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Cow/calf preweaning efficiency of Nellore and *Bos taurus* × *Bos indicus* crosses[1]

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ABSTRACT: The objectives of this study were to determine if percentage *Bos taurus* (0 or 50%) of the cow had an effect on ME requirements and milk production, and to compare cow/calf efficiency among 3 mating systems. Metabolizable energy requirements were estimated during a feeding trial that encompassed a gestation and lactation feeding trial for each of 2 groups of cows. Cows were 0 or 50% *Bos taurus* (100 or 50% Nellore) breed type: Nellore cows (NL; n = 10) mated to Nellore bulls, NL cows (n = 9) mated to Angus bulls, Angus × Nellore (ANL; n = 10) and Simmental × Nellore (SNL; n = 10) cows mated to Canchim (5/8 Charolais 3/8 Zebu) bulls. Cows were individually fed a total mixed diet that contained 11.3% CP and 2.23 Mcal of ME/kg of DM. At 14-d intervals, cows and calves were weighed and the amount of DM was adjusted to keep shrunk BW and BCS of cows constant. Beginning at 38 d of age, corn silage was available to calves ad libitum. Milk production at 42, 98, 126, and 180 d postpartum was measured using the weigh-suckle-weigh technique. At 190 d of age, calves were slaughtered and body composition estimated using 9-10-11th–rib section to obtain energy deposition. Regression of BW change on daily ME intake (MEI) was used to estimate MEI at zero BW change. Increase in percentage *Bos taurus* had a significant effect on daily ME requirements (Mcal/d) during pregnancy ($P < 0.01$) and lactation ($P < 0.01$). Percentage *Bos taurus* had a positive linear effect on maintenance requirements of pregnant ($P = 0.07$) and lactating ($P < 0.01$) cows; during pregnancy, the ME requirements were 91 and 86% of those in lactation (131 ± 3.5 vs. 145 ± 3.4 Mcal·kg$^{-0.75}$·d^{-1}) for the 0 and 50% *B. taurus* groups, respectively. The 50% *B. taurus* cows, ANL and SNL, suckling crossbred calves had greater total MEI ($4{,}319 \pm 61$ Mcal; $P < 0.01$) than 0% *B. taurus* cows suckling NL ($3{,}484 \pm 86$ Mcal) or ANL calves ($3{,}600 \pm 91$ Mcal). The 0% *B. taurus* cows suckling ANL calves were more efficient (45.3 ± 1.6 g/Mcal; $P = 0.03$) than straightbred NL (35.1 ± 1.5 g/Mcal) and ANL or SNL pairs (41.0 ± 1.0 g/Mcal). Under the conditions of this study, crossbreeding improved cow/calf efficiency and showed an advantage for cows that have lower energy requirements.

Key words: breed type, energy requirement, maintenance, milk production

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INTRODUCTION

The output of the cow/calf enterprise is a function of weaning weight and the number of calves weaned (Dickerson, 1970). Weaning weight is an important trait and can be increased by crossbreeding programs (Short et al., 1996) utilizing different *Bos taurus* × *Bos indicus* crosses. Ferrell and Jenkins (1984), Solis et al. (1988), and Montaño-Bermudez et al. (1990) showed that breeds with greater milk production potential, associated with greater weaning weights, also had greater maintenance needs than breeds with lower milk production potential.

Maintenance requirements of cows represent approximately 50% of the total energy requirements for beef production (Ferrell and Jenkins, 1984). At restricted feed availability, breeds with greater maintenance requirements could have reduced performance relative to breeds with less maintenance requirements, resulting in reduced feed efficiency (Frisch and Vercoe, 1978). Green et al. (1991) reported that the most efficient system was represented by cows with less BW and de-

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creased maintenance energy requirements. Beef production in Brazil (165 million cattle), as well as in other tropical and subtropical countries, is conducted mainly in extensive systems where feed availability is limited. In Brazil almost 80% of beef cattle are represented by Zebu breeds (mostly Nellore) and its crosses. Studies reporting nutrient requirements and efficiency of cows from tropically adapted breeds are scarce. Research in this area is important to provide data that more closely matches cow genetics with their environment and production system.

The objectives were to estimate energy requirements and milk production of straightbred Nellore and Continental/British × Nellore crosses; and compare cow/calf efficiency among 3 mating systems (straightbred Nellore cow/calf pair, Nellore cows suckling Angus × Nellore calves, and crossbred cows suckling crossbred calves).

MATERIALS AND METHODS

All procedures with animals were conducted according to the University of São Paulo ethical standards established by the College of Agriculture Research Commission.

Animals and Management

The study was conducted at Embrapa (São Carlos, SP, Brazil) from October 2005 to October 2006. The cows produced for this study were from the same Nellore breeding herd, where Nellore dams were mated by natural service to Nellore bulls or artificially inseminated to Aberdeen Angus or Simmental bulls. The sires were represented by 6 Angus, 8 Simmental, and 7 Nellore.

Twenty mature cows for each group of percentage *Bos taurus*, Nellore (**NL**; 0% *Bos taurus*) cows and Angus or Simmental × Nellore (**ANL** or **SNL**; 50% *Bos taurus*) cows, were sampled for use in the study. The 50% *B. taurus* cows were mated by AI to Canchim (5/8 Charolais 3/8 Zebu) bulls (n = 3), whereas the 0% *B. taurus* females were mated by AI to NL (n = 4) or Aberdeen Angus (n = 2) bulls during the fall breeding season, from April to June 2005. As a result we had 2 groups of cows (0 or 50% *Bos taurus*) and 3 mating systems: straightbred NL cows with NL calves, NL cows suckling ANL calves, and ANL or SNL cows suckling crossbred calves (**CC**). The first system represents a low-input pair adapted to a challenging environment. The second system uses crossbreeding with a low-input cow and a high-growth-potential calf. The last system uses crossbreeding with high genetic potentials for growth in both the cows and calves.

Cows were kept on pasture and received a mineralized salt fed at a rate of 65 $g \cdot cow^{-1} \cdot d^{-1}$. At the beginning of the experiment, the cows were 60 ± 1.3 mo of age and with their third calf.

Table 1. Composition of the experimental diets fed (on a DM basis) during gestation (189 to 263 d after mating) and lactation (190-d nursing period)

Item	%
Ingredient	
Corn silage	93.7
Soybean meal	4.6
Urea	0.7
Mineral salt[1]	1.0
Nutrient composition	
ME,[2] Mcal/kg	2.23
CP, % (analyzed)	11.3

[1]14% Ca, 9% P, 15% Mg, 0.53% Zn, 0.13% Mn, 0.3% Fe, 0.2% Cu, 100 mg/kg of Co, 145 mg/kg of I, 43 mg/kg of Se on a DM basis (Salpec 90, Fertibras, Araraquara, SP, Brazil).

[2]From TDN estimated by Weiss et al. (1992) using NDF digestion coefficient = 0.85.

Gestation. The trial was conducted from October 19, 2005, to March 2, 2006. Calves were weaned approximately 248 d before initiation of the gestation study. At 189 ± 11 d after mating, cows were distributed in individual pens with ad libitum access to water and received a total mixed diet (Table 1) containing 11.3% CP and 2.23 Mcal/kg of DM. The ME content of the diet was calculated from the TDN concentration, which was estimated according to the equation of Weiss et al. (1992), using 0.85 as the rate of degradation of the potentially digestible NDF. Cows were fed daily at 0800 h. The DM of feed was determined weekly. Orts were collected daily, weighed, and sampled, and at the end of the trial, a composite sample per cow was prepared and analyzed for DM, NDF, ADF, lignin, ash, ether extract, CP, NDIN, and ADIN. Cows were weighed at 14-d intervals after a 16-h shrink. Cow BCS (1 to 9 scale; Fox et al., 1992) was evaluated by 2 trained evaluators at first and last BW. Cow shrunk BW (**SBW**) was defined as full BW minus estimated weight of the gravid uterus calculated by the equation of Ferrell et al. (1976) as reported by Freetly et al. (2005).

At the start of the trial, maintenance ME requirements ($\mathbf{ME_m}$) were estimated according to NRC (1996). Based on the variation of SBW during the trial, the amount of feed provided to each cow was adjusted to maintain SBW. The energy requirements for pregnancy (conceptus: $\mathbf{ME_y}$) were estimated according to NRC (1996). Metabolizable energy intake (**MEI**) was calculated as the sum of ME_m and ME_y.

At 263 ± 12 d after mating, cows were transferred to pasture for calving. During this period, cows received mineralized salt, and the ME consumption was not recorded. After calving, the energy required for gestation, weights of the gravid uterus, and variation of cow SBW were corrected for the actual birth weight. Difference between initial and final SBW was observed during the gestation trial. The daily MEI at zero BW change for each cow was estimated by regression of BW change on daily MEI.

There were 5 male and 5 female calves in the CC group: ½ Canchim, ¼ Simmental, ¼ NL (**CSN**) and ½ Canchim, ¼ Angus, ¼ NL (**CAN**); 8 males and 2 females in the NL group, and 4 males and 5 females in the ½ Angus ½ NL (ANL) group. One ANL was born dead. Male calves were not castrated or implanted.

Lactation. At 17 ± 8.9 d postpartum, 39 cow/calf pairs were redistributed in the individual pens. Cows were not exposed to bulls during the fall breeding season in 2006 and consequently, reproductive data were not evaluated. Cows were fed the same total mixed diet offered during pregnancy (Table 1). At 38 d of age, corn silage was fed to calves ad libitum. Cow and calf feeders were separated physically so that cows had no access to the feeders used by calves and vice versa, and individual cow and calf intakes were recorded. Animals were fed twice daily at 0700 and 1500 h. Dry matter intake was determined weekly. Orts were collected daily, weighed, and sampled, and at the end of the trial, a composite sample per cow was prepared and analyzed for DM, NDF, ADF, lignin, ash, ether extract, CP, NDIN, and ADIN. Cows and calves were weighed in the morning before feeding every 14 d. Cow BCS was evaluated by 2 trained evaluators.

At the beginning of the trial (first 14 d), daily MEI was estimated based on NE requirements for maintenance, according to the NRC (1996) and ME requirements for lactation ($\mathbf{ME_l}$) as described by Freetly et al. (2005).

The DMI of each individual cow was adjusted at 14-d intervals to minimize change in BW and keep BCS constant. The DMI was adjusted to zero SBW change during lactation as described for the gestation phase.

Milk yields at 42, 98, 126, and 180 d postpartum were determined using the weigh-suckle-weigh technique (Cundiff et al., 1974). Before each measurement cow/calf pairs were separated for 16 h. Calves were weighed, allowed to suckle under constant observation, and then reweighed. This was repeated after the pairs were separated for another 8 h. The daily milk yield was determined by adding the 16- and 8-h BW changes. At 60 and 150 d postpartum, calves were removed for the same 16- and 8-h intervals, and each cow was milked by hand. Samples of each milking were combined for analysis. To aid in milking, 2 mL of oxytocin (Ocitocina Forte UCB, Jaboticabal, SP, Brazil) per cow per milking was administered. Total milk yield at 190 d of lactation and peak lactation were calculated using the equations developed by Jenkins and Ferrell (1984). Total milk solids were determined, and milk samples were analyzed for fat, protein, and lactose by infrared spectrophotometry (Bentley Instruments Inc., Chaska, MN). Secreted milk energy was estimated using values of 9.29, 5.47, and 3.95 Mcal/kg for fat, protein, and lactose, respectively (NRC, 2001).

Individual BW change was used to calculate ME_l. For cows that mobilized body tissue, the efficiency of conversion of mobilized NE to secreted milk was assumed to be 82.4% (Moe et al., 1971). Total milk energy secreted minus NE from mobilized tissue was assumed to be the energy from diet that was used to produce milk. The efficiency of conversion of diet ME to milk was assumed to be 64.4% (Moe et al., 1971). The ME_m was calculated as the difference between total MEI adjusted for zero BW change and ME_l from diet.

Calves were slaughtered at weaning (190 ± 11 d), and retained energy (**RE**) was calculated as the difference between body energy at weaning and at birth. The body composition and performance data of the calves are not presented in this manuscript. Two variables of cow/calf efficiency were calculated and analyzed: gross efficiency, defined as calf BW gain divided by total ME consumed by cow and calf from 17 to 190 d after calving; and energetic efficiency, defined as calf RE/cow and calf MEI.

Pregnant Cows. Cow BW, BW change, BCS, gestation length, MEI and ME requirement data were analyzed by ANOVA using the GLM procedure (SAS Inst. Inc., Cary, NC). Percentage *Bos taurus* of the cow was included as a fixed effect and calf BW at birth as a covariate. Sex of calf and its interaction with cow *Bos taurus* percentage were also tested when gestation length was analyzed. The interaction was not significant and was deleted from the model.

Lactating Cows. Data collected during the lactation phase were analyzed by ANOVA. The statistical model included cow *Bos taurus* percentage as a fixed effect and average BCS as a covariate. Total MEI by cows and by cow/calf pairs during lactation trait and gross and energetic cow/calf efficiency were analyzed by ANOVA for 3 mating systems: straightbred NL (NL/NL pair), NL cows suckling ANL calves (NL/ANL pair), and ANL or SNL cows suckling crossbred calves (CC). Those Angus (n = 6), Simmental (n = 8), and NL (n = 7) bulls cited above were classified individually and included in the model to evaluate the sire of cow effect on cow and cow/calf traits; the effect was not significant and it was omitted from the model.

Tukey's test was used to compare the means of BW, BW change, BCS, gestation length, milk production, milk composition, and energy requirements. Orthogonal contrast for breed type was included to compare the means between ANL and SNL cows. Tukey's test was used to compare mating system means, and orthogonal contrast for breed cross was included to compare cow/calf MEI and cow/calf efficiency between ANL cows suckling CAN calves and SNL cows suckling CSN calves. Cow BW at the beginning of the trial and at weaning were analyzed using paired *t*-test procedure (SAS Inst. Inc.) to evaluate the difference between initial and final BW.

RESULTS AND DISCUSSION

Gestation Requirements

The 50% *B. taurus* cows were heavier ($P < 0.01$; Table 2) than 0% *B. taurus* cows. Body weight change (P

Table 2. Least squares means (±SE) of cow shrunk BW, BCS, gestation length, and energy requirements of pregnant cows from 189 to 263 d after mating with varying *Bos taurus* percentage (0% Nellore or 50% Angus or Simmental × Nellore)

	Bos taurus percentage			Mean square – contrast for breed type[1]	
Variable	0	50	*P*-value	NLs × NLc	ANL × SNL
Initial shrunk BW, kg	462 ± 11	524 ± 10	<0.01	470	1,565
Final shrunk BW, kg	477 ± 11	540 ± 11	<0.01	4.7	1,355
Average BW gain, kg	15 ± 3.5	16 ± 3.4	0.88	571	7.8
Average shrunk BW, kg	471 ± 11	537 ± 11	<0.01	392	871
Average BCS[2]	5.3 ± 0.1	5.5 ± 0.1	0.23	0.02	0.54
Gestation length, d	291 ± 1.7	288 ± 1.6	0.28	644***	68†
Cow MEI,[3] Mcal/d	15.6 ± 0.2	17.6 ± 0.2	<0.01	0.002	2.98†
Cow MEI,[3] kcal·kg$^{-0.75}$/d	157 ± 1.9	161 ± 1.9	0.20	33	49
Cow ME$_m$,[4] kcal·kg$^{-0.75}$/d	119 ± 1.9	125 ± 1.8	0.07	40	229*
Cow ME$_y$,[5] kcal·kg$^{-0.75}$/d	37.7 ± 1.4	36.3 ± 1.4	0.51	0.56	66.7

[1]NLs × NLc = straightbred Nellore cow and calf vs. Nellore cow suckling crossbred calf; ANL × SNL = Angus × Nellore vs. Simmental × Nellore cow.
[2]BCS on a 1 to 9 scale.
[3]Daily ME intake for zero BW change (estimated from regression, within cow %BW on MEI).
[4]ME requirement for maintenance.
[5]ME requirement for conceptus.
***$P < 0.001$; *$P < 0.05$; †$P < 0.10$.

= 0.88) and BCS ($P = 0.23$) were not different between cow groups. When calf *B. taurus* percentage effect was considered, NL cows mated to NL bulls had greater gestation length (296 ± 1.7 d; $P < 0.01$) than NL cows mated to Angus bulls (283 ± 1.5 d). Paschal et al. (1991) and Browning et al. (1995) reported that *Bos indicus*-sired calves had longer gestations compared with *Bos taurus*-sired calves. Gestation length was not different ($P = 0.23$) for male and female animals. Gregory et al. (1978) reported sex of calf differences, in which male calves averaged 1.3 d longer than females. Paschal et al. (1991) observed interaction of breed of sire and sex of calf for gestation length, but that interaction could not be statistically evaluated in the present study. Birth weight of calf (36 ± 2.2 for NL, 33 ± 1.8 for ANL, and 41 ± 1.2 kg for CC calves) was positively related ($P = 0.03$) to gestation length. A positive relationship between gestation length and BW at birth has been reported (Andersen and Plum, 1965). Reynolds et al. (1980) reported that for each 1-d increase in gestation length, BW at birth of the calf increased by 0.25 to 0.30 kg.

The estimated daily MEI (Mcal/d) for zero maternal BW change was different ($P < 0.01$) between 0 and 50% *B. taurus* cows, but when it was analyzed in relation to the metabolic body size (kcal·kg$^{-0.75}$·d^{-1}), it did not differ ($P = 0.20$; Table 2) between breed types. Requirements for maintenance were approximately 5% less ($P = 0.07$) for the 0% than for the 50% *B. taurus* group: 119 ± 1.9 vs. 125 ± 1.8 kcal of ME·kg$^{-0.75}$·d^{-1}, respectively. Ferrell et al. (1976) obtained similar requirements with pregnant Hereford heifers (118.5 to 120.7 kcal·kg$^{-0.75}$·d^{-1}), which were not significantly different from nonpregnant heifers (112.3 kcal·kg$^{-0.75}$·d^{-1}). In this study, Simmental crosses (128 ± 2.5 kcal·kg$^{-0.75}$·d^{-1}) had greater ($P = 0.05$) ME$_m$ than ANL (121 ± 2.3 kcal·kg$^{-0.75}$·d^{-1}) cows. Montaño-Bermudez et al. (1990) recorded that pregnant cows from breeds with high and medium milk production had greater ME$_m$ than cows with low milk production potential. Ferrell et al. (1976) estimated daily heat production by the liver, heart, and kidney from pregnant and nonpregnant heifers and did not observe differences between those groups. They concluded that pregnancy had little effect upon maternal utilization of ME in heifers. Smith and Baldwin (1974) observed significant differences between pregnant-nonlactating and nonpregnant-nonlactating cows in heart and mammary gland weights. Milk production potential of different breed types seems to affect maintenance requirements during pregnancy. Changes occurring in the mammary system may be additional requirements of pregnancy (J. O. Sanders, Texas A&M University, College Station, TX; personal communication). Mammary gland development during pregnancy varied between 55.8 and 100% of total mammary gland (Dijkstra et al., 1997). In this study, energy requirements for mammary tissue are included in maintenance requirements of pregnant cows.

Pregnancy requirements were not different ($P = 0.51$; Table 2) between 50 and 0% *B. taurus* cows evaluated from 189 to 263 d after mating. Ferrell and Jenkins (1985) estimated the total annual requirements for 4 different cow types and suggested that the variation in energy requirements for gestation and lactation among breed types appear to be small relative to variation in maintenance requirements.

Lactation Requirements

The 50% *B. taurus* cows were heavier ($P = 0.05$) than 0% *B. taurus* cows (Table 3). Within the 50% *B. taurus* group, ANL cows weighed less ($P < 0.01$) than

Table 3. Least squares means (±SE) of cow shrunk BW, BCS, milk production, milk composition, and energy requirements of cows from calving to 190 d in milk, with varying *Bos taurus* percentage (0% Nellore or 50% Angus or Simmental × Nellore)

	Bos taurus percentage			Mean square – contrast for breed type[1]	
Variable	0	50	*P*-value	NLs × NLc	ANL × SNL
Initial shrunk BW, kg	484 ± 10	515 ± 9	0.03	29	13,711**
Final shrunk BW, kg	503 ± 9	535 ± 9	0.02	622	12,709**
Average BW gain, kg	19 ± 5.9	20 ± 5.8	0.98	386	18
Average shrunk BW, kg	494 ± 10	522 ± 9	0.05	262	17,480**
Average BCS[2]	5.0 ± 0.02	5.1 ± 0.02	0.11	0.004	0.04
Milk yield, kg (190 d in milk)	828 ± 46	1,244 ± 45	<0.01	64,072	35,780
Peak milk yield, kg/d	5.8 ± 0.3	8.6 ± 0.3	<0.01	0.006	5.03†
Fat, %	5.7 ± 0.2	5.1 ± 0.2	0.03	0.90	0.10
Protein, %	3.9 ± 0.1	3.4 ± 0.1	<0.01	0.02	0.07
Lactose, %	4.6 ± 0.1	4.4 ± 0.1	0.15	0.01	0.03
Dried extract, %	15.5 ± 0.2	14.0 ± 0.2	<0.01	1.1	0.6
Milk energy secreted, Mcal	761 ± 43	1,039 ± 42	<0.01	33,652	49,231
Milk energy, Mcal/kg of DM	5.97 ± 0.04	5.96 ± 0.04	0.87	0.031	0.001
Cow MEI,[3] Mcal/d	20.4 ± 0.4	24.9 ± 0.4	<0.01	2.3	11.9*
Cow MEI,[3] kcal·kg$^{-0.75}$/d	195 ± 3.0	229 ± 2.9	<0.01	322	67
Cow ME_m,[4] kcal·kg$^{-0.75}$/d	131 ± 3.5	145 ± 3.4	<0.01	4.7	157
Cow ME_l,[5] kcal·kg$^{-0.75}$/d	65.4 ± 3.6	84.9 ± 3.5	<0.01	370	35

[1]NLs × NLc = straightbred Nellore cow and calf vs. Nellore cow suckling crossbred calf; ANL × SNL = Angus × Nellore vs. Simmental × Nellore cow.
[2]BCS on a 1 to 9 scale.
[3]Daily ME intake for zero BW change (estimated from regression, within cow %BW on MEI).
[4]ME requirement for maintenance.
[5]ME requirement for lactation.
**$P < 0.01$; *$P < 0.05$; †$P < 0.10$.

SNL cows (488 ± 12 vs. 550 ± 11 kg). The 50% *B. taurus* cows had greater ($P < 0.01$) total milk production (190 d in milk) and peak milk yield than 0% *B. taurus* cows (Table 3). Cruz et al. (1997) also reported less milk production for Nellore compared with Canchim cows. Reynolds et al. (1978) observed 16% greater milk production for cows suckling crossbred than straightbred calves. Cartwright and Carpenter (1961) observed that crossbred calves tend to nurse more frequently than straightbred calves, which can stimulate greater milk production. However, in this study, the milk production of 0% *B. taurus* cows was not affected by sire breed. This result agrees with previous studies evaluating Nellore cows suckling Nellore or *B. taurus* × NL calves (Espasandin et al., 2001; Restle et al., 2003) and suggests that milk production potential is limited in NL cows when producing crossbred calves.

Although 0% *B. taurus* cows had decreased milk production compared with 50% *B. taurus* cows, milk fat content was greater ($P = 0.03$; Table 3). Several studies reported that Zebu cows have greater fat and protein content. The negative correlation between milk production and fat content has been reported in previous studies (Cruz et al., 1997; Restle et al., 2003). Calegare et al. (2007) observed greater milk production and decreased fat content for 50% *B. taurus* cows (ANL, SNL) than NL (1,072 kg and 3.6 to 4.0% vs. 672 kg and 4.9% for 180 d in milk). Milk protein percentage and dried extract were also greater ($P < 0.01$) for 0% *B. taurus* cows than for 50% *B. taurus* cows (Table 3). Restle et al. (2003) observed that NL cows had greater concentrations of all milk components compared with Charolais cows.

Cows with 50% *B. taurus* had greater ($P < 0.01$; Table 3) daily ME requirements than 0% *B. taurus* cows. Calegare et al. (2007) reported a significant linear effect of *B. taurus* percentage increasing total milk production and daily MEI for cows with 0, 31.5, and 50% *B. taurus* breed type. In that study, daily MEI increased from 205 kcal·kg$^{-0.75}$·d^{-1} for NL cows to 229 kcal·kg$^{-0.75}$·d^{-1} for 50% *B. taurus* (ANL, SNL), and the intermediate *B. taurus* percentage consumed 216 kcal of ME·kg$^{-0.75}$·d^{-1}. Crossbreeding systems, particularly with European breeds, increase the genetic potential for weaning weight. In addition, continued selection for growth has resulted in heavier mature BW and greater milk production potential. Greater potential for growth, mature BW, and milk production are accompanied by increases in nutrient requirements for maintenance and lactation (Cundiff et al., 1983; Jenkins and Ferrell, 1983), which may be greater than improvements in productivity.

Change in cow size does not have the same impact on energy requirements as a change in milk production (Prichard and Marshall, 1993). In this study, 50% *B. taurus* cows were heavier than 0% *B. taurus* cows. The MEI (kcal·kg$^{-0.75}$·d^{-1}) was not different during pregnancy ($P = 0.20$; Table 2); however, during lactation, 50% *B. taurus* cows had 15% greater ($P < 0.01$; Table 3) MEI than 0% *B. taurus* cows. McMorris and Wilton

(1986) observed significant differences in MEI between Hereford and Simmental cows during lactation, which were correlated to milk production and mature size differences between breeds. Montaño-Bermudez and Nielsen (1990) evaluated cows of similar mature size and reported 10 and 12% greater energy requirements for cows with medium and high milk production potential relative to those with low potential for milk. Ferrell and Jenkins (1984) estimated maintenance requirements of mature nonpregnant, nonlactating cows from different breed types characterized by low (Angus × Hereford and Charolais × Angus/Hereford) and high milk production potential (Jersey × Angus/Hereford and Simmental × Angus/Hereford). Energy requirements for zero BW/energy change tended to be greater for cow types with greater potential for milk production. Results from Montaño-Bermudez et al. (1990) indicated that variation in milk production explained 23% of the variation in energy requirements for maintenance.

The increased ME_m of 50% *B. taurus* cows was about 10% ($P < 0.01$; Table 3) compared with 0% *B. taurus* cows. The ME_m for pregnant cows was less than those in lactation, but the ratio between the requirements of 0 and 50% *B. taurus* breed type was similar. The ME_m of pregnant cows was 91 and 86% of those during lactation for 0% *B. taurus* and for 50% *B. taurus* cows, respectively. Montaño-Bermudez et al. (1990) reported that the maintenance requirements in gestation were 73 to 83% of those in lactation. Those values are expected to vary with stage of gestation (Ferrell et al., 1976) and amount of milk produced during lactation.

The lactation requirement was greater ($P < 0.01$) for 50% *B. taurus* than for 0% *B. taurus* cows (Table 3). In this study, the same group had greater milk production and daily MEI. Armstrong et al. (1990) reported that the largest and heaviest milking cows consumed the most feed and weaned the heaviest calves. The nutrition requirements of cows for lactation and fetal development are directly proportional to milk production and the BW of the calf at birth (Hargrove, 1993).

Jenkins and Ferrell (2007) evaluated differences among breed types of cattle for BW maintained per unit of DMI and the effect of feed rate on BW stasis. The results showed an interaction between breed and nutrition level. Ferrell and Jenkins (1993) reported that the predicted heat production of Hereford cows became greater than for Simmental at the greatest daily DMI allowance. Thus, the most efficient breed in restricted nutritional environments may not have the best performance in an unrestricted nutritional situation. However, when the nutritional environment is limited, breeds with greater energy requirements could have the worst performance. When nutrients are scarce and there are periods of underfeeding leading to BW fluctuations, decrease in input requirements during specific phases of the cow production cycle could be a strategy to reduce feed costs (Freetly et al., 2000, 2005). Freetly et al. (2000) reported that neither fertility nor BW of calf were negatively affected when cows were managed for limited BW gain during mid-pregnancy followed by rapid BW gain during late pregnancy.

Cow/Calf Efficiency

Calf preweaning performance and body composition are being reported in a separate manuscript (Calegare et al., 2009). The 50% *B. taurus* cows had greater ($P < 0.01$) total MEI than 0% *B. taurus* cows (Table 4). Within 50% *B. taurus* cows, SNL cows had greater (4,449 ± 82; $P = 0.03$) total MEI than ANL cows (4,188 ± 82 Mcal). The daily MEI by cow/calf pair was less ($P = 0.06$; Table 4) for straightbred NL than for NL/ANL and crossbred cow/calf pairs. The difference between straightbred NL and NL/ANL pairs corresponds well to the greater amount of silage consumed by ANL compared with NL calves (Calegare et al., 2009). The SNL/CSN pair had greater (4,732 ± 72; $P = 0.01$) total MEI than ANL/CAN cow/calf pairs (4,460 ± 73 Mcal).

The NL/ANL pairs had the greatest gross efficiency ($P = 0.03$; Table 4) compared with crossbred and straightbred cow/calf pairs. The crossbred cow/calf group consumed 14% more ME compared with NL/ANL pairs, whereas calves from crossbred cows had 5% more BW gain in the preweaning period than ANL calves. The greater BW gain of the CC calves was insufficient to compensate for their greater MEI. However, the performance of calves from ANL and SNL cows was 30% greater than the BW gain of NL calves. In this comparison, greater gains of the calves more than compensated for the greater MEI of crossbred cow/calf pairs when compared with straightbred NL.

Cow/calf efficiency is a combination of the feed energy requirement of the cow and the calf and calf BW or energy gain. The results of the present study have shown an advantage for groups where cows have decreased energy requirements. However, greater genetic growth potential is required in postweaning enterprises (Jenkins et al., 2000). The success of beef production depends on the combination between breed types chosen for the appropriate nutrition level during the cow/calf and the growing-finishing periods.

Nellore straightbred pairs had decreased ($P < 0.01$; Table 4) energetic efficiency (kcal of RE/Mcal of MEI by cow/calf pair) compared with NL/ANL and crossbred cow/calf pairs, which had around 30 and 34% greater RE than NL calves, respectively. The greater BW gain of CC calves and the difference in body composition between CC and NL calves were more than enough to compensate for the greater MEI of NL/ANL and crossbred cow/calf pairs. The ANL/CAN pairs had decreased MEI and around 11% greater ($P = 0.12$) energetic efficiency than SNL/CSN pairs; 103 ± 4.8 vs. 92 ± 4.8 kcal/Mcal, respectively. Calegare et al. (2007) reported greater energetic efficiency for ANL/CAN pairs compared with SNL/CSN pairs (102.6 ± 5.3 vs. 80.7 ± 6.1 kcal/Mcal). In this study, Continental crosses had 6% greater energy requirements and 6% less RE in empty body of calves compared with British

Table 4. Least squares means (±SE) of energy requirements and cow/calf efficiency from calving to 190 d in milk for the 3 mating systems

	Mating system[1]				Contrast for breed cross[2]
Variable	1	2	3	*P*-value	ANL × SNL
Cow total MEI,[3] Mcal	3,484 ± 86[b]	3,600 ± 91[b]	4,319 ± 61[a]	<0.01	339,045*
Cow/calf total MEI,[4] Mcal	3,757 ± 78[c]	3,970 ± 83[b]	4,597 ± 56[a]	0.07	366,966**
Cow/calf MEI, Mcal/d	21.6 ± 0.4[c]	22.9 ± 0.5[b]	26.5 ± 0.3[a]	0.06	12.7**
Gross efficiency,[5] g/Mcal	35.1 ± 1.5[c]	45.3 ± 1.6[a]	41.0 ± 1.0[b]	0.03	5.94
Energetic efficiency,[6] kcal/Mcal	78 ± 4.9[b]	107 ± 5.1[a]	97 ± 3.5[a]	<0.01	594

[a–c]Within a row, means without a common superscript differ.

[1]1 = straightbred Nellore; 2 = Nellore cow mated to Angus bull; 3 = Angus or Simmental × Nellore cows mated to Canchim (5/8 Charolais 3/8 Zebu) bull.

[2]ANL × SNL = Angus × Nellore vs. Simmental × Nellore cow.

[3]Total ME intake (MEI) by cow from 17 to 190 d postpartum.

[4]Total MEI by cow/calf pair from 17 to 190 d postpartum.

[5]Cow/calf efficiency = grams of calf BW gain/Mcal of total MEI by cow/calf pair.

[6]Cow/calf efficiency = kcal of calf retained energy/Mcal of MEI by cow/calf pair.

$^{**}P < 0.01$; $^{*}P < 0.05$.

crosses. Jenkins et al. (1991) reported greater conversion efficiency for Angus/Hereford- and Red Poll-sired cows than for Chianina (large size) and Gelbvieh (large size and greater milk production). In the present study, SNL cows had greater ($P = 0.01$) BW and greater peak milk yield (9.0 vs. 7.9 ± 0.4 kg/d; $P = 0.09$) than ANL.

Frisch and Vercoe (1977) considered that the ability to adapt to the nutritional environment varies among animals. In tropical grazing conditions, *Bos indicus* cattle have more BW gain or less BW loss than *Bos taurus* cattle (Frisch, 1973). While in a temperate grazing environment, 3/4 Brahman steers consumed less feed but had similar BW gain as Herefords (Moran, 1976). Under ad libitum conditions, *Bos taurus* consumed more feed and gained BW faster than *Bos indicus* steers (Frisch and Vercoe, 1977). Straightbred NL is adapted to a nutritionally restricted environment; its lower heat production may be an advantage to reduce the energy requirements of the breeding herd. *Bos taurus* × *Bos indicus* crosses express maximum heterosis and complementarity effects such as parasite resistance and tenderness, respectively. Of course, there is no single breed capable of offering every positive trait (Green et al., 1999).

Outputs such as calf weaning weight could be improved by mating systems that exploit differences between paternal and maternal lines (Fitzhugh et al., 1975). Calegare et al. (2007) reported that gross efficiency was 18% greater for 50% *B. taurus* cows with 3-breed-cross calves than straightbred NL cow/calf pairs, and the group with greater BW gain/energy deposition and medium MEI was the most efficient. Green et al. (1991) observed that gross cow/calf efficiency was 11% greater for crossbred cows of *B. indicus* × *B. taurus* than for *B. taurus* × *B. taurus* cows. When different crossbreeding schemes were compared and equal reproductive performance was assumed, the NL/ANL cow/calf pair showed the greatest gross efficiency in the conditions of this study.

Inclusion of *Bos taurus* percentage showed advantages on cow/calf efficiency compared with straightbred Nellore pairs under the conditions of this study. The decreased energy requirements associated with the reduced growth rate from Nellore/Nellore cow/calf pairs may be profitable when the nutritional environment is limited. However, evaluation of the whole production system must consider reproductive rate and postweaning efficiency and subsequently, carcass quality. The breed type data in this study can be used to parameterize models for the simulation of beef production systems. More data for these breed types should be obtained under different nutritional levels and evaluated under different economic scenarios.

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