating to birth weight in the context of our results.

Parameters Reflecting Placental Function

The majority of studies on cattle placental characteristics and birth weight are based on cloned or in vitro fertilized concepti (e.g., Hill et al. (1999) and Chavatte-Palmer et al. (2006)). Only few studies focused on in vivo conceived concepti were mostly in dairy breeds and mainly evaluated influences of hormone levels associated with placental function at various gestational ages on birth weight. Furthermore, morphological placental characteristics and correlations with birth weight in these studies were only obtained at term (Echternkamp, 1993; Zhang et al., 1999; Pfarrer et al., 2006; Sullivan et al., 2009b).

Our observed correlations of average placentome width at weeks 7 and 8, and of placentome thickness at week 7, with birth weight, and the lack of correlation of embryo-fetal crown-rump length with birth weight suggest that placental capacity to drive fetal growth is established as the embryo transitions from embryo to fetal stage. This could provide valuable insights into optimization of first trimester nutritional management of heifers, and, ultimately enhanced prediction and/or manipulation of birth weight as it is established that growth patterns of placental traits in ruminants at later stages of gestation are associated with birth weight variation. Concepti produced by cloning and in vitro fertilization are different biological models to concepti generated in vivo, but in comparison with noncloned controls can provide important information regarding biological processes. Placentome length growth curves in Holstein heifers tended to plateau after day 180 of gestation for noncloned fetuses with normal birth weight, but continued to increase through gestation in clones which frequently display excessive birth weights (Kohan-Ghadr et al., 2008). In sheep, early to mid-gestation nutrient restriction drives significant changes in placentome shape that may affect programming of postnatal performance (Steyn et al., 2001). In cattle with *B. taurus*–*B. indicus* genetics, the number of cotyledons in the expelled placenta was increased by high dietary protein in the second trimester of gestation and varied with genotype. Placental weight was influenced by maternal undernutrition

during early gestation dependent on dam genotype. Calf birth weight was associated with placental weight and cotyledonary weight and surface area, but not with the number of cotyledons. The correlations of average placentome thickness at week 7 with branding weight and weaning weights in our data that were equal to or stronger than its correlation with birth weight may provide information about programming of postnatal growth in beef cattle and warrants further investigation.

The sire $\times$ sex interaction effect on placentome thickness and amnion width may be explained through data reported by Bellows et al. (1993) who bred F_1 females of multiple crosses to high- and moderate-growth Angus sires and found that the 3 largest placentomes from the high-growth sire were lighter than those from the moderate-growth sire in female fetuses, although the opposite trend was seen in male fetuses.

Crown-Rump Length and Fetal Size

The lack of correlation between crown-rump length at weeks 7 and 8 and birth weight in our data corresponds to results from other cattle studies. Reduced crown-rump lengths at weeks 5 to 12 of gestation in combination with increased calf weights have been reported for concepti from in vitro fertilized and cloned embryos (Bertolini et al., 2002; Hiendleder et al., 2004; Chavatte-Palmer et al., 2006). After in vitro fertilization, *B. taurus* fetuses produced from the same sire were shorter at days 51 and 58 of gestation, whereas amnion length did not differ in comparison with controls, but calves were longer and heavier at birth (Bertolini et al., 2002). Reduced crown-rump length and placentome width without differences in amnion width or placentome length at days 50 and 62 of gestation were also observed in Holstein clones (Chavatte-Palmer et al., 2006).

Gestation Length Aspects

The relationship between gestation length and birth weight is of specific interest when considering *B. indicus* and *B. taurus* genetics with their significant gestation length differences. Significantly longer gestation lengths and lighter birth weights have been reported for *B. indicus* breeds compared with most *B. taurus* breeds (Plasse et al., 1968). Differences in gestation length have also been reported in calves of *B. indicus* $\times$ *B. taurus* crosses (Reynolds et al., 1980), including those from embryo transfer experiments (Amen et al., 2007). A more

recent report by [Mercadante et al. \(2013\)](#) indicated mean gestation length and birth weight of 281.2 d and 34.4 kg from gestating females that were at least 80% Angus and under 20% Brahman, 290.9 d and 32.7 kg, respectively, from females at least 80% Brahman and under 20% Angus, and 284.4 d and 36.2 kg, respectively, from Brangus females (5/8 Angus 3/8 Brahman). Thus, *B. indicus* cattle may compensate for slower fetal development through increased gestation length. The low coefficient of variation in gestation length observed in the present study (2%) likely reflects selection for specific *B. indicus* or *B. taurus* alleles involved in control of gestation length and biological constraints as variation similar to other traits such as birth weight with a CV of 15%, could jeopardize survival of the fetus and/or dam. [Mercadante et al. \(2013\)](#) also observed similar embryo-fetal sizes between *B. indicus* and *B. taurus* in early pregnancy (days 33 to 48) but reduced fetal size in *B. indicus* from days 53 to 62. It is likely that dam and fetal genotypes interact in *B. indicus* × *B. taurus* crosses and influence the relationship between gestation length and birth weight. This is supported by data from [Jacobsen et al. \(2000\)](#) who reported that male Holstein AI calves had higher birth weights than female AI calves, but no such sex difference was detected in IVP calves sired by the same bull.

Calf Genotype Considerations

Differences in birth weights among *B. indicus*–*B. taurus* crosses have been widely recognized including very large differences between male and female calves when *B. indicus* sires are bred to *B. taurus* dams ([Lemos et al., 1984](#); [Paschal et al., 1991](#); [Herring et al., 2005](#)). This contrasts with minimal to no birth weight differences between sexes when *B. taurus* sires are bred to *B. indicus* dams ([Brown et al., 1993](#); [Browning et al., 1995](#); [Riley et al., 2007](#)), and proportional differences when *B. indicus* and *B. taurus* are present in both parents ([Amen et al., 2007](#); [Dillon et al., 2015](#)). The difference in birth weight between male and female calves in this study was 2.2 kg, and this is similar to results of [Sullivan et al. \(2009b\)](#) in *B. indicus*–*B. taurus* composite populations. Additionally, [Sullivan et al. \(2009b\)](#) reported a maternal diet treatment × breed type interaction in *B. indicus*–influenced heifers affecting birth weight where certain combinations produced calves that weighed 3.3 to 8.5 kg less. Whether some of the potential genotype interactions with sex that occur in reciprocal crosses could also persist in composite populations remains unknown.

It has been speculated that differences in uterine blood flow may explain differences in birth weight between *B. indicus* and *B. taurus* ([Ferrell, 1991](#)). Several possible genetic mechanisms have been proposed ([Thallman et al., 1993](#)) as contributory factors for *B. indicus*–*B. taurus* reciprocal birth weight differences, including mitochondrial DNA, Y chromosome dimorphism, genomic imprinting, nonrandom X chromosome inactivation, and maternal environmental programming in the first 7 d of pregnancy. However, in Brangus (5/8 Angus, 3/8 Brahman) composite populations, investigation of pedigree source of mitochondrial DNA ([Rohrer et al., 1994](#)) and Y chromosome ([Herring and Sanders, 1991](#)) have not explained variation in birth weight.

Crosses between 2 recently diverged rodent (*Peromyscus*) species caused dramatic parent-of-origin effects on growth and development; *Peromyscus maniculatus* females crossed with *Peromyscus polionotus* males produced growth-retarded conceptuses, whereas the reciprocal cross caused fetal overgrowth even to the point of lethality, and, that hybrid effects were particularly pronounced in the placenta ([Vrana et al., 2000](#); [Loschiavo et al., 2007](#)). Additionally, [Loschiavo et al. \(2007\)](#) identified an interaction involving an imprinted autosomal region with a portion of the X chromosome contributing to these developmental differences. [Dillon et al. \(2015\)](#) recently analyzed historical data containing reciprocal crosses of *B. indicus* (Brahman) and *B. taurus* (Simmental) and stated a potential similar phenomenon involving the X chromosome and an imprinted autosome modeled birth weight for line cross and gender dimorphism. The influences of placental development in *B. indicus*–*B. taurus* reciprocal crosses is very limited and needs more investigation. [Fitzsimmons et al. \(2008\)](#) reported divergence in fetal size as well as uterine and placental size in reciprocal F₁ Angus–Brahman calves that corresponded to birth weight differences in other studies, and [Xiang et al. \(2014\)](#) reported maternal genome predominantly contributed to variation in gross and histomorphological placental parameters, fetal weight, and fetal organ weights, whereas paternal genome predominantly contributed to fetal fluids weight, umbilical cord weight and length, and placental and umbilical cord efficiency.

CONCLUSIONS

Birth weight is an economically important trait to beef cattle producers because it is related

to dystocia incidence and postnatal growth and development. As many studies on placental measures and their relationships with birth weight were conducted in dairy breeds, a better understanding of the placental-calf genotype relationship in beef cattle, and particularly among *B. taurus*–*B. indicus* crosses and composites, is needed. This study found relationships between placentome parameters at 7 and 8 wk of gestation with birth weight, branding weight, and weaning weight of Droughtmaster calves, suggesting early and significant effects of placental parameters on postnatal performance. A better understanding of in utero mechanisms influencing growth in *B. indicus*–*B. taurus* composites would aid in prediction of calf growth curves and could provide knowledge for improved beef cattle selection and management strategies in major beef producing regions.

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