Nutritional Strategies for Developing Replacement *Bos Indicus*-Influenced Beef Heifers

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Introduction

Approximately 45% of U.S. beef cows are located in southern and southeastern states where *Bos indicus*-influenced cattle and extreme heat conditions predominate (NASS, 2017). Despite their wide importance, *Bos indicus*-influenced cattle are typically managed using practices developed for *Bos taurus* breeds reared in temperate zones. *Bos taurus* and *B. indicus* are different subspecies that diverge in social and biological functions (Cooke et al., 2020). Under the same environmental and nutritional conditions, *Bos taurus* and *Bos indicus* cattle exhibit differences in feed digestion (Habib et al., 2008; Bell et al., 2017) and physiology (Sartori et al., 2016).

A major limiting factor for reproductive success of *Bos indicus*-influenced beef heifers is the late attainment of puberty due to genetics, environment (i.e. heat stress), and nutrition. Heat stress is detrimental to cattle metabolism, growth, reproduction, health, and welfare (Mader, 2003; Key et al., 2014) and will become a greater challenge in the future due to the potential impact of global climate change (IPCC, 2007). Environmental conditions are considered thermoneutral when thermal-humidity index (**THI**) ≤ 70, mild heat stress when 70 ≤ THI < 74, heat stress when 74 ≤ THI < 77, and severe heat stress when THI ≥ 77 (Davis et al., 2003). **Figure 1** shows the average, minimum and maximum daily THI values obtained at the University of Florida - Range Cattle Research & Education Center (Ona, FL). From June to October 2019, average THI values were within or above the threshold considered as heat stress. Also, maximum THI values often reached severe heat stress levels. These challenging conditions during summer partially explain the poorer average daily gain (**ADG**; **Table 1**) of heifers, despite the greater nutritional composition of forage during Summer vs. Fall.

The cow-calf industry in Florida relies on warm-season forages as the main source of feed for beef cattle. This forage type often does not meet the requirements of growing heifers, even if herbage mass is not a limiting factor. Moore et al. (1991) compiled the nutritional analysis of 637 samples of forages commonly grown in Florida (bahiagrass, bermudagrass, digitgrass, stargrass, and limpograss) and reported that most of these grasses contained between 5 to 7% crude protein (**CP**) and 48 to 51% total digestible nutrients (**TDN)**, on the basis of dry matter (**DM)**. Developing heifers require diets with at least 55% TDN and 8.5% CP on a DM basis to achieve adequate growth rates (≥ 0.50 kg/d; NRC, 1996). Nevertheless, successful reproductive

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performance can still be obtained if heifers become pubertal before the initiation of breeding season (Moriel et al., 2017). For instance, our previous study funded by the Florida Cattlemen Enhancement Board demonstrated that average final pregnancy rates were 82% for heifers that achieved puberty BEFORE the start of the breeding season compared to 36% for heifers that achieved puberty DURING the breeding season. In this article, we will provide a summary of our previous and on-going studies to optimize growth and reproduction of *Bos indicus*-influenced beef heifers in tropical/subtropical environments.

Post-Weaning Energy Intake

Increasing the post-weaning energy intake led to positive impacts on the reproductive physiology of heifers (Moriel et al., 2017). Our group has observed that heifers supplemented with concentrate DM at 1.75% of their body weight for the entire development period (September to March) had greater overall ADG, puberty attainment before the start of the breeding season, and pregnancy rates compared to heifers supplemented at 1.25% of their body weight (**Table 2**). Lifetime productivity is significantly improved when heifers calve early in their first calving season (Cushman et al., 2013). Supplementation at 1.75% also increased the percentage of heifers calving during the first 4 weeks of the calving season. Total amount of supplement consumed during the study was 1,350 lb and 1,888 lb for heifers supplemented at 1.25% and 1.75% of body weight, respectively. Concentrate supplement cost was $0.15/lb. Total feed cost per heifer was $203 and $283 for heifers supplemented at 1.25% and 1.75%, respectively. Assuming all calves from these heifers are weaned with 550 lb at $1.40/lb, the net return per heifer after discounting feed costs would be $87 greater for heifers supplemented at 1.75% vs. 1.25% of body weight**,** despite their greater supplementation cost.

Frequency of Concentrate Supplementation

Up to 63% of annual production costs in cow/calf operations are associated with cattle feeding (Miller et al., 2001). Decreasing the frequency of concentrate supplementation from daily to 3 times weekly, for example, can help to reduce these costs by more than half. When supplementation frequency is reduced, the amount of supplement fed weekly remains the same (i.e., 21 kg/week), but the amount of concentrate fed at each feeding event is increased compared to daily supplementation (3 kg/day for 7 days vs*.* 7 kg/day on Mondays, Wednesday, and Fridays).

Previous studies reported that reducing the frequency of energy supplementation from daily to 3 times weekly had no impact (Drewnoski et al., 2011; Moriel et al., 2016) or decreased ADG of beef calves by 10 to 21% (Cooke et al., 2008; Artioli et al., 2015). Discrepancies among these results can be associated to differences in supplement composition, animal breed and sex, location of the study, forage species and quality, and the potential interactions among those factors (Artioli et al., 2015). However, differences in daily forage DM intake between cattle offered frequent or infrequent energy supplementation is the primary factor explaining the variable growth performance among these studies. When supplementation frequency is reduced, cattle consume a large portion of concentrate in a single day and receive no concentrate supplementation on the next day. This less frequent schedule of supplementation leads to fluctuations in forage and nutrient intake.

In terms of performance of beef heifers, reducing the frequency of supplementation may be detrimental to reproduction. Moriel et al. (2012) evaluated the impact of similar weekly energy supplementation that was offered either daily (**S7 heifers**) or 3 times weekly (**S3 heifers**; Monday, Wednesday, and Friday) on growth and reproductive performance of developing beef heifers fed stargrass. Supplements were offered at weekly rates of 16 kg of DM/heifer. On days that both S3 and S7 heifers were supplemented, S3 heifers had lower hay DM intake compared with S7 heifers (2.55 vs. 3.36 kg/day, respectively). On days that only S7 heifers were supplemented, S3 heifers also had lower hay DM intake (3.15 vs. 3.38 kg/day for S3 and S7 heifers, respectively). Consequently, overall mean hay DM intake was 15.4% lower for S3 vs. S7 heifers (2.85 vs. 3.37 kg/day, respectively). Estimated net energy of gain (**NEg**) intake followed the same pattern observed on total DM intake, and overall estimated NEg intake was slightly greater for S7 vs. S3 heifers (2.75 vs. 2.59 Mcal/day, respectively). However, the magnitude of differences on estimated overall NEg intake between S7 and S3 heifers was not sufficient to impact ADG (0.28 vs. 0.27 kg/day for S3 and S7, respectively). Despite the similar ADG, attainment of puberty and pregnancy were delayed by decreasing the frequency of energy supplementation (**Figure 2**). At the end of the breeding season, approximately 38% of S7 heifers were pubertal, whereas only 17% of S3 heifers were pubertal. Final pregnancy rates did not differ between treatments but S7 heifers became pregnant earlier in the breeding season (**Figure 2**).

Enhanced reproductive performance have been associated with increased blood concentrations of glucose, insulin, and insulin-like growth factor 1 (**IGF-1**; Hess et al., 2005). In cattle, GnRH secretion is impaired when glucose availability is inadequate, but resumed when glucose levels are adequate (Hess et al., 2005). Cows with low plasma insulin concentrations have impaired LH surge, reduced numbers of LH receptors in the dominant follicle, and fail to ovulate (Diskin et al., 2003). Insulin-like growth factor 1 is a major metabolic signal regulating reproduction in cattle (Wettemann and Bossis, 2000; Thatcher et al., 2001). Plasma glucose, insulin and IGF-1 are positively affected by nutrient intake (Vizcarra et al., 1998; Bossis et al., 1999) and supplementation frequency (Cooke et al., 2007). For instance, plasma glucose and insulin concentrations were greater for S3 vs. S7 heifers on the days that only S7 heifers received supplementation, but not on days that both treatment groups were supplemented. More importantly, heifers supplemented every day had less daily variation in plasma concentrations of glucose and IGF-I than heifers supplemented 3 times weekly (**Figure 3**; Moriel et al., 2012). The differences in plasma concentrations of glucose and insulin were attributed to the pattern of nutrient intake of each treatment, and this lower fluctuation in blood parameters with a more frequent supplementation schedule likely collaborated for the improved puberty achievement compared to infrequent supplementation (Moriel et al., 2012).

Recently, we attempted to overcome the negative effects of frequency of supplementation by increasing the amount of supplement offered to heifers. In this 2-year study, heifers were supplemented with concentrate DM at: 1.25% of body weight offered 3 times weekly (**1.25-3X**); 1.25% of body weight offered 7 times weekly (**1.25-7X**); 1.75% of body weight offered 3 times weekly (**1.75-3X**); or 1.75% of body weight offered 7 times weekly (**1.75-7X**). The hypothesis was that by increasing the concentrate supplementation amount, heifers offered reduced frequency of supplementation would achieve similar puberty attainment and pregnancy percentage compared to heifers supplemented daily. Contrary to our hypothesis, effects of supplementation frequency × amount were not detected ($P \geq 0.71$) for any variable. Growth and reproductive performance of heifers supplemented at 1.25% or 1.75% were discussed previously (**Table 2**). Similar to our previous studies, growth and reproductive performance of heifers supplemented 3 times weekly were reduced compared to heifers supplemented daily (**Table 3**). Although pregnancy rates did not differ, heifers supplemented 3 times weekly calved later during their first calving season compared to heifers supplemented daily (**Table 3**). Therefore, despite including greater supplementation amounts and a puberty induction protocol, heifer reproductive performance was significantly jeopardized when supplementation frequency was reduced from daily to 3 times weekly.

Growth Pattern (Stair-Step Strategy)

Modifying the growth pattern during the post-weaning phase has been used to promote reproductive success of *Bos taurus* heifers. Lynch et al. (1997) developed beef heifers to achieve an even weight gain from weaning until breeding (EVENGAIN) or achieve a low weight gain from weaning until 45 days before breeding followed by a high weight gain in the final 45 days before breeding (LOW-HIGH). Both groups were fed enough nutrients to achieve 65% of the expected mature body weight by the start of the breeding season. The strategy of low weight gain followed by high weight gain is called Stair-Step strategy and is usually implemented to explore compensatory gains that occur when nutrition level is increased immediately after a period of nutrient restriction. In that study (Lynch et al., 1997), LOW-HIGH heifers had greater first-service conception rate compared to EVENGAIN heifers (71% vs. 56%). Although final pregnancy rates did not differ between these two treatments (88% vs. 88%), the greater first conception rates of LOW-HIGH heifers led to increased percentage of heifers calving early in their first calving season, which has been associated with greater lifetime productivity and longevity. Another study also reported that heifers developed using a Stair-Step strategy had approximately twice as many primordial follicles (an indicator of ovarian reserves) at 14 months of age compared to heifers developed on an even gain program (Freetly et al., 2014). This response is important because primordial follicles found within the ovary serve the needs of the entire reproductive lifespan. Also, larger ovarian reserves might be associated with increased fertility in cattle (Cushman et al., 2014). Hence, the Stair-Step strategy may allow producers to further improve the reproductive performance of their heifers without increasing feed costs. It is important to highlight that the studies described above used *Bos taurus* heifers. It is unknown if this strategy would generate similar results in heifers developed in the Florida, particularly due the *Bos indicus* genetic contribution and the hot and humid Summer/early-Fall delaying puberty attainment. Our on-going study will explore the Stair-Step strategy for developing Brangus heifers to determine if such nutritional strategy may or may not be applied in FL production system.

The experiment will be conducted at the Range Cattle REC (Ona, FL) from September 2019 to June 2020 (Year 1) and replicated from September 2020 to June 2021 (Year 2). In September of each year, 64 Brangus heifers will be allocated into 1 of 16 bahiagrass pastures (4 heifers/pasture). Treatments will be assigned to pastures (8 pastures/treatment) and will consist of: control heifers supplemented with concentrate DM at 1.50% of body weight from September until the start of the breeding season in December (day 0 to 100 of the study; **CON**); or stair-step heifers initially offered concentrate DM at 1.05% of body weight from September to October (day 0 to 50 of the study), and then, concentrate DM at 1.95% of body weight (DM basis) from October until the start of the breeding season in December (**SST**; day 50 to 100 of the study). In average, both treatments will be supplemented with concentrate DM at 1.50% of body weight from September to December (22% CP and 73% TDN; DM basis).

In year 1, total supplement DM offered to heifers did not differ between treatments (410 vs. 405 ± 3.5 kg/heifer for SST and CON, respectively; $P = 0.26$). In terms of growth, ADG from day 0 to 50 did not differ between treatments (0.63 vs. 0.62 ± 0.040 kg/day; $P = 0.87$) but was greater for SST vs. CON heifers from day 50 to 100 (0.73 vs. 0.56 ± 0.044 kg/day; $P = 0.01$), leading to a tendency for greater overall ADG (0.68 vs. 0.59 ± 0.031 kg/day; $P = 0.07$) and greater body weight at start of estrus synchronization protocol for SST vs. CON heifers (311 vs. 302 ± 2.1 kg; $P = 0.009$).

Intravaginal thermometers were inserted into heifers to determine the intravaginal temperatures every 30 min from day 25 to 31 (Sep 7^{th} to 12^{th}) and day 85 to 91 of the study (Nov 6^{th} to 12^{th}; see **Figure 1** for THI values). From day 25 to 31, SST heifers had significantly lower intravaginal temperatures from 0930 h to 1800 h compared to CON heifers (nearly 0.25 to 0.32ºC lower for SST vs. CON), which is likely a result of lower heat increment and partially explains the lack of treatment effects on heifer ADG from day 0 to 50 despite the drastic differences in supplement DM offered (1.05 vs. 1.50% of body weight for SST and CON, respectively). From day 85 to 91, supplement DM amount did not ($P = 0.39$) affect intravaginal temperature of heifers, which likely prevented energy waste to cope with heat stress and allowed the greater ADG of SST vs. CON heifers.

Although overall ADG tended to differ, reproductive tract scores (4.52 vs. 4.37 ± 0.173 for SST and CON, respectively; $P = 0.58$) and percentage of pubertal heifers at the start of the synchronization protocol (79.3 vs. 71.9 ± 8.23 % of total for SST and CON, respectively; $P = 0.54$) did not differ between treatments. We will repeat this study for another year to confirm these results, but based on data from year 1, the SST strategy offered an opportunity to harvest greater growth performance before the start of the breeding season without increasing feed costs. This enhanced growth performance did not lead to any advantage on heifer puberty attainment before breeding in year 1 of our study but might be important in situations when heifer post-weaning body weight are lighter than those reported herein.

Early-Weaning

Metabolic imprinting is the process by which nutrition during early-stages of a calf's life may permanently change its development and subsequent performance (Lucas, 1991). This concept has substantial economic implications for agriculture and should be explored to improve the performance of animals destined for food production. Early-weaning is a management practice consisting of permanent calf removal at ages often less than 5 months. Conversely, normal weaning traditionally occurs when calves are between 7 to 9 months of age. Early-weaning has been shown to improve calf growth (Moriel et al., 2014) and feed efficiency and reproductive performance of cows (Arthington and Kalmbacher, 2003). Despite the positive effects of early-weaning on cattle performance, few beef producers are willing to adopt the early-weaning practice because of the limited amount of information on how to manage early-weaned calves and increased labor associated with feeding calves daily. Thus, our group conducted a 2-year study at the UF/IFAS Range Cattle Research and Education Center to evaluate different calf management systems for early-weaned beef calves and their long-term consequences to heifer growth and reproduction (Moriel et al., 2014).

In January of each year (day 0 of the study), Brangus calves (70 days of age) were assigned to remain with their dams and be normally weaned at 250 days of age (day 180 of the study; **NW**), or early-weaned at 70 days of age and randomly assigned to 1 of 3 early-weaning management systems from day 0 to 180 of the study: 1) ryegrass and bahiagrass grazing for 180 days (**EWPAST**); 2) high-concentrate diet in drylot for 180 days (**EW180**); and 3) high-concentrate diet in drylot for 90 days, then bahiagrass grazing for additional 90 days (**EW90**). When early-weaned calves were in drylot, they were limit-fed the high-concentrate diet at 3.5% of body weight (as-fed). When early-weaned calves were on pasture, they were supplemented with the same high-concentrate diet at 1.0% of body weight (as-fed). Calves that were kept with the mothers until weaning (250 days of age) did not receive supplementation from 70 to 250 days of age.

We observed that EW90, EW180, and EWPAST heifers had similar or greater growth performance from day 0 to 180 than NW heifers (**Table 4**). From day 180 of the study until the end of the breeding season (day 395), all heifers were supplemented with concentrate DM at 1.5% of body weight (as-fed). During this period, no differences were detected for ADG among treatments (in average = 0.68 kg/day). Interestingly, limit-feeding a high-concentrate diet in drylot, for at least 90 days, increased the percentage of heifers cycling at the start of the breeding season compared to normally weaned heifers (**Table 4**). More specifically, a greater percentage of early-weaned heifers fed high-concentrate diet in drylot for only 90 days achieved puberty at the start of the breeding season, despite having similar body weight and ADG compared NW heifers. This response indicates that we can successfully hasten puberty achievement if *Bos* *indicus*-influenced beef heifers by temporarily exposing young calves to high-concentrate diets and high-growth rates starting at approximately 70 days of age.

Pre-Weaning Injections of Bovine Somatotropin

The exact nutrition-mediated mechanisms involved in this early activation of the reproductive axis in beef heifers are unknown. However, circulating IGF-I can affect gonadotropin secretion and activity required for the first ovulation and subsequent puberty achievement in beef heifers by influencing hypothalamic–pituitary secretory activity (Schillo et al., 1992) and augmenting the effects of gonadotropins in ovarian follicular cells (Spicer and Echternkamp, 1995). Thus, metabolic imprinting may be explored by identifying strategies to increase heifer ADG and plasma IGF-1 during the developmental phase leading to optimized future reproductive performance. In agreement, heifer ADG and plasma IGF-1 concentrations from 70 to 160 days of age explained approximately 34% of the variability on age at puberty (Moriel et al., 2014). Although postweaning injections of bovine somatotropin (**bST**) hastened puberty attainment of *Bos taurus* heifers (Cooke et al., 2013), less emphasis has been placed on preweaning management strategies despite their greater impact on heifer puberty attainment compared with postweaning management practices.

Bos taurus and *Bos indicus* are different subspecies that diverge in social and biological functions (Cooke et al., 2020). Under the same environmental and nutritional conditions, *Bos taurus* and *Bos indicus* cattle not only exhibit diet-dependent differences in intake, digestion and ruminal fermentation (Habib et al., 2008; Bell et al., 2017), but also different ovarian function, circulating hormones and metabolites (Sartori et al., 2016). These differences may determine the direction and magnitude of performance responses to similar management applied to *Bos taurus* or *Bos indicus* breeds. Thus, we conducted 2 studies to evaluate the impacts of preweaning injections of bST on growth and reproductive performance of Brangus (*Bos indicus* × *taurus*; Experiment 1; Piccolo et al., 2018) and Nellore beef heifers (*Bos indicus*; Experiment 2; Moriel et al., 2019).

In Experiment 1, suckling Brangus heifers were stratified by body weight (147 ± 20 kg) and age (134 ± 11 days) on day 0, and randomly assigned to receive an s.c. injection of saline (**SAL**; 5 mL; 0.9% NaCl) or 250 mg of sometribove zinc (**BST**; Posilac, Elanco, Greenfield, IN) on days 0, 14, and 28. Heifers and respective dams were managed as a single group on bahiagrass pastures from day 0 until weaning (day 127), and provided the same diet during the entire post-weaning phase. In Experiment 2, suckling Nellore heifers were stratified by body weight (97 ± 16 kg) and age (80 ± 10 days), and randomly assigned to receive s.c. injections of saline (5 mL 0.9% NaCl) or 250 mg of sometribove zinc (**BST**) on days 0 and 10 of the study. Then, all Nellore heifers were managed as a single group in *Brachiaria decumbens* pastures, weaned on day 177, and provided a corn silage–based TMR from weaning until the end of the study (day 380).

In Experiment 1, Brangus-crossbred heifers administered preweaning bST injections had an 8.6 ng/mL increase in plasma IGF-1 concentrations (103 vs. 95 ± 3.2 ng/mL; $P = 0.05$) and 7.2% increase on ADG from days 0 to 42 (1.15 vs. 1.07 ± 0.03 kg; $P = 0.07$), but no differences on overall pre-weaning ADG (0.88 and 0.89 ± 0.02 kg/day; $P = 0.50$) and post-weaning ADG (0.28 and 0.30 ± 0.02 kg/day; $P = 0.61$) compared to saline heifers. Also, heifers assigned to BST tended to achieve puberty 26 days earlier (388 vs. 414 ± 13 days; $P = 0.10$), had greater percentage of pubertal heifers on days 244, 263, 284, and 296 of the study ($P \leq 0.04$; Fig. 4), and tended to have greater overall pregnancy percentage (82 vs. 69 ± 6.1%; $P = 0.10$) compared to saline heifers.

In Experiment 2, preweaning bST injections increased plasma IGF-1 concentrations by 52 ng/mL (211 vs. 159 ± 9.3 ng/mL; $P = 0.0001$) and ADG from days 0 to 10 by 35% (0.65 vs. 0.48 ± 0.061 kg/day; $P = 0.03$), but did not affect overall pre-weaning ADG (0.45 vs. 0.47 ± 0.009 kg/day; $P = 0.24$), tended to decrease post-weaning ADG by 3.6% (0.80 vs. 0.83 ± 0.014 kg/day; $P = 0.07$) and decreased puberty attainment on days 349, 359, and 380 ($P \leq 0.05$; Fig. 4) compared to saline injections.

Sartori et al. (2016) reported that *B. indicus* cattle naturally have greater circulating IGF-I concentrations compared with *B. taurus* cohorts. Moreover, Mendonça et al. (2013) demonstrated that even under the same environment and diet, *Bos taurus*–influenced dairy cows have less circulating concentrations of IGF-I compared to *Bos indicus* cows, which might be related to the different organ sensitivity to IGF-1. It is possible that the greater increment on plasma IGF-1 concentrations following bST injection in Experiment 2 vs. 1, in combination with the interval between bST injections, was detrimental to the development of the reproductive axis of Nellore heifers. Further studies investigating the effects of breed on ovarian activity and gene expression in reproductive tissue organs and brain, following bST injections, are warranted to confirm this hypothesis.

Conclusions

Despite the challenges encountered by *Bos indicus*-influenced beef heifers including extreme heat and humid conditions in combination with forages of relatively poor nutritional composition, acceptable reproductive performance may still be achieved. Some of these successful nutritional management practices to enhance growth and reproduction included: increasing the concentrate DM offered to heifers from 1.25% to 1.75% of body weight; daily rather than infrequent (3X/week) concentrate supplementation; stair-step strategy to boost growth (reproductive performance to be tested in 2019/2020); and early-exposure to high-concentrate diets. Although preweaning injections of bST are currently not allowed for beef cattle, our results indicated that early manipulation of the somatotrophic axis may benefit the reproductive performance of Brangus but not Nellore beef heifers. Identifying additional strategies that can enhance calf performance during early postnatal life may provide unique opportunities to optimize feed resources and increase the profitability of beef cattle operations.

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Table 1. Growth performance of beef heifers assigned to a low, medium, or high post-weaning growth rates during a 168-day development period (3 years; Moriel et al., 2017)

	Supplementation amount				
	Low	Medium	High	SEM	*P*
Average daily gain kg/day					
Sep to Oct	0.11^a	0.14^a	0.32^b	0.050	0.02
Oct to Nov	0.19^a	0.45^b	0.54^b	0.046	<0.0001
Nov to Dec	0.30^a	0.59^b	0.66^b	0.042	<0.0001
Dec to Jan	0.27^a	0.42^b	0.58^c	0.031	0.001
Jan to Feb	0.22^a	0.33^b	0.35^b	0.037	0.10
Feb to Mar	0.35^a	0.51^b	0.62^c	0.031	0.002
Overall ADG, kg/d	0.25^a	0.41^b	0.51^c	0.020	<0.0001
Target ADG, kg/d	0.45	0.73	1.00		

Within a row, means without common superscript differ ($P \leq 0.05$).

Table 2. Reproductive performance of heifers supplemented at 1.25% or 1.75% of their body weight (BW, dry matter basis) for 167 days (September to March). Two-year study funded by Florida Cattlemen Enhancement Board (Moriel et al., in preparation)

Item	1.25% of BW	1.75% of BW	SEM	*P*
Average daily gain, kg/day	0.65	0.71	0.015	0.02
% of total				
Pubertal heifers at start of the breeding season	81	92	4.0	0.05
Final pregnancy rate	65	83	5.3	0.02
Heifers calving within the first 4 weeks of the calving season	68	51	7.7	0.05

[1]Heifers were offered concentrate at 1.25% or 1.75% of their body weight (DM basis). Effects of frequency of supplementation x concentrate amount were not detected ($P \geq 0.71$) for any variable in this study.

Table 3. Reproductive performance of heifers supplemented daily (7X) or 3 times weekly (3X) for 167 days (September to March). Two-year study funded by Florida Cattlemen Enhancement Board (Moriel et al., *in preparation*)

Item[1]	7X	3X	SEM	*P*
Average daily gain, kg/day	0.65	0.71	0.014	0.007
% of total				
Pubertal heifers at start of the breeding season	86	80	4.0	0.03
Final pregnancy rate	75	72	5.2	0.70
Heifers calving within the first 4 weeks of the calving season	76	43	7.7	<0.01

[1]Heifers were offered concentrate at 1.25% or 1.75% of their body weight (DM basis). Effects of frequency of supplementation × concentrate amount were not detected ($P \geq 0.71$) for any variable in this study.

Table 4. Growth and reproductive performance of beef heifers developed on different management systems from the time of early weaning (EW; day 0 of the study) until the time of normal weaning (NW; day 180 of the study; Moriel et al., 2014)

	Treatments					
Item	NW	EWPAST	EW180	EW90	SEM	*P*
Body weight[1], kg						
day 90 (Early-weaning)	139[a]	135[a]	164[b]	171[b]	3.7	<0.001
day 180 (Normal weaning)	212[a]	178[b]	262[c]	216[a]	6.4	<0.001
day 335 (Breeding season)	323[a]	292[b]	363[c]	327[a]	7.9	<0.001
Age at puberty, days	429[a]	418[a]	298[b]	358[c]	14.9	<0.001
Body weight at puberty, kg	342[a]	306[b]	286[b]	292[b]	11.9	0.09
Pubertal heifers at start of breeding season, % of total	30[a]	40[a]	100[b]	80[b]	13.2	0.002
Pregnant heifers, % of total	60	50	78	70	15.6	0.64

[a,b] Within a row, means without common superscript differ ($P \leq 0.05$).

[1] Calves (70 days of age) were assigned to remain with their dams and be normally weaned at 250 days of age (day 180 of the study; NW), or early-weaned at 70 days of age and randomly assigned to: ryegrass and bahiagrass grazing for 180 days (EWPAST); high-concentrate diet in drylot for 180 days (EW180); or high-concentrate diet in drylot for 90 days, then bahiagrass grazing for additional 90 days (EW90). From the time of normal weaning to the end of the breeding season, all heifers were provided concentrate DM supplementation at 1.5% of body weight.

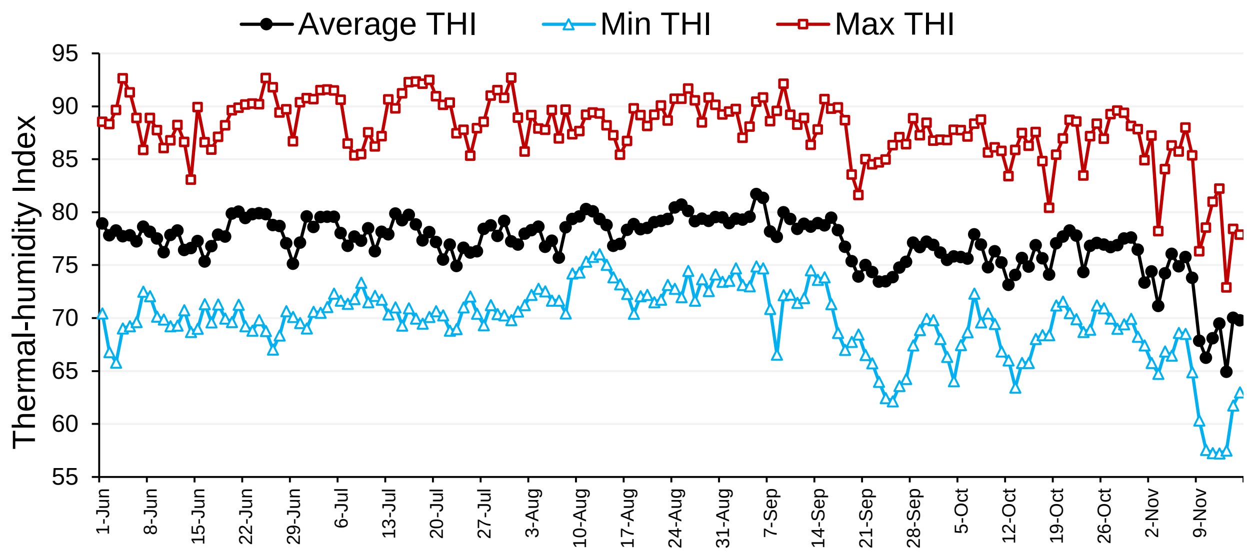

Figure 1. Daily average, minimum and maximum thermal-humidity index (THI) values observed from June to November 2019 at the Range Cattle Research and Education Center. THI = (1.8 × Temperature + 32) – [(0.55-0.0055 × Relative Humidity) × (1.8 × Temperature – 26)].

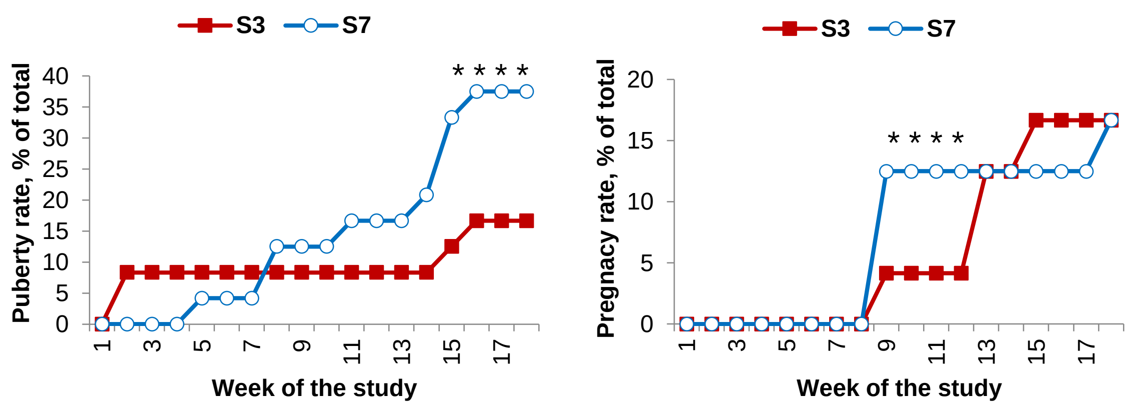

Figure 2. Weekly puberty (left) and pregnancy (right) attainment of beef heifers fed warm-season forages and supplemented with concentrate daily (S7) or 3 times weekly (S3; Moriel et al., 2012). *$P \leq 0.05$.

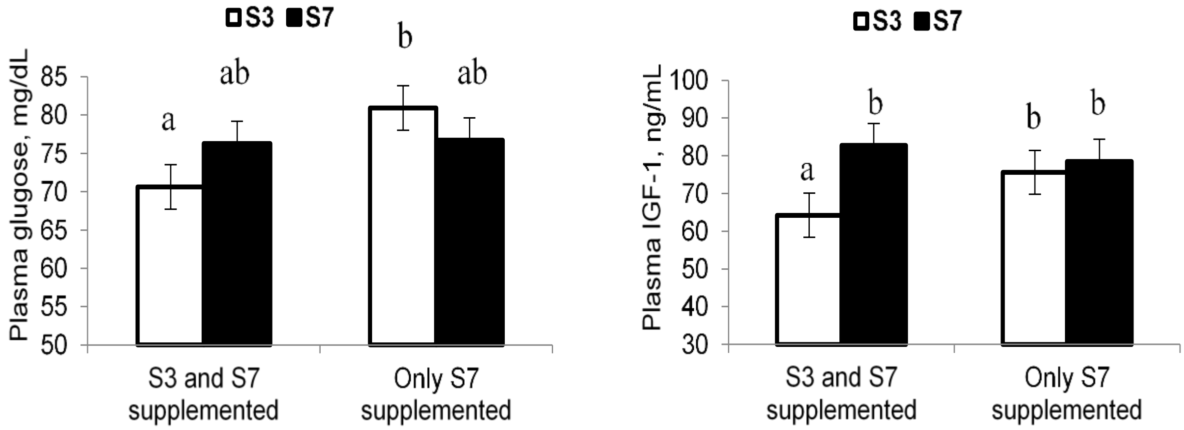

Figure 3. Plasma concentrations of glucose (left) and IGF-1 (right) of beef heifers supplemented with concentrate daily (S7) or 3 times weekly (S3; Moriel et al., 2012). The X-axis represent the days that both S3 and S7 heifers were supplemented (Monday, Wednesday, and Friday) and days that only S7 heifers were supplemented (Tuesday, Thursday, and Friday). ^{a,b} $P \leq 0.05$.

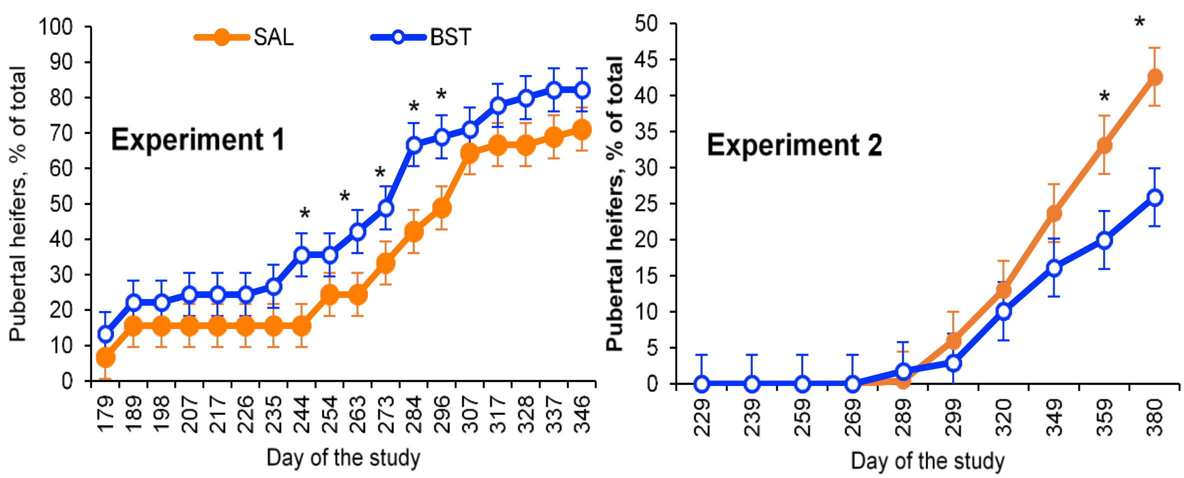

Figure 4. Puberty attainment of Brangus (Experiment 1) and Nellore (Experiment 2) beef heifers. In Experiment 1, heifers were stratified by age on day 0 and assigned to receive injection of saline (SAL) or 250 mg of sometribove zinc (BST) on days 0, 14, and 28. In Experiment 2, heifers were stratified by age on day 0 and assigned to receive injections of SAL or BST on days 0 and 10 of the study. *$P \leq 0.05$.

SESSION NOTES