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Comparison of cow productivity indicators in Brahman and Bos taurus × Bos indicus cows under tropical conditions

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Abstract

Evaluating cow productivity in tropical beef systems is complex because efficiency depends on the integration of reproductive performance, calf growth, and cow maintenance requirements. The objective of this study was to compare alternative productivity indicators in Brahman and Bos taurus × Bos indicus cows managed under tropical conditions, with emphasis on their ability to account for cow size and consistently rank genotypes. Retrospective production records from 194 cows (46 Brahman and 148 F1 Bos taurus × Bos indicus) and 583 calves were analyzed. Productivity indicators included weaning weight (WW), kilograms of calf weaned per cow exposed to breeding (KCW), and ratios expressing calf output relative to cow weight or metabolic body weight. Data were analyzed using mixed models, paired comparisons, rank correlations, and linear regression. Cow genotype significantly affected all productivity measures ($P < 0.05$). Crossbred cows, particularly Angus × Zebu and Charolais × Zebu, showed superior performance compared with Brahman cows. Indicators expressing productivity relative to cow weight or metabolic weight provided greater discriminatory capacity and ranking consistency. Regression analysis revealed a significant negative relationship between cow weight and calf weaning weight (-0.29 ± 0.05; $P < 0.001$), indicating that increased cow size was not associated with improved calf output. Productivity measures integrating reproductive success and cow size offer a more biologically meaningful assessment of efficiency under tropical conditions.

Introduction

Improving efficiency in cow–calf systems is a primary goal in beef cattle production; however, defining and measuring cow productivity continues to pose a significant challenge. Cow efficiency arises from the interaction among reproductive performance, calf growth, and cow maintenance requirements, all of which are significantly affected by cow size and biological type (MacNeil, 2005; Mulliniks et al., 2021). As a result, the selection of a productivity indicator is crucial for genetic assessment and management choices, especially in extensive and pasture-based settings.

Calf weaning weight (WW) and kilograms of calf weaned per cow exposed to breeding are still commonly used to evaluate cow productivity. Although these measures incorporate calf growth and reproductive success, they fail to account for differences in cow size and maintenance requirements, potentially biasing comparisons among genotypes with contrasting mature weights (Dinkel and Brown, 1978; Rahnefeld et al., 1993). Recent studies have confirmed that larger cows do not necessarily produce proportionally heavier calves, often resulting in reduced biological efficiency when productivity is evaluated on an absolute basis (Ziegler et al., 2020; Mulliniks et al., 2021).

To address this limitation, several composite productivity indicators have been proposed, including expressions of calf output relative to cow weight at weaning or cow metabolic weight ($kg^{0.75}$). These indices aim to integrate calf growth, reproductive performance, and cow maintenance requirements into a single biologically meaningful metric (Kress et al., 2001; Williams et al., 2018). However, the practical performance of these indicators varies, and their ability to consistently rank cows across genotypes remains insufficiently evaluated.

This problem is particularly relevant in tropical beef production systems, where Bos indicus and Bos taurus × Bos indicus cows predominate. These genotypes differ markedly in mature size, reproductive efficiency, and growth patterns, which can substantially alter cow rankings depending on the productivity metric used (Nuñez-Domínguez et al., 2010; Matos et al., 2019). Recent evidence suggests that crossbred cows often outperform purebred Bos indicus cows when productivity is expressed relative to cow weight or metabolic weight, despite having similar or lower absolute weaning weights (Ziegler et al., 2020).

After many years of study, there is still no agreement on which productivity measure best integrates cow size, reproductive success, and calf growth under tropical conditions. Few studies have simultaneously evaluated multiple indicators using both parametric and rank-based approaches to assess their consistency in classifying cows and their effectiveness in controlling residual variance.

Therefore, the objective of this study was to compare alternative productivity indicators in Brahman and Bos taurus × Bos indicus cows managed under tropical conditions, focusing on their ability to account for cow size, incorporate reproductive performance, and consistently rank cows across genotypes. By combining mean comparisons, paired tests, and rank correlations, this study aims to identify productivity measures that provide a robust and biologically sound evaluation of cow efficiency, with direct implications for selection and management in tropical beef production systems.

Materials and Methods

Study location and animals

This study utilized retrospective production records from a tropical beef cattle herd at the Experimental Station “Las Margaritas” (INIFAP), located in Hueytamalco, Puebla, Mexico. The dataset contained records from 194 cows, which included 46 Brahman cows and 148 Bos taurus × Bos indicus F1 cows (Angus × Zebu, Hereford × Zebu, Charolais × Zebu, and Brown Swiss × Zebu). The cows produced calves between 1988 and 1999, resulting in a total of 583 calf records.

Cows were managed under a rotational grazing system based on native tropical grasses (Axonopus spp. and Paspalum spp.). All animals were managed under the same environmental and nutritional conditions throughout the study period.

Reproductive management

Heifers were first exposed to breeding when they reached approximately 300 kg of body weight. Breeding was conducted in two fixed seasons per year: spring (March–May) and autumn (September–November). Each breeding season lasted 63 days, consisting of 42 days of artificial insemination followed by 21 days of natural mating. Pregnancy diagnosis was performed by rectal palpation 45 days after the end of each breeding season.

Cows failing to conceive after two consecutive breeding seasons and heifers failing after three breeding seasons were culled. Calving occurred in two corresponding seasons, and calves were weaned on a

common date within each calving season. The average age at weaning was 220 days. Male calves were not castrated.

Brahman cows were mated to Brahman bulls throughout the study period. F1 cows were mated to Bos indicus bulls from 1986 to 1989, and to bulls of the corresponding European breed from 1990 to 1998. Semen for artificial insemination was obtained from commercial sources, whereas natural service bulls were purchased from purebred breeders, except for Brahman bulls, which were produced within the herd.

Productivity traits and efficiency indicators

Cow productivity was evaluated using calf weaning performance as the biological output. The following productivity indicators were calculated:

- Weaning weight (WW): body weight of the calf at weaning.
- Cow weight at weaning (CWW): body weight of the dam at calf weaning.
- Kilograms of calf weaned per cow exposed to breeding (KCW): coded as zero when a cow failed to wean a calf and as calf weaning weight otherwise.
- KCW adjusted for cow age at weaning (KCWcov): kilograms of calf weaned per cow exposed, including cow age at weaning as a covariate.
- KCW per unit of cow weight at weaning (KCW/CWW).
- KCW per unit of cow metabolic weight (KCW/MBW): where metabolic body weight (MBW) was calculated as $CWW^{0.75}$.
- Kleiber ratio at weaning (KR): calculated as average daily gain from birth to weaning divided by metabolic body weight of the calf ($kg^{0.75}$).

These indicators were selected to represent increasing levels of biological integration, from simple measures of calf growth to composite indicators incorporating reproductive success and cow maintenance requirements.

Statistical analyses

Data were analyzed using the MIXED procedure of SAS (SAS Institute Inc., Cary, NC, USA). Separate models were fitted for each productivity indicator. Fixed effects included cow genotype, year of cow birth, season of cow birth, and cow age at weaning. The sire nested within sire breed was included as a random effect. Two-way interactions identified as significant ($p < 0.05$) in preliminary analyses were retained in the final models.

Mean comparisons among cow genotypes were performed using Fisher's protected least significant difference test. To evaluate the ability of each productivity indicator to discriminate among cow genotypes, the number of significant paired t-tests ($p < 0.05$) was recorded for each method.

To assess the consistency of cow rankings across productivity indicators, Spearman rank correlations were calculated among all indicators. In addition, Pearson correlations were estimated to evaluate linear associations between productivity measures.

Finally, the relationship between calf weaning weight and cow weight at weaning was examined using linear regression analysis with the REG procedure of SAS, in order to quantify the marginal response in calf weaning weight associated with changes in cow size.

Results

Cow genotype and cow age at weaning significantly affected all productivity indicators ($P < 0.05$), whereas season of cow birth had no effect. Year of cow birth influenced KCW, KCW/CWW, and KCW/MBW but not WW, CWW, or KR (Table 1).

Table 1
Significance levels for the effects considered in the models of six productivity measures in Bos taurus and Bos taurus x Bos indicus cows

Effect	WW	CWW	KBD	KBDCov	KCW/CWW	KCW/MBW	KR
Cow Genotype	< .0001	< .0001	< .0001	< .0001	< .0001	< .0001	0.0003
Year of calving	0.8083	0.6964	0.0012	0.4523	< .0001	0.0002	0.3302
Season of calving	0.4586	0.9289	0.4622	0.7245	0.2043	0.2487	0.2654
Age of the cow at weaning	< .0001	0.0053	< .0001	0.006*	< .0001	< .0001	0.0009

WW = Weaning Weight; CWW = Cow Weight at Weaning; KBD = Kilograms of Weaned Calf per Cow at Breeding; KBDCov = Kilograms of Weaned Calf per Cow at Breeding with Cow Weight at Weaning as a Covariate; KCW/CWW= Kilograms of calf weaned per cow at breeding by cow weight at weaning; KCW/MBW= Kilograms of calf weaned by metabolic weight of the cow; KR = Kleiber ratio at weaning. ( ) Ranking of cow genotypes by method.

Least squares means by genotype are shown in Table 2. Brahman cows had lower WW and CWW than all Bos taurus × Bos indicus cows ($P < 0.05$). Angus × Zebu and Charolais × Zebu cows ranked highest for KCW, whereas Brown Swiss × Zebu cows showed the lowest values among crossbreds. Brahman cows produced approximately 40% of the average KCW observed in Bos taurus × Bos indicus cows.

When productivity was expressed relative to cow weight (KCW/CWW) or metabolic weight (KCW/MBW), Angus × Zebu cows maintained the highest ranking, Brahman cows remained lowest, and the remaining crossbreds showed intermediate performance. KCW, KCW/CWW, and KCW/MBW generated the highest number of significant pairwise comparisons among genotypes, whereas CWW and KR showed fewer significant differences.

Table 2
Least squares means and standard errors for seven productivity measures in *Bos taurus* and *Bos taurus x Bos indicus* cows.

Cow genotype	PD	CWW	KBD	KBDCov	KCW/CWW	KCW/MBW	KR
Brahman	129.54 ± 5.82 [a] (5)	195.75 ± 27.47[a](5)	45.28 ± 6.91[a](5)	65.6 ± 12.8[3a](5)	0.12 ± 0.02[a](5)	0.54 ± 0.07[a](5)	12.67 ± 0.20[a](5)
Angus x Cebú	185.33 ± 5.60[bc](2)	363.81 ± 39.06[b](1)	135.30 ± 8.43[b](1)	151.29 ± 15.78[b](1)	0.33 ± 0.02[b](1)	1.50 ± 0.09[b](1)	13.71 ± 0.18[b](1)
Hereford x Cebú	174.17 ± 4.04 [b](3)	360.61 ± 28.95[b](2)	103.53 ± 6.01[c](3)	140.98 ± 11.23[b](2)	0.26 ± 0.01[c](3)	1.16 ± 0.06[c](3)	13.23 ± 0.13[b](4)
Charolais x Cebú	188.46 ± 4.53 [c](1)	359.22 ± 32.66[b](3)	116.67 ± 6.58[bc](2)	134.30 ± 12.48[b](3)	0.27 ± 0.02[c](2)	1.23 ± 0.07[c](2)	13.66 ± 0.14[b](2)
Suizo Europeo x Cebú	173.69 ± 5.14 [b](4)	328.33 ± 38.15[b](4)	93.96 ± 7.6 [d](4)	122.23 ± 15.38[b](4)	0.23 ± 0.02[c](4)	1.02 ± 0.08[c](4)	13.53 ± 0.18[b](3)
Significant T-tests	(6)	(4)	(7)	(4)	(7)	(7)	(4)

WW = Weaning Weight; CWW = Cow Weight at Weaning; KBD = Kilograms of Weaned Calf per Cow at Breeding; KBDCov = Kilograms of Weaned Calf per Cow at Breeding with Cow Weight at Weaning as a Covariate; KCW/CWW = Kilograms of calf weaned per cow at breeding by cow weight at weaning; KCW/MBW = Kilograms of calf weaned by metabolic weight of the cow; KR = Kleiber ratio at weaning. ( ) Ranking of cow genotypes by method.

Spearman rank correlations were high (≥ 0.90) among KCW, KCWcov, KCW/CWW, and KCW/MBW, indicating consistent genotype ranking across these measures (Table 3). KR showed weaker associations with the remaining indicators.

Table 3
Spearman correlations for productivity measures in Bos taurus and Bos taurus x Bos indicus cows

Trait	CWW	KBD	KBDCov	KCW/CWW	KCW/MBW	KR
PD	0.70	0.90*	0.70	0.90*	0.90*	0.80
CWW		0.90*	1.00*	0.90*	0.90*	0.70
KBD			0.90*	1.00*	1.00*	0.90*
KBDCov				0.90*	0.90*	0.70
KCW/CWW					1.00*	0.90*
KCW/MBW						0.90*

*=p < 0.05; WW = Weaning Weight; CWW = cow weight at weaning; KBD = kilograms of calf weaned per cow at mating; KBDCov = Kilograms of calf weaned per cow at mating with cow weight at weaning as a covariate; KCW/CWW = Kilograms of weaned calf per cow in breeding per cow weight at weaning; KCW/MBW = Kilograms of weaned calf per metabolic weight of the cow; KR = Kleiber ratio at weaning.

Regression analysis revealed a significant negative relationship between calf weaning weight and cow weight at weaning ($P < 0.001$). The regression coefficient was -0.29 ± 0.05, indicating that for each additional kilogram of cow weight, calf weaning weight decreased by 0.29 kg on average.

Discussion

The results of this study demonstrate that the evaluation of cow productivity in tropical beef production systems is strongly influenced by the indicator used, particularly when comparing cows of different genotypes and body sizes. Cow genotype and cow age at weaning significantly affected all productivity measures, confirming that biological type and physiological maturity are major determinants of both calf output and overall efficiency. In contrast, season of cow birth had no detectable effect, suggesting that environmental variation associated with season was effectively controlled under the management conditions of this herd.

Brahman cows exhibited lower productivity across all evaluated indicators compared with Bos taurus × Bos indicus cows. These differences were evident not only in absolute weaning weight but also in composite indicators incorporating reproductive success and cow size. The superior performance of crossbred cows, particularly Angus × Zebu and Charolais × Zebu, is consistent with heterosis effects for growth and maternal performance reported in Bos indicus–influenced systems (McCarter et al., 1991; Ziegler et al., 2020). Crossbreeding in tropical environments has been shown to enhance preweaning growth and reproductive performance, contributing to improved biological efficiency under environmental stress.

When productivity was expressed as kilograms of calf weaned per cow exposed to breeding (KCW), marked differences among genotypes were observed. This indicator integrates reproductive success and calf growth, making it more informative than weaning weight alone. However, KCW does not account for variation in cow size and maintenance requirements. Previous studies have demonstrated that larger cows do not necessarily produce proportionally heavier calves, which may reduce biological efficiency when output is evaluated independently of maintenance costs (Dinkel and Brown, 1978; Ziegler et al., 2020).

The adjustment of KCW using cow weight at weaning as a covariate (KCWcov) altered genotype rankings and favored heavier cows. Although covariate adjustment statistically accounts for differences in mean body weight, it also reduces biologically meaningful variation associated with size differences among genotypes. Similar observations were reported by Rahnefeld et al. (1993), who showed that productivity evaluations adjusted for cow weight may obscure differences attributable to biological type. In the present study, KCWcov showed lower discriminatory capacity compared with indicators explicitly incorporating size in ratio form.

In contrast, productivity indicators expressing calf output relative to cow weight (KCW/CWW) or metabolic body weight (KCW/MBW) provided a more balanced assessment of efficiency. These measures consistently produced the greatest number of significant pairwise comparisons and exhibited high rank correlations, indicating strong discriminatory ability and stable genotype classification. Expressing output relative to metabolic body weight aligns with the biological principle that maintenance energy requirements scale to body weight raised to the 0.75 power (Kleiber, 1932) and has been widely used to standardize comparisons among animals of different sizes.

The regression analysis revealed a significant negative relationship between calf weaning weight and cow weight at weaning (− 0.29 ± 0.05; $P < 0.001$). This inverse association indicates that increases in cow body weight were not accompanied by proportional increases in calf output within the evaluated population. In practical terms, heavier cows tended to produce slightly lighter calves. This finding suggests that greater mature size may be associated with higher maintenance energy demands without corresponding improvements in maternal productivity under tropical pasture-based conditions. Similar patterns have been described in extensive systems where increases in cow size do not translate into improved biological efficiency (Rahnefeld et al., 1993; Ziegler et al., 2020). Under resource-constrained environments, larger cows may allocate a greater proportion of available energy to body maintenance rather than milk production or calf growth, thereby reducing efficiency on a relative basis.

The Kleiber ratio showed lower discriminatory capacity compared with KCW-based indicators. Although it incorporates metabolic scaling, the Kleiber ratio primarily reflects calf growth efficiency rather than whole-cow productivity integrating reproductive performance and maternal resource allocation. Therefore, it appears less suitable as a comprehensive indicator of cow efficiency in cow–calf systems where reproductive success is a critical component of economic performance.

Overall, the present results demonstrate that productivity measures integrating reproductive success, calf output, and cow size provide a more biologically meaningful evaluation of efficiency than simple growth-based metrics or covariate-adjusted measures. In tropical beef production systems, where environmental constraints and maintenance costs are critical determinants of profitability, evaluating productivity relative to cow size rather than emphasizing absolute body weight may support more sustainable selection and management strategies.

Implications

The results of this study have direct implications for genetic evaluation and management decisions in tropical beef production systems. Selection strategies based solely on absolute calf weaning weight or cow body may not enhance biological efficiency under tropical pasture-based conditions. The negative association between cow weight and calf weaning weight indicates that increasing mature size does not guarantee improved calf output and may reduce efficiency due to greater maintenance requirements. Productivity indicators that integrate reproductive success and express calf output relative to cow weight or metabolic weight provide a more biologically relevant framework for evaluating cows of different genotypes. The adoption of these indicators may contribute to improved resource use efficiency, reduced maintenance costs, and more sustainable breeding programs in tropical environments.

Conclusions

The evaluation of cow productivity in tropical beef systems is highly influenced by the productivity indicator used, particularly when comparing cows of different genotypes and body sizes. Indicators based solely on calf weaning weight or kilograms of calf weaned per cow exposed do not fully reflect biological efficiency when cow size and maintenance requirements are not considered.

Productivity measures that express calf output relative to cow weight or metabolic weight provided a more biologically meaningful and statistically robust assessment of cow efficiency. These indicators improved genotype discrimination and maintained consistent ranking patterns across analytical approaches.

The significant negative relationship between cow weight and calf weaning weight indicates that increased cow size was not associated with improved calf performance in this population. This finding reinforces the importance of evaluating productivity relative to maintenance requirements rather than emphasizing absolute body size.

Overall, productivity indicators integrating reproductive performance, calf output, and cow size are better suited for guiding selection and management decisions in tropical beef production systems.

Declarations

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Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

Author contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Vicente E. Vega Murillo, Jorge Bustos Ayil and Cesar G. Luna Azuara, and Rene Carlos Calderon-Robles. The first draft of the manuscript was written by Jorge Bustos Ayil, Rene Calderon-Chagoya, Moises Montaño Bermúdez and Vicente E. Vega Murillo. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Data availability

The data presented in this study are not available due to institutional policies, and the data that support the findings of this study are available in this article.

Ethics approval

This is an observational study; no ethical approval is required.

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