Influence of Frame Size and Body Condition Score on Performance of Brahman Cattle[1,2]

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ABSTRACT: The effects of frame size (FS) and body condition score (BCS) on performance of Brahman cows were evaluated using records collected from 1984 to 1994 at the Subtropical Agricultural Research Station, Brooksville, Florida. Age at puberty (AP), calving rate (CR), calving date (CD), survival rate (SR), weaning rate (WR), birth weight (BWT), weaning weight (WWT), preweaning ADG, and kilograms of calf produced per cow exposed (PPC) were obtained from first- (n = 215), second- (n = 130), and third or greater-parity (n = 267) dams. Based on hip height at 18 mo of age, heifers were assigned to three FS groups: small (115 to 126 cm), medium (127 to 133 cm), or large (134 to 145 cm). Small and medium FS heifers attained puberty at younger ($P < .05$) ages (633.2 ± 12.3 and 626.4 ± 12.0 d) than large FS heifers (672.3 ± 17.1 d). Calving rate in large FS second-parity dams was 27% less ($P < .05$) than in small and medium FS dams. In third or greater-parity dams, CR was greater ($P < .05$) for small FS cows than for medium and large FS cows. Across the three parity groups, CR improved with increasing BCS. Except for the first-parity dams, animals with better fall BCS calved earlier ($P < .05$). In first-parity dams, SR was less ($P < .01$) in large (47.9 ± 11.0%) than in small (80.7 ± 5.2%) and medium (83.4 ± 4.7%) FS groups. Weaning rates of large FS first- and second-parity dams were less ($P < .05$) than those of small and medium FS dams. Second-parity dams with BCS 3 had lower ($P < .05$) WR than dams with BCS 4 and 5. Within first- and third or greater-parity dams, BWT of calves born to small FS cows were the lightest, and those born to large FS dams were the heaviest; those born to medium FS dams were intermediate ($P < .05$). In second-parity dams, BWT of calves of large FS dams were greater ($P < .05$) than those of small and medium FS dams. In first-parity dams, calves weaned by small FS cows had lower ($P < .05$) WWT than those weaned by higher FS cows. In the third or greater-parity group, large FS dams weaned heavier calves ($P < .05$) than other dams. In all parity groups of dams, calves out of large FS cows had greater ADG ($P < .05$) than those from small and medium FS cows. In first-parity dams, PPC was comparable between small and medium FS dams, but both tended to be greater ($P < .10$) than PPC of large FS dams. Small and medium FS females reached puberty at an earlier age, calved earlier, and had greater calving, survival, and weaning rates, as well as greater kilograms of calf produced per cow exposed than the large FS females. As the large FS cows matured, they seemed to have overcome the negative effects imposed by FS that were observed at younger ages. Their performance traits were generally all comparable to those of smaller cows once they had reached maturity.

Key Words: Zebu, Somatotype, Body Conformation, Height, Reproductive Traits, Production

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Introduction

The effect of frame size (**FS**) on the cow's reproductive traits has become of greater concern in recent years due to the preference for increased size, and particularly height, in Brahman cattle as well as in nearly all other breeds. Frame size is defined by hip height at a particular age and is correlated with growth rate. Thus, even though selection for increased FS likely has been advantageous due to increased growth rate, its impact on female fertility traits such as age at puberty and re-

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breeding efficiency while lactating may have been negative.

The influence of cow size on reproduction and maternal performance has been studied primarily in composite or crossbred populations (Buttram and Willham, 1989), in which it was difficult to determine whether differences were attributable to differences in size or to breed composition. The magnitude of differences in cow size that exists in many breeds of beef cattle in the United States today is great (Jenkins et al., 1991), and the within-breed studies that have been reported to date have not examined the impact of such large differences on reproductive and production traits.

Body condition score (**BCS**) has been shown to have an extremely important impact on fertility rates in beef cattle in Florida (Kunkle et al., 1994) and, therefore, should be considered in conjunction with the effects of FS. The objectives for this study were to determine the effect of heifer FS and fall body condition score on age at puberty and subsequent calving rate, calving date, calf survival rate, weaning rate, calf birth and weaning weights, preweaning ADG, and kilograms of calf per cow exposed in first-, second- and third or greater-parity Brahman dams.

Materials and Methods

The data were collected from Brahman cattle born between 1984 and 1994 at the Subtropical Agricultural Research Station (STARS), Brooksville, Florida. The geographical coordinates of STARS (Main Station) are 28° 38′ 00″ north latitude and 82° 21′ 30″ west longitude. Average annual rainfall is 1,372 mm, and over half of that falls in June, July, August, and September. Average year-round temperature is approximately 22°C, with occasional frosts from November through March.

The foundation Brahman herd at STARS used to generate the females for this study was composed of 54 purebred and 61 upgraded cows in 1983. The upgraded cattle descended from Brahman-sired cows purchased from a commercial Florida herd using a rotational crossbreeding program and were at least two-thirds Brahman. The grade cattle used in this study had been upgraded using purebred sires at least two additional generations. The foundation cow herd was assigned to mating groups based on fall hip height measurements. The mean hip height of the foundation mature cows was 136 cm and ranged from 128 to 145 cm. Two breeding herds of small FS sires mated to cows with the smallest hip heights (generally under 135 cm), one breeding herd using a moderate FS sire with cows with intermediate hip heights (generally 135 to 137 cm), and two breeding herds of large FS sires with cows with the highest hip heights (generally over 137 cm) were used each year in an effort to generate as much variation in hip height as possible in their resulting progeny. All sires used were purebreds and were obtained from cooperating purebred herds as well as from within the STARS Brahman herd. All heifers born from these matings were retained and assigned to small (116.0 to 125.5 cm), medium (126.0 to 133.5 cm), and large (134.0 to 145.5 cm) FS groups based on their 18-mo hip height. Only data from heifers generated in the study were included in the analyses. Other than during the breeding season, females of differing FS were maintained in the same contemporary groups. Females with physical (e.g., udder, feet, and leg problems) or reproductive unsoundness (e.g., not pregnant two consecutive years) or diseases were culled. No cows were culled on the basis of productivity (e.g., weaning weight of calves). There were no major differences in culling rates among the FS groups.

A 120-d breeding season was used throughout the study. Heifers were first exposed at approximately 24 mo of age. Calves were born from late December to early April. Calves remained with their dams on bahiagrass (*Paspalum notatum* Flügge) pastures until weaning in September, when calves were grouped by sex and fed a commercially prepared, medicated supplement (65% TDN, 14% CP, plus antibiotics) for approximately 1 mo. Heifers were fed .91 to 2.27 kg/d of concentrate (depending on the year) and 1.81 kg/d molasses (1993 to 1995), and hay (bahiagrass, perennial peanut, or Alyce clover) was provided for ad libitum intake during winter until spring of the following year when growth of bahiagrass pasture was adequate to support the heifers. As heifers approached 2 yr of age, during their second winter, they were given free access to bahiagrass hay and 1.81 kg/d of molasses.

Cows grazed bahiagrass (*Paspalum notatum* Flügge) or mixed bahiagrass-legume pastures throughout the study. Bahiagrass hay (large round bales) was offered free choice from first frost (about November 15) through approximately April 1, when spring grass became available. Cows were supplemented three times each week at a rate equivalent to .9 $kg \cdot cow^{-1} \cdot d^{-1}$ of a commercially available 20% CP range cube supplement (≤ 5% crude fiber, ≤ 4% total mineral ingredients, ≥ 2% crude fat, ≥ 4,545 USP units vitamin A/kg, ≥ 2,272 USP units vitamin D_3/kg, and ≥ 4.5 USP units vitamin E/kg) fed on the ground. Depending on availability, perennial peanut (*Arachis glabrata* Benth) hay (large round bales) was substituted for the 20% CP range cubes at the rate of 2.3 to 2.7 kg of perennial peanut hay for .9 kg of 20% CP range cube supplement. Additionally, cow herds were supplemented with blackstrap molasses fed in open troughs twice weekly at a rate equivalent to 1.9 $kg \cdot cow^{-1} \cdot d^{-1}$. Until 1989, supplementation of the cow herd with molasses began with first frost (approximately November 15), and supplementation with 20% CP range cubes began at the start of calving (approximately January 1). After 1989, supplementation of the cow herd with range cubes began at first frost, and molasses supplementation began at the start of calving. As with the feeding of hay, range cube and molasses supplementation ceased when pasture growth commenced (approximately April 1). A custom mineral mixture (25% to 32% salt, 15 to 18% Ca, 5 to 8% P, ≥ .94% Fe, ≤ .15% F, ≥ .10% Cu, ≥ .01% Co, and .0010 to .0015% Se) was offered throughout the year in mineral boxes.

The BCS for all females were recorded in September of each year when pregnancy testing and weaning of calves were performed. The fall BCS was originally assessed on a scale ranging from 1 = emaciated to 17 = extremely fat. These scores were reassigned to conform with the 1-to-9 system of body condition scoring (Richards et al., 1986) currently being used by the beef industry. Corresponding values reassigned from the scale 1 to 17 to the scale 1 to 9 were as follows: 1 to 1; 2 to 2; 3 and 4 to 3; 5 to 4; 6 and 7 to 5; 8 to 6; 9, 10, and 11 to 7; 12, 13, and 14 to 8; and 15, 16, and 17 to 9. Calving status was determined from calving records and coded as a categorical trait (1 = calved, 0 = did not calve).

Reproductive traits examined were age at puberty in heifers (**AP**) and their subsequent calving rate (**CR**), calving date (**CD**), calf survival rate (**SR**), and weaning rate (**WR**). Age at puberty was defined to be the age (days) at first detected ovulatory estrus. Criteria for determination of age at puberty were described previously (Senseman, 1989; Vargas et al. 1998). Calving rate was the percentage of cows exposed during the breeding season that subsequently calved. Calf survival was the percentage of calves born alive that survived to weaning (1 = survived, 0 = died before weaning). Calving date was expressed as a Gregorian date. Weaning rate was defined as the percentage of cows exposed to breeding that weaned a calf (1 = weaned, 0 = did not wean). Production traits evaluated were actual birth weight (**BWT**), actual weaning weight (**WWT**), preweaning ADG, and production per cow (**PPC**). Production per cow was expressed as actual kilograms of calf weaned relative to the total number of cows that entered the breeding season.

The reproductive and calf weight traits were analyzed separately for the three parity groups of cows. The parity groups were first-parity dams, second-parity dams, and third or greater-parity dams. Records considered for the last two parity groups were limited to those for cows that weaned a calf the previous year to ensure that only cows lactating during the breeding season were included in the analysis. Because cows were not culled unless they were not pregnant for two consecutive years, cows that failed to become pregnant as lactating 3-yr-olds could have reentered the data set as lactating 5-yr-olds while being rebred to calve at 6 yr. Pregnancy data for nonlactating 4-yr-olds and the weight and other data from this subsequent calf born at 5 yr were not included in the analyses. Therefore, the records used in any subsequent parity were a subset of the records for the previous parity. Because this subset of the data defines a subpopulation of females required to become pregnant while lactating, it more closely represents a commercial population. Total number of dams meeting the above criteria for each parity were as follows: first parity, 215; second parity, 130; and third or greater parity, 267. Throughout the study, husbandry was in accordance with guidelines recommended by the Consortium (1988).

Statistical Analysis

Age at puberty in heifers was analyzed using a least squares model that included the fixed effects of year of birth (**YR**), FS, BCS, and the interaction effects. Data for hip height of heifers at 18 mo of age were initially analyzed using a least squares model that included the fixed effects of YR, FS, and the interaction effect. Because the interaction was not significant, it was deleted from the original model, and the data were reanalyzed using the reduced model. To evaluate the relationship between FS and BCS within each parity group, data were fitted by least squares methods to a model that considered BCS as the dependent variable and YR and FS as the independent variables. When the YR × FS interaction was not significant, it was deleted from the original model, and the data were reanalyzed using the reduced model.

Main effects included in the final model used to evaluate the reproductive traits, including AP in heifers, and production traits in first-, second, and third or greater-parity dams were YR, FS, BCS, FS × BCS interaction, and a random error component. Analyses for CD, SR, BWT, and WWT considered the additional effect of sex of calf (**SEX**), which was dropped from the original model when found not to be significant. In the analysis of CD of the lactating cows, the effect of sex of the nursing calf was included. All possible two-factor interactions involving this effect were included in preliminary analyses, but because they did not influence ($P >$ .15) any of the variables, they were removed from the original model, and the data were reanalyzed using the reduced model. Parity differences in the third or greater-parity group were partially confounded with year effects. Linear contrasts were computed for comparison of levels of FS and BCS for each of the three parity groups of dams. Data were analyzed by least squares ANOVA using the GLM produced of SAS (1988) and are reported as least squares means ± SE.

Results and Discussion

Hip Height and Body Condition Score

Large FS heifers (136.4 ± .45 cm) were taller ($P <$ .001) than medium FS (129.2 ± .23 cm) and small FS (121.7 ± .27 cm) heifers. The relationships between FS and BCS in each of the three parity groups of cows are presented in Table 1. Effects of YR and FS on BCS of first-parity dams were important ($P < .001$). Even though this parity group represents nonlactating 2½-yr-old heifers, the FS effects on BCS show that large FS heifers achieved lower ($P < .05$) BCS than the small and medium FS heifers. The lower BCS for the large FS heifers indicate that the nutritional level in this experiment did not adequately meet their require-

Table 1. Least squares means for body condition scores (BCS) for first-, second-, and third or greater-parity Brahman dams by frame size (FS)

	Parity					
Item	n	First	n	Second	n	Third or greater
Mean	215	6.0 ± .05	130	4.1 ± .07	267	4.7 ± .05
FS						
Small	77	6.2 ± .08[a]	48	4.1 ± .12	107	4.7 ± .09
Medium	97	5.9 ± .07[b]	61	3.9 ± .11	101	4.5 ± .09
Large	41	5.6 ± .13[c]	21	4.1 ± .19	59	4.5 ± .12

[a,b,c]Means with a different superscript letter within a column differ ($P < .05$).

ments. Frame size was not an important source of variation for BCS in second-parity (P = .43) or third or greater-parity (P = .17) dams, probably because lactational energy demands obscured any direct effect of size, especially as the cows reached maturity. Body condition score in lactating cows seemed to remain almost constant (≥ 4.5) in subsequent parities.

Age at Puberty

The average age at puberty in heifers was 633 ± 6.7 d. In the southern United States, AP of 816 d (Reynolds et al., 1963), 537 d (Baker et al., 1989), and 590 d (Plasse et al., 1968) have been reported for Brahman heifers, whereas in Argentina, Mezzadra et al. (1993) reported AP of 507 d. In general, *Bos indicus* heifers achieved puberty at later ages than *Bos taurus* heifers (Plasse et al., 1968; Galina and Arthur, 1989). In a five-breed diallel that included the Angus, Brahman, Hereford, Holstein, and Jersey breeds and their crosses, Nelsen et al. (1982) reported that straightbred Brahman heifers were the oldest, heaviest, and tallest at puberty. Frame size tended to be a significant source of variation (P = .06) for AP (Table 2). Small (633 ± 12.3 d) and medium (626 ± 12.0 d) FS heifers were younger ($P < .05$) at puberty than large (672 ± 17.1 d) FS heifers. Body condition score (P = .29) and the interaction FS × BCS (P = .35) did not affect AP. For *Bos taurus* breeds, Ferrell

Table 2. Least squares means for age at puberty (AP) by frame size (FS) and body condition score (BCS) at 18 mo of age in Brahman heifers

Item	n	Age at puberty, d
FS		
Small	75	633 ± 12.3[a]
Medium	84	626 ± 12.0[a]
Large	34	672 ± 17.1[b]
BCS		
3	50	666 ± 13.8
4	48	653 ± 14.6
5	58	631 ± 13.3
6	16	628 ± 24.9
7	21	640 ± 21.2

[a,b]Means with different superscripts within a column and item (i.e., FS and BCS) differ ($P < .05$).

(1982) reported that AP was not related to BCS of heifers at 452 d of age. Furthermore, Grass et al. (1982) failed to demonstrate that heifers attained puberty at a consistent level of body condition.

Calving Rate

Calving rate in first-parity dams averaged 92.1 ± 1.76% in this study. A similar value (90%) was reported by Peacock and Koger (1980) for Brahman heifers from several ranches in Florida. Frame size did not influence ($P < .31$) CR in first-parity heifers. Because heifers were exposed to breeding at 2 yr of age when the majority of them had already reached puberty, FS was not expected to influence CR (Morris, 1980).

Frame size group had a significant effect ($P < .05$) on the CR of second-parity dams. Only 63.1 ± 3.21% of the young Brahman females that weaned their first calf calved the subsequent year. Calving rate in large FS second-parity dams (41.0 ± 8.38%) was more than 25% lower than that in small (65.8 ± 5.42%) and medium (69.0 ± 4.85%) FS cows (Table 3). The number of observations for large FS second-parity females is low because the low survival rate of calves from first-parity large FS females resulted in their dams being eliminated from the second-parity analysis. Calving rate in mature dams (third or greater-parity dams) averaged 90.3 ± 1.63% and was affected ($P < .01$) by FS. The CR of mature small FS cows was greater ($P < .01$) than that of the medium and large FS mature cows.

Calving rate improved with increasing BCS. Calving rate in first-parity dams with BCS 5 was lower ($P < .05$) than that of dams having BCS 6 or 7. Calving rate of second-parity dams with BCS 3 was markedly lower ($P < .01$) than that of cows with BCS 4 or 5. In mature dams, CR was the lowest ($P < .01$) in cows with BCS 3. Mature cows with BCS 4 or 6 had comparable CR values. These results are in accord with previous studies of *Bos taurus* and *Bos indicus* beef cattle in which body condition score corresponded directly to pregnancy and calving rates (Richards et al., 1986; Kunkle, 1994; Vargas, 1994).

No FS × BCS interaction was detected in first- and second-parity dams for CR. Thus, within each FS group, CR was favorably and directly related to BCS. However, in third or greater-parity dams there was a FS × BCS

Table 3. Least squares means for calving rate (CR) by frame size (FS) and body condition score (BCS) for parity groups of Brahman cattle

	First-parity dams		Second-parity dams		Third or greater-parity dams	
Item	n	CR, %	n	CR, %	n	CR, %
FS						
Small	77	93.5 ± 3.09	48	65.8 ± 5.42[a]	107	93.5 ± 3.41[c]
Medium	97	88.5 ± 2.71	61	69.0 ± 4.85[a]	101	78.5 ± 4.02[d]
Large	41	97.3 ± 6.81	21	41.0 ± 8.38[b]	59	79.8 ± 5.33[d]
BCS						
3	0	—	44	17.1 ± 6.54[c]	22	67.5 ± 6.10[c]
4	0	—	41	69.4 ± 6.72[d]	79	86.7 ± 3.26[d]
5	68	84.5 ± 3.40[a]	45	88.8 ± 6.44[e]	141	94.5 ± 2.58[e]
6	86	96.6 ± 3.23[b]	0	—	25	87.1 ± 6.81[d]
7	61	98.3 ± 6.75[b]	0	—	0	—

[a,b]Means with a different superscript letter within a column and item (i.e., FS and BCS) differ ($P < .05$).
[c,d,e]Means with a different superscript letter within a column and item differ ($P < .01$).

interaction ($P < .01$). Within BCS 3, the calving rate of large FS cows was greater ($P < .05$) than the CR of medium FS cows. Within BCS 4, the CR of large FS cows was greater ($P < .05$) than the CR of both the small and medium FS cows. Within the moderate BCS groups (BCS 5 and 6), taller cows had a lower CR than those of small and medium FS mature cows.

Calving Date

Cows that calve late in the calving season often do not return to estrus before the end of the subsequent breeding season. Thus, CD is an important reproductive trait. Overall CD for first-parity dams averaged 34.6 ± 1.78 d and was similar among the three FS (Table 4). Second-parity dams (CD = 62.6 ± 3.37 d) calved later in the calving season, indicating that conception occurred approximately 30 d later than that of the nonlactating 2-yr-olds in the first-parity group. Growing young cows that are under lactational stress likely suppress cyclic ovarian activity and as a result have a prolonged period of postpartum anestrus (Williams, 1990). Short et al. (1990) reported that first-calf heifers (2 yr old) had longer postpartum intervals of anestrus and lower reproductive rates than dams 3 yr old and older. There was a tendency for the taller cows to calve later than shorter cows. There were no differences among the FS for CD in mature cows, nor was the interaction FS × BCS significant. Overall, small and medium FS cows with similar and adequate BCS (≥ 5) became pregnant earlier than large FS cows and, as a result, they are more likely to calve successively over a number of years.

Body condition score the previous fall influenced ($P < .01$) CD. Heifers with greater BCS at 18 mo calved earlier ($P < .05$) than heifers with lesser BCS. Body condition score the previous fall did not affect ($P = .15$) CD in second-parity dams. Although the number of pregnancies was affected by BCS, BCS did not seem to be a determining factor of when the pregnancies occurred. Overall CD for lactating mature cows was 55.5 ± 1.87 d and was affected ($P < .01$) by BCS. Cows with BCS 3 calved later ($P < .05$) than cows with higher BCS.

Table 4. Least squares means for calving date (CD) by frame size (FS) and body condition score (BCS) for parity groups of Brahman cattle

	First-parity dams		Second-parity dams		Third or greater-parity dams	
Item	n	CD, d	n	CD, d	n	CD, d
FS						
Small	72	33.9 ± 3.14	34	55.0 ± 8.49	100	59.3 ± 3.80
Medium	87	33.8 ± 2.83	38	65.0 ± 5.65	87	65.0 ± 5.30
Large	39	36.9 ± 6.61	10	82.0 ± 13.70	53	64.0 ± 7.08
BCS						
3	0	—	9	67.1 ± 14.00	15	87.4 ± 8.58[a]
4	0	—	32	77.3 ± 7.55	69	60.4 ± 3.79[b]
5	55	50.0 ± 3.54[a]	41	57.5 ± 6.13	132	56.2 ± 2.91[b]
6	84	28.8 ± 3.16[b]	0	—	24	47.0 ± 8.50[b]
7	59	25.8 ± 6.55[b]	0	—	0	—

[a,b]Means with a different superscript letter within a column and item (i.e., FS and BCS) differ ($P < .05$).

Table 5. Least squares means for survival rate (SR) by frame size (FS) and body condition score (BCS) for parity groups of Brahman cattle

	First-parity dams		Second-parity dams		Third or greater-parity dams	
Item	n	SR, %	n	SR, %	n	SR, %
FS						
Small	72	80.7 ± 5.23[a]	34	97.5 ± 6.44	100	77.6 ± 4.76
Medium	87	83.4 ± 4.71[a]	38	88.1 ± 4.27	87	86.9 ± 6.62
Large	39	47.9 ± 11.00[b]	10	93.9 ± 10.33	53	95.7 ± 8.87
BCS						
3	0	—	9	95.3 ± 10.57	15	88.8 ± 10.76
4	0	—	32	92.8 ± 5.68	69	94.1 ± 4.74
5	55	82.2 ± 5.89	41	91.4 ± 4.50	132	85.5 ± 3.65
6	84	73.3 ± 5.25	0	—	24	78.5 ± 10.60
7	59	56.5 ± 10.89	0	—	0	—

[a,b]Means with a different superscript letter within a column and item (i.e., FS and BCS) differ ($P < .01$).

Survival Rate

Calf survival rate was affected by FS ($P < .05$) only in first-parity dams. Survival rate was greater ($P < .01$) for calves out of small (80.7 ± 5.23%) and medium (83.4 ± 4.71%) FS first-calf heifers bred to comparably sized bulls than for calves out of large FS first-calf heifers bred to large FS sires (47.9 ± 11.0%; Table 5). There is no reason to expect calves from the large FS first-parity dams to be more susceptible to cold weather or "weak calf syndrome" (Franke et al. 1975; Turner, 1980). It seems likely that a greater incidence of calving difficulty associated with their larger calves (Bellows and Short, 1994) is primarily responsible for their very low survival rate. Survival rates in calves out of second-parity and mature dams were not affected ($P < .14$) by FS or BCS.

Weaning Rate

Frame size affected ($P < .05$) WR in first- and second-parity dams. Small and medium FS had greater ($P < .05$) weaning rates than the large FS heifers and cows (Table 6). The lower WR for the large FS first-parity cows in this study was primarily due to increased calf mortality because these heifers were bred to the large FS sires. The extremely low pregnancy rate seems to have been responsible for the reduced WR in the second-parity group. Frame size was not a factor influencing WR in third or greater-parity cows.

Fall body condition score did not affect WR in first-parity dams. Weaning rate in second-parity dams with BCS 3 was lower ($P < .05$) than those of dams with BCS 4 or 5. Weaning rate of third or greater-parity dams tended to be affected ($P < .10$) by BCS. Weaning rate in mature dams with BCS 3 was 58.8 ± 9.53%, lower ($P < .05$) than that observed in dams with BCS 4 (82.1 ± 5.09% and BCS 5 (80.9 ± 4.03%), but, unexpectedly, similar to the WR (66.4 ± 10.63%) observed in dams with BCS 6.

Birth Weight

The average BWT of calves born in this study was 32.3 ± .39 kg. Reynolds et al. (1980) reported a 25.8-kg birth weight for Brahman calves. In his review, Plasse (1978) reported an average unadjusted birth weight in

Table 6. Least squares means for weaning rate (WR) by frame size (FS) and body condition score (BCS) for parity groups of Brahman cattle

	First-parity dams		Second-parity dams		Third or greater-parity dams	
Item	n	WR, %	n	WR, %	n	WR, %
FS						
Small	77	75.0 ± 5.33[a]	48	64.9 ± 5.81[a]	107	71.8 ± 5.33
Medium	97	74.3 ± 4.67[a]	61	59.8 ± 5.20[a]	101	68.5 ± 6.28
Large	41	46.2 ± 11.76[b]	21	38.3 ± 8.98[b]	59	75.8 ± 8.33
BCS						
3	0	—	44	17.9 ± 7.00[a]	22	58.8 ± 9.53[a]
4	0	—	41	64.6 ± 7.20[b]	79	82.1 ± 5.09[b]
5	68	69.8 ± 5.88	45	80.6 ± 6.90[b]	141	80.5 ± 4.03[b]
6	86	70.8 ± 5.58	0	—	25	66.4 ± 10.63[a]
7	61	54.8 ± 11.65	0	—	0	—

[a,b]Means with a different superscript letter within a column and item (i.e., FS and BCS) differ ($P < .05$).

Table 7. Least squares means for birth weight (BWT) by frame size (FS), body condition score (BCS), and sex of calf (SEX) for parity groups of Brahman cattle

	First-parity dams		Second-parity dams		Third or greater-parity dams	
Item	n	BWT, kg	n	BWT, kg	n	BWT, kg
SEX						
Male	107	33.2 ± .65[a]	43	35.8 ± .91[a]	117	35.3 ± .67[a]
Female	91	30.5 ± .73[b]	39	32.3 ± 1.07[b]	123	32.9 ± .67[b]
FS						
Small	72	28.0 ± .68[a]	34	30.1 ± 1.20[a]	100	29.9 ± .66[a]
Medium	87	31.4 ± .61[b]	38	34.2 ± .80[b]	87	33.9 ± .91[b]
Large	39	36.0 ± 1.43[c]	10	37.8 ± 1.97[b]	53	38.6 ± 1.25[c]
BCS						
3	0	—	9	31.8 ± 1.97	15	35.1 ± 1.43
4	0	—	32	35.3 ± 1.05	69	35.1 ± .65
5	55	33.1 ± .76[a]	41	35.0 ± .86	132	33.9 ± .54
6	84	30.5 ± .68[b]	0	—	24	32.5 ± 1.47
7	59	31.9 ± 1.42[b]	0	—	0	—

[a,b,c]Means with a different superscript letter within a column and item (i.e., SEX, FS, and BCS) differ ($P < .05$).

Brahman calves in Latin America of 27.2 kg and an average of 28.4 kg for the United States. Male calves were heavier ($P < .05$) at birth than female calves out of all parity groups of dams (Table 7), in agreement with results observed in previous studies (Plasse, 1978; Thrift, 1997).

Frame size had an effect ($P < .01$) on BWT of calves out of all three dam parity groups. Within first-parity dams, BWT of calves increased ($P < .05$) with FS. A similar tendency was observed in the second- and third or greater-parity dams group. The average BWT of calves from the large FS cows was approximately 8 kg greater than BWT of calves from the small FS cows across all parity groups. This difference is due in part to the differential in FS of the bulls used. If all FS groups of females had been mated to similarly sized bulls, we would expect smaller differences in BWT among the FS groups. These results are supported by those of Jenkins et al. (1991), who found a positive within-breed phenotypic correlation (.37) between BWT and adult hip height. Even though Gore et al. (1994) did not find a relationship between BWT and maternal size, large cows tended to have calves of greater BWT than cows of smaller size.

Body condition score tended ($P < .10$) to affect BWT in first-parity dams. However, heifers with BCS 5, the lowest score within this parity group, had calves with greater ($P < .05$) BWT (33.1 ± .76 kg) than heifers with BCS 6 (30.5 ± .68 kg) or BCS 7 (31.9 ± 1.42 kg), a trend that is not readily understood. Body condition score of cow did not affect BWT of calves from second- ($P = .27$) and third or greater-parity ($P = .23$) dams. However, absolute values for mature cows (Table 7) show a tendency for the birth weights of their calves to decrease with increased BCS.

Weaning Weight

The WWT of the calves were similar across parity groups. Calves from the first-parity dams were older at weaning, and this overcame the anticipated lower WWT. Sex of calf influenced WWT of calves out of first- ($P < .001$) and second-parity ($P < .05$) dams but not out of the third or greater-parity dam group ($P = .53$).

Frame size affected ($P < .001$) WWT of calves from first-parity dams. Weaning weights of calves from small FS cows (192.7 ± 4.40 kg) were lower ($P < .05$) than those of calves out of medium (216.3 ± 3.92 kg) and large (226.0 ± 7.01 kg) FS cows. Frame size did not affect ($P = .98$) WWT of calves out of second-parity dams. In the third or greater-parity group, small and medium FS dams weaned calves of similar weights (199.2 ± 6.95 and 203.3 ± 8.53 kg, respectively), both of which were lighter ($P < .05$) than those weaned by large FS dams (231.2 ± 10.79 kg). The expected superiority of the large FS dams for WWT, which was not expressed in second-parity dams, was probably due to the later calving dates for this FS group.

Body condition tended ($P = .09$) to affect WWT in first-parity dams. Thus, heifers that entered the previous winter season in better body condition tended to wean heavier calves the next fall. Part of this weight advantage for calves from heifers in better BCS is also likely due to their earlier CD (Table 4) that allowed their calves to be older, and thus, heavier, at weaning. In older dams, as BCS increased, WWT of their calves increased numerically (Table 8). This may reflect the ability of older cows to maintain more fat reserves that could be mobilized for milk production.

Preweaning Average Daily Gain

Average daily weight gains of the nursing calves are presented in Table 9. Sex of calf influenced ADG of calves out of first- ($P < .001$) and second-parity ($P < .05$) dams but not that of calves from third or greater-parity dams ($P = .22$).

Frame size affected ($P < .05$) ADG of calves. Preweaning ADG of calves from small FS first-parity cows (747

Table 8. Least squares means for weaning weight (WWT) by frame size (FS), body condition score (BCS), and sex of calf (SEX) for parity groups of Brahman cattle

	First-parity dams		Second-parity dams		Third or greater-parity dams	
Item	n	WWT, kg	n	WWT, kg	n	WWT, kg
SEX						
Male	79	218.9 ± 3.99[a]	40	201.6 ± 7.64[c]	94	213.2 ± 6.35
Female	74	204.4 ± 4.12[b]	37	183.2 ± 8.80[d]	111	209.3 ± 6.16
FS						
Small	55	192.7 ± 4.40[c]	34	191.4 ± 9.69	80	199.2 ± 6.95[c]
Medium	72	216.3 ± 3.92[d]	33	191.8 ± 6.92	77	203.3 ± 8.53[c]
Large	26	226.0 ± 7.01[d]	10	193.9 ± 15.99	48	231.2 ± 10.79[d]
BCS						
3	0	—	9	182.8 ± 15.93	12	190.5 ± 13.46
4	0	—	30	194.1 ± 8.61	63	217.4 ± 5.90
5	45	201.6 ± 5.12[c]	38	200.2 ± 7.12	113	212.2 ± 5.05
6	64	216.0 ± 4.63[d]	0	—	17	224.8 ± 12.92
7	44	217.4 ± 6.00[d]	0	—	0	—

[a,b]Means with a different superscript letter within a column and item (i.e., SEX, FS, and BCS) differ ($P < .001$).
[c,d]Means with a different superscript letter within a column and item differ ($P < .05$).

± .02 g/d) was lower ($P < .01$) than that of calves from medium (837 ± .01 g/d) and large FS cows (900 ± .03 g/d). In second- and third or greater-parity dams, calves out of large FS cows were the fastest-gaining ($P < .05$) compared to those out of small and medium FS cows. These differences, which are consistent with the other growth traits evaluated, likely reflect a positive phenotypic correlation between milk production and body size of the cow (Morris and Wilton, 1976), the inherent growth pattern of the large frame size calf (Menchaca et al., 1996), and the ability of the fastest-gaining calves to consume enough forage to meet their increased nutritional demands for growth (Grings et al., 1996). No difference was found in ADG of calves from first-, second-, and third or greater-parity dams attributable to the effect of body condition score.

Production Per Cow

Weight of calf weaned per cow exposed is more important than calf weaning weight per se (Ferrell, 1982) and is a function of calving rate, calf survival rate, and calf weaning weight. Overall production per cow (PPC) averaged 148.4 ± 6.65, 113.1 ± 7.02, and 161.7 ± 5.79 kg of calf for first-, second-, and third or greater-parity dams, respectively.

The kilograms of calf weaned per cow exposed tended ($P = .08$) to be influenced by FS in first-parity dams

Table 9. Least squares means for preweaning average daily gain (ADG) by frame size (FS), body condition score (BCS), and sex of calf (SEX) for parity groups of Brahman cattle

	First-parity dams		Second-parity dams		Third or greater-parity dams	
Item	n	ADG, g/d	n	ADG, g/d	n	ADG, g/d
SEX						
Male	79	864 ± .01[a]	40	891 ± .03[c]	94	897 ± .02
Female	74	792 ± .02[b]	37	812 ± .03[d]	111	868 ± .02
FS						
Small	55	747 ± .02[c]	34	815 ± .03[c]	80	831 ± .03[c]
Medium	72	837 ± .01[d]	33	817 ± .03[c]	77	858 ± .03[c]
Large	26	900 ± .03[d]	10	922 ± .05[d]	48	958 ± .04[d]
BCS						
3	0	—	9	853 ± .05	12	864 ± .05
4	0	—	30	882 ± .03	63	908 ± .02
5	45	819 ± .02	38	819 ± .03	113	884 ± .02
6	64	828 ± .02	0	—	17	872 ± .05
7	44	837 ± .02	0	—	0	—

[a,b]Means with a different superscript letter within a column and item (i.e., SEX, FS, and BCS) differ ($P < .001$).
[c,d]Means with a different superscript letter within a column and item differ ($P < .05$).

Table 10. Least squares means for production per cow (PPC) by frame size (FS) and body condition score (BCS) for parity groups of Brahman cattle

	First-parity dams		Second-parity dams		Third or greater-parity dams	
Item	n	PPC, kg	n	PPC, kg	n	PPC, kg
FS						
Small	77	143.3 ± 11.64[a]	48	121.8 ± 11.85[a]	107	140.6 ± 12.30
Medium	97	161.9 ± 10.21[a]	61	115.4 ± 10.60[a]	101	150.3 ± 14.30
Large	41	102.9 ± 25.70[b]	21	80.5 ± 18.31[b]	59	176.8 ± 19.84
BCS						
3	0	—	44	32.1 ± 14.29[a]	22	107.2 ± 21.49[a]
4	0	—	41	123.1 ± 14.68[b]	79	179.4 ± 11.71[b]
5	68	140.2 ± 12.84	45	162.6 ± 14.08[c]	141	172.4 ± 9.92[b]
6	86	153.6 ± 12.19	0	—	25	164.7 ± 24.52[b]
7	61	114.4 ± 25.46	0	—	0	—

[a,b,c]Means with a different superscript letter within a column and item (i.e., FS and BCS) differ ($P < .05$).

(Table 10). Production per cow of small (143.3 ± 11.64 kg) and medium (161.9 ± 10.21 kg) FS first-parity dams were similar and both tended ($P = .07$) to be greater than the PPC of large FS cows (102.9 ± 25.70 kg). In second-parity dams, the PPC differences for the large FS cows compared to the small and medium FS cows were not as great ($P = .16$). Similarly, the effect of FS on production per cow in third or greater-parity dams was not significant ($P = .28$), but, contrary to the results seen for younger cows, mature cows of large FS produced more calf weight at weaning per cow exposed to breeding than either medium or small FS mature cows. The calves from large FS cows were, however, sired by larger FS bulls than those from the small and medium FS groups.

The kilograms of calf weaned per cow exposed in first-parity dams was not affected ($P = .35$) by BCS. In second-parity dams, however, PPC was highly affected by BCS ($P < .001$). In third or greater-parity dams, production per cow was affected ($P < .05$) by BCS, and there was a tendency ($P = .10$) for the FS × BCS interaction to affect it as well. Second-parity dams with BCS 3, 4, and 5 weaned 32.1 ± 14.29, 123.1 ± 14.68, and 162.6 ± 14.08 kg of calf per cow, respectively. Mature cows with BCS 3, 4, 5, and 6 weaned 107.2 ± 21.49, 179.4 ± 11.71, 172.4 ± 9.92, and 164.7 ± 24.52 kg of calf, respectively.

These results indicate that variation in cow FS affects reproductive and production performance in Brahman cattle and that the impact of FS on reproductive performance was greater at younger ages (first- and second-parity dams) than in mature dams (third or greater-parity dams). As the large FS Brahman cows matured, they seemed to have overcome the negative effects imposed by FS that were observed at younger ages. Their pregnancy rates, calf survival rates, and body condition scores were generally all comparable to those of smaller cows once they had reached maturity. Thus, after the large FS cows ceased growing, the nutritional regimen provided at STARS seemed to more closely meet their requirements for maintenance and lactation. The small FS cows were able to meet their nutrient requirements during lactation and, thus, maintained adequate body condition scores and higher pregnancy rates as young cows. Likely, this is also a reflection of earlier maturity in the small FS group (Menchaca et al., 1996).

Implications

The practice of selecting Brahman cattle for greater hip heights seems likely to have resulted in delayed puberty and reduced female fertility in young lactating females. It may be possible to overcome some of these disadvantages through increased nutrition, but the costs associated with this added nutrition may be excessive, especially in purebreds with excessive frame scores. Although cattle with the shortest hip heights may have better fertility traits, their reduced growth potential and the possibility of inadequate carcass weight must also be considered in determining the optimal cow size for a given management situation. The recommended cow size is likely to be a moderate one so that the cows can be maintained in adequate body condition under nutritional levels attainable under commercial conditions and produce steer progeny with acceptable carcass weights.

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