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Original article

Development of dual-purpose heifers under grazing and captivity, during drought and rainy seasons

Desarrollo de vaquillas doble propósito en pastoreo y estabulado, durante época de sequía y lluvias

Heifers development during drought/
Desarrollo de becerras durante sequía

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Abstract

Livestock farming faces several factors that affect the development of heifers, such as the dry season. This study aimed to compare the anatomical-physiological, sanitary, and economical parameters of dual-purpose post-weaning heifers raised in stalls and on grazing, fed the same grass species during the drought and rain periods. Nine Giroland-Brown Swiss cross heifers were used, divided into the grazing group (GG; n = 4) and the captivity group (CG; n = 5). A linear fixed effects model with a factorial design was implemented. The average daily gain (ADG) during the dry season was observed to be 419 ± 95 g/day/heifer and 310 ± 15 g/day/heifer for GG and CG, respectively. However, during the rainy season, GG increased while CG decreased body weight (790±131 and –110 ± 63 g/day/heifer, respectively). During the rainy season, grazing management (GG; $0.88 ± 0.09 USD/day/heifer) is 30 % less expensive than captivity management (CG; $1.25 ± 0.07 USD/day/heifer). However, grazing management is only 5.7 % cheaper during the drought period. It is concluded that heifers in confinement have the same growth rate after weaning when provided with the same pasture, and fed the same species, compared to those grazed. However, this is not the case during the rainy season, being higher in the latter. In addition, the grazing system was more economical than the captive system. Likewise, the rainy period was more economical than the dry period.

Keywords:

Dry season, Bovine raising; Beta-hidroxybutirates; Replacement calves; Growth.

Resumen

La ganadería se enfrenta a diversos factores que afectan el desarrollo de las vaquillas como la temporada de estiaje. El propósito de este estudio fue comparar los parámetros anatomo-fisiológicos, sanitarios y económicos de vaquillas doble propósito post-destete criadas en estabulación y pastoreo, alimentadas con la misma especie de pasto durante períodos de sequía y lluvia. Se usaron nueve vaquillas de cruza Girolando Pardo Suizo divididas en dos grupos, el grupo de pastoreo (GG; n = 4) y el grupo estabulado (CG; n = 5). Se implementó un modelo lineal de efectos fijos con diseño factorial. Se observó que la ganancia diaria promedio (ADG) durante la temporada de sequía fue de 419 ± 95 g/día y 310 ± 15 g/día para GG y CG, respectivamente. Sin embargo, durante la temporada de lluvias, GG mostró un aumento y fue superior al CG. Durante la temporada de lluvias, el manejo en pastoreo (GG; $ 0.88 ± 0.09 USD/día/vaquilla) es 30 % menos costoso que el manejo en establo (CG; $ 1.25 ± 0.07 USD/día/vaquilla). Sin embargo, durante el período de sequía, el manejo del pastoreo es sólo un 5.7 % más barato. Se concluye que las novillas en confinamiento tienen la misma tasa de crecimiento después del destete cuando se les proporciona el mismo pasto, alimentadas con la misma especie, en comparación con las que se pastorean. Sin embargo, esto no es así durante el período de lluvia, siendo en este último más alto. Además, el sistema de pastoreo fue más económico que el sistema en confinamiento. De la misma manera, el período de lluvias fue más económico que el período de sequía.

Palabras Clave:

Estiaje, Crianza de bovinos; betahidroxibutiratos; becerras de reemplazo; crecimiento.

Introduction

In Mexico, multipurpose livestock systems are located in humid (wet) and dry tropical climates, with 33.4 % dedicated to this activity (González-Padilla *et al.,* 2019). However, one of the problems of dual-purpose systems in the Mexican tropics is the high age at first birth of the animals (Arellano *et al.,* 2006). In this system type, the age at first calving was 40.3 ± 6.6 months in the Huastecas region at the beginning of this century (Arellano *et al.,* 2006). It has now been reduced to 36.1 ± 2 months (Ríos-Utrera *et al.,* 2020). Therefore, the first mating occurs at two or more years old. However, the lack of heifer development studies and productive performance presents a dilemma for the management to decide between grazing or captivity breeding, and the information-based research focuses on heifer performance during drought. The farmers complicate those decisions due to the variations in weather conditions (drought and rainy periods). Regarding this issue, there are a few studies focused on physiological, anatomical, and sanitary parameters. In addition, small livestock herd producers often lack the knowledge or budget to decide which management system is cheapest economically (Lassala *et al.,* 2020). Farmers' priority is to earn income by selling milk, and heifers are often malnourished (Silva *et al.,* 2021), making alternatives beneficial for developing countries and improving productivity and reproductive efficiency (Tao *et al.,* 2018; Orihuela & Galina, 2019). Therefore, the Mexican government provided capital to develop an informed decision-making program for feeding additional heifers (SAGARPA, 2017) Indeed, many factors influence the performance and weight of heifers after weaning. e.g. weaning type (Orihuela & Galina, 2019), management during weaning (Lassala *et al.,* 2020), parasite burden (Castañeda *et al.,* 2021), heat and cold stress (Roland *et al.*, 2016; Montevecchio *et al.*, 2022) and the feeding system type (Carballo, 2009; Ferrufino & Arias, 2015). Under tropical conditions, confinement systems (feedlots) previously provided higher average daily gain (ADG) than grazing. Comprehensive studies on costly diets and grazing (Gomes & Piva, 2002; Casagrande *et al.,* 2013; Ferrari *et al.,* 2022). Hence, we

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hypothesized that if heifers were fed the same grass species in the stalls fed (pens) as in the pasture system, heifers would have the same ADG after weaning. Therefore, this study aimed to compare the anatomical-physiological, sanitary, and economic parameters of multipurpose heifers after weaning in drought and rainy periods, on grazing or in captivity, and fed on the same pasture species.

Materials and Methods

Ethical statement

This study was conducted following the Bioethics Committee and Animal Welfare (CBBA) of the Autonomous University of Tamaulipas. The certificate's number was CBBA_13_2021 and was dated June 15th, 2021.

Currently, it is common to use the three "R's" (reduce, replace and refine), if it is possible to use a minimum number of animals for research (Comisión Nacional de Bioética, 2022). Second, these groups studied were conceived taking as reference previous studies in the area (Barrón *et al.,* 2023), since the interest of the study is to generate information and innovations with cooperating ranchers where the average herd is 19 heads and the average number of cattle in development is 5.3, and 33 % of systems in the area manage the dual-purpose, which it becomes more complex every year due to the drought accentuation. Finally, bovine research is one of the most expensive.

Study area

The study was conducted in the Las Huastecas region, located along the Gulf of Mexico. This warm region hosts 19 % of the national herd (Carballo, 2009; SIAP, 2018) and is mainly managed in pastoral systems (González-Padilla *et al.,* 2019). The work was conducted from June to September, during the rainy season. It should be highlighted that recently this region has been affected by drought (NADC, 2022). The study was located in the Altamira municipality, Tamaulipas, Mexico, which is between the parallels 22° 20' and 22° 49' N and the meridians 98° 21' and 97° 50' W, with an altitude between 50 and 300 masl. The temperature range is 22 to 26 °C and annual precipitation is 900 to 1,100 mm. The weather ranges from warm subhumid to semi-warm subhumid with rain in summer (INEGI 2010).

General conditions and treatments

The study animals were nine Girholando X Brown Swiss cross heifers, which were in low body condition before the study. They were 294 days old and had a body weight of 96.4 kg. The study was divided into three periods: an adaptation period from May to June (60 days), a dry period from July to August (58 days), and a rainy period in September (24 days). During the adaptation period, the animals were vaccinated against paralytic rabies and the 8-way polyvalent vaccine against clostridiosis and pasteurellosis was used. They were also treated for gastrointestinal nematodes and external parasites, with macrocyclic lactones and phenylpyrazolones. Then, at the beginning of the study during the drought period, divided two groups according to age, weight, and body condition score (BCS; Table 1): the captivity group (CG; n = 5) and the grazing group (GG; n = 5; Table 1). These groups lasted throughout the rainy season.

The heifers in the captive group were kept in an individual pen (2 x 6 m) with a roof over the feeder area and the rest without shade which had a water container. It was impossible to keep the pens clean during the rainy period because they did not have a concrete floor, although manure was removed during this period. On the other hand, the heifers in the grazing group were kept on a 400 x 400 m meadow of giant star grass (*Cynodon plectostachyus*) throughout the study without rotation. They grazed day and night. However, these heifers drank water from the small dam.

Table 1. Age, physiological traits, and corporals (mean ± SEM) of postweaning dual-purpose heifers in both experimental groups in the beginning.

PARAMETER	EXPERIMENTAL GROUPS		AVERAGE
	CG	GG	
Age (d)	273 ± 39	315 ± 51	294
Body weight (kg)	94.9 ± 9.7	98.0 ± 9.7	96.4
Beta-hydroxybutyrates (mmol/L)	0.3 ± 0.03	0.3 ± 0.04	0.3
ZOOMETRIC MEASURES			
Thoracic circumference (cm)	105.1 ± 3.6	109.5 ± 4.7	107.3
Body length (cm)	97.2 ± 2.0	101.9 ± 4.5	99.5
Body condition score	2.8 ± 0.18	2.56 ± 0.06	2.68

Both groups were fed giant star grass (*C. plectostachyus*) containing 6.5 % and 12.4 % crude protein *ad libitum* during the drought and rainy seasons, respectively (Carballo, 2009). This *ad libitum* was achieved as follows: For CG heifers, fresh and succulent pasture grass was cut at ground level from the paddock, where GG was grazing, using a machete each morning and provided for free choice on a feeder. Feeders were refilled when empty during the day. GG were grazing in a paddock that had been cut for the CG group and they could eat the sprouts during rainy period. Moreover, each heifer was fed 0.5 kg of commercial concentrate (17.5 % crude protein and 1 881 Mcal/kg net energy) at 10:00 am each day. Mineral salts and water were freely provided to both groups. During the drought and rainy periods, supplementation was the same.

Evaluated variables

Body weight and average daily gain (ADG). The heifers were weighed twice per month at 07:00 h using an electronic balance (500 kg capacity) with 0.05 kg precision and the ADG for both groups was calculated as follows:

$$\frac{\text{weight at 10 measurement} - \text{weight at 0 measurement}}{82\ \text{d}}$$

The ADG for both groups in the drought period was calculated as follows:

$$\frac{\text{weight at 6 measurement} - \text{weight at 0 measurement}}{58\ \text{d}}$$

The ADG for both groups in the rainy period was calculated as follows:

$$\frac{\text{weight at 10 measurement} - \text{weight at 6 measurement}}{24\ \text{d}}$$

Body condition score (BCS). An experienced field technician estimated this parameter for both groups twice per month throughout the study. The scale was 1 to 5 for dairy youth heifers (< 421 d age; Archbold *et al.,* 2012)

Zoometric measurements. Thoracic circumference and body length were monthly measured twice using a flexible tape measure (Salazar *et al.,* 2010). The total circumference gained was calculated as follows:

$$\text{thoracic circumference at measurement 10} - \text{thoracic circumference at measurement 0}$$

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The total length gained was calculated as follows:

$$\text{body length at measurement } 10 - \text{body length at measurement } 0$$

Blood beta-hydroxybutyrates levels. The blood beta-hydroxybutyrates concentration was sampled from each heifer once per month 2 h after feeding or grazing (CG and GG, respectively), via jugular venipuncture, using a sterile insulin syringe. The blood betahydroxybutyrates were estimated using a test strip (Freestyle Optium Neo, Witney UK).

Average daily grass intake. Daily grass consumption was measured three times throughout the study (once during drought and twice during rainy). In each of the measurements at CG, the fresh and succulent cut grass is weighed and then given to the heifers in separate pens at 08:00 h. The discarded grass (no intaken) was weighed at the end of the day and the difference between the weights was taken as the daily grass consumption. The heifers were then fed individually every 2 hours until the end of the day (20:00 h). Before measurement day at GG, heifers spent the night in the pen before daily grass intake was measured. On the day of measurement, heifers were weighed at 7:00 h. and taken out to pasture to graze. If the heifer defecated, the feces were immediately collected in a plastic bag. This was done several times as the heifer defecated. Then, at the end of the day, all stools were weighed. Fresh water was weighed in a bucket before offering it in the paddock. The remaining amount of water is weighed and the difference between the weighing was taken as the daily water intake. Finally, GG heifers were weighed at the end of the day, once they stopped eating. The amount of herbs consumed daily was calculated using the following formula:

$$\text{Daily amount of grass consumed} = \text{final heifer weight} - \text{initial heifer weight} - \text{total water intake} + \text{total feces defecated}$$

In this research, losses due to evapotranspiration were not considered.

Tick count. To assess which group of heifers presented more parasitism affecting the productive performance in tropical areas during drought and rainy, tick count and fecal eggs count were done. Therefore, the tick count of *Rhipicephalus microplus* on the heifers was evaluated by counting all the nymph and adult ticks (3.0 to 8.0 mm in diameter) found on them. Samples were collected at the last three measurements of the study (one measurement in the drought period and two in the rainy period) for both groups. The same field technician did tick collection and counting. Collections were done in the morning (08:00 h) by placing a heifer in a covered handling pen and inspecting it from its head to the base of the tail, including the anterior and posterior limbs and the ventral region (Castañeda *et al.,* 2021).

Fecal eggs count. The heifer feces samples were collected immediately after defecation in the last three biweekly measurements of the study. They were stored at an environmental temperature in the polycarbonate cooler. At the laboratory, a coproparasitoscopic analysis was performed with 3 g of sample homogenized in 20 mL of glucose solution, later they were homogenized in a Vortex and filtered, centrifuged at 1500 revolutions per minute for 10 minutes, and then observed under a microscope at 4 and 10X, The McMaster technique was performed with the positive samples to obtain the egg count per gram of feces. The chambers McMaster were left to stand for 5 min, and they were placed in a microscope, the nematode eggs were counted at 10X, and the total number of eggs found was the addition in both chambers, the McMaster formula was used for eggs per gram of feces calculation (Alonso-Díaz *et al.,* 2015).

Feeding system cost. The feeding system cost was calculated considering features such as commercial concentrate, daily grass intake, mineral salt, vaccines, dewormers, vitamins, dehorned, mortality (it was specifically calculated for this herd), eventual job, fixed job, facility depreciation, bought tools, fuel, and ear tags. This parameter was calculated in US dollars and the exchange rate was 20.11 Mexican peso (MXN)/one US dollar (USD) on the day that it was calculated.

Statistical analysis

All dependent variables except BCS and the fecal egg count had a normal distribution. The fecal egg count became normal by the square transformation. However, the results are presented in arithmetic form (no transformation) to better understand this parameter interpretation. Data on body weight, zoometric measurements, blood beta-hydroxybutyrate levels, average daily grass intake, tick count, fecal eggs count, and feeding system cost in heifers were analyzed using the factorial design with a fixed effect linear model of Statgraphics Centurion v18 (2017). The factor treatment had two levels (GG and CG groups), and the factor period had two levels (drought and rainy), and their interactions. The heifers´ age and beginning weight were considered as covariates and the random effects of heifer and residual.

$$Y_{ijk} = \mu + Treatm_{i} + Period_{j} + TreatmXPeriod_{ij} + \beta\,(x_{i} - \bar{X}) + \Delta(x_{i} - \bar{X}) + e_{ijk}, were:$$

Y_{ijk} was the ijkth observation of the variable measured (body weight, zoometric measurements, blood beta-hydroxybutyrates levels, average daily grass intake, tick count, parasite eggs in feces, and feeding system cost).
μ was the overall mean.
$Treatm_i$ was the effect of ith treatment.
$Period_j$ was the effect of jth measurement.
$TreatmXPeriod_{ij}$ was the interaction between treatment and period.
$\beta\ (x_i - \bar{X})$ was the effect of covariate heifer´s beginning weight.
$\Delta\ (x_i - \bar{X})$ was the effect of covariate heifer´s age.
e_{ijk} represented the random error associated with each observation.

Separate individual independent t-tests were also performed to compare point by point on all dependent variables. However, the variable BCS was compared by the Mann–Whitney U test. ADG during the drought period, ADG during the rainy period, total circumference gained, and total length gained were compared by t-test. The level of significance was set at $p < 0.05$.

Results

Body weight, BCS, and ADG

During the drought period, mean body weight was not different between CG and GG heifers and increased in both groups (Figure 1, group effect $p = 0.0008$). The effect of the group was not kept during the rainy period ($p = 0.0001$), during which period body weight increased for GG heifers ($p = 0.0001$). An interaction (group × period) on the body weight of heifers was detected (P = 0.0006). The covariate analysis revealed that the beginning weight and age of the heifers had an effect ($p = 0.0001$ and $p = 0.0216$) on the body weight throughout the study. Likewise, the BCS showed similar behavior. Nevertheless, the median BCS was not statistically different between CG and GG heifers at any measurement (Figure 1). The ADG was higher for GG heifers than CG heifers, considering both periods (Figure 1, $p = 0.0040$).

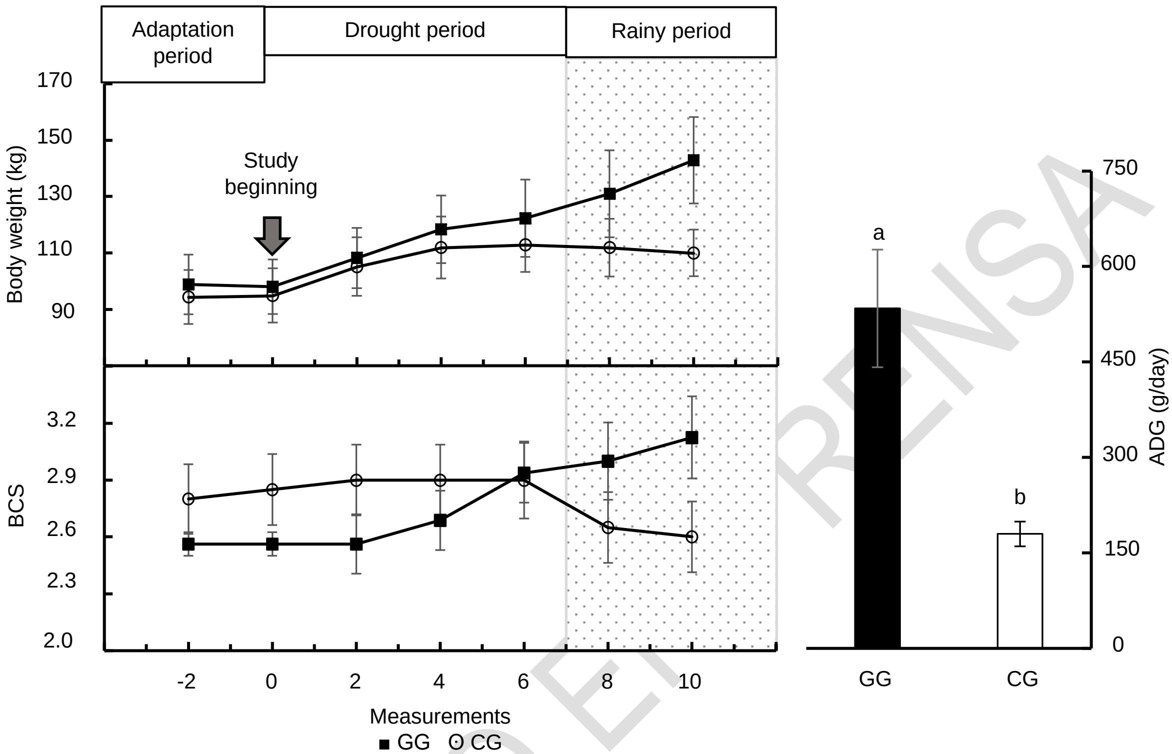

Figure 1. The pattern of least squares means in (±SEM) body weight and BCS from heifers that grazed (GG; ■) during the drought and rainy periods. The second group was managed in captivity (CG; ʘ), they were fed with fresh-cut grass daily where GG was grazed. In the right panel is shown the ADG. Literals denoted statistical differences ($p < 0.01$).

ADG by period

During the drought period, the ADG was not different between CG and GG heifers ($p = 0.3200$). Otherwise, during the rainy period, ADG was greater for GG than CG heifers ($p = 0.0001$; Figure 2).

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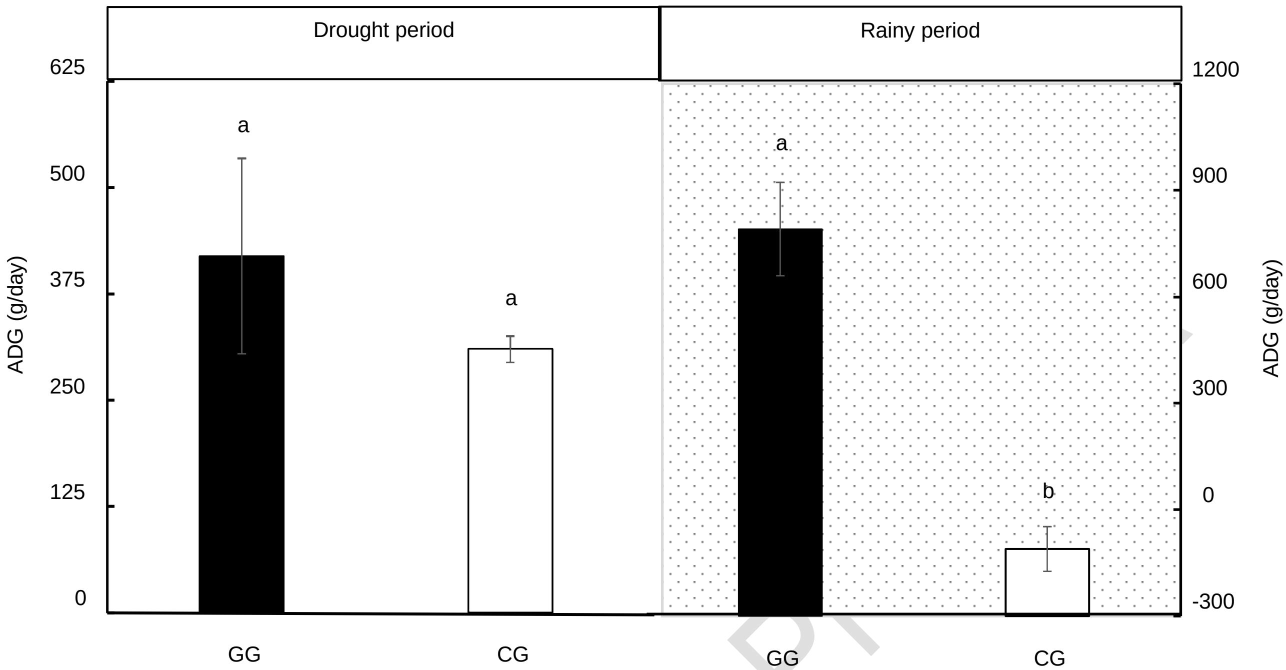

Figure 2. Means in (± SEM) ADG during the drought period and during the rainy period from heifers that grazed (GG; black bar). The second group was managed in captivity (CG; white bar), they were fed with fresh-cut grass daily where GG was grazed. Literals denoted statistical differences ($p < 0.01$).

Zoometric measurements

The body´s length and thoracic circumference are shown in the upper and lower left panels in Figure 3, respectively. There was an effect of the group and period of the animals on those parameters ($p = 0.0001$). An interaction (group × period) on the body weight of heifers was detected ($p = 0.0088$) for both parameters. The covariate analysis revealed that the beginning weight and age of the heifers had an effect ($p = 0.0001$ and $p = 0.0101$, respectively). The body length and thoracic circumference (Figure 3) showed differences in comparison to the last measurement between groups ($p = 0.0527$ and $p = 0.0525$, respectively). Likewise, the total circumference gained and total length gained during the study were higher in GG heifers than in CG heifers (Figure 3; $p = 0.0046$ and $p = 0.0341$, respectively).

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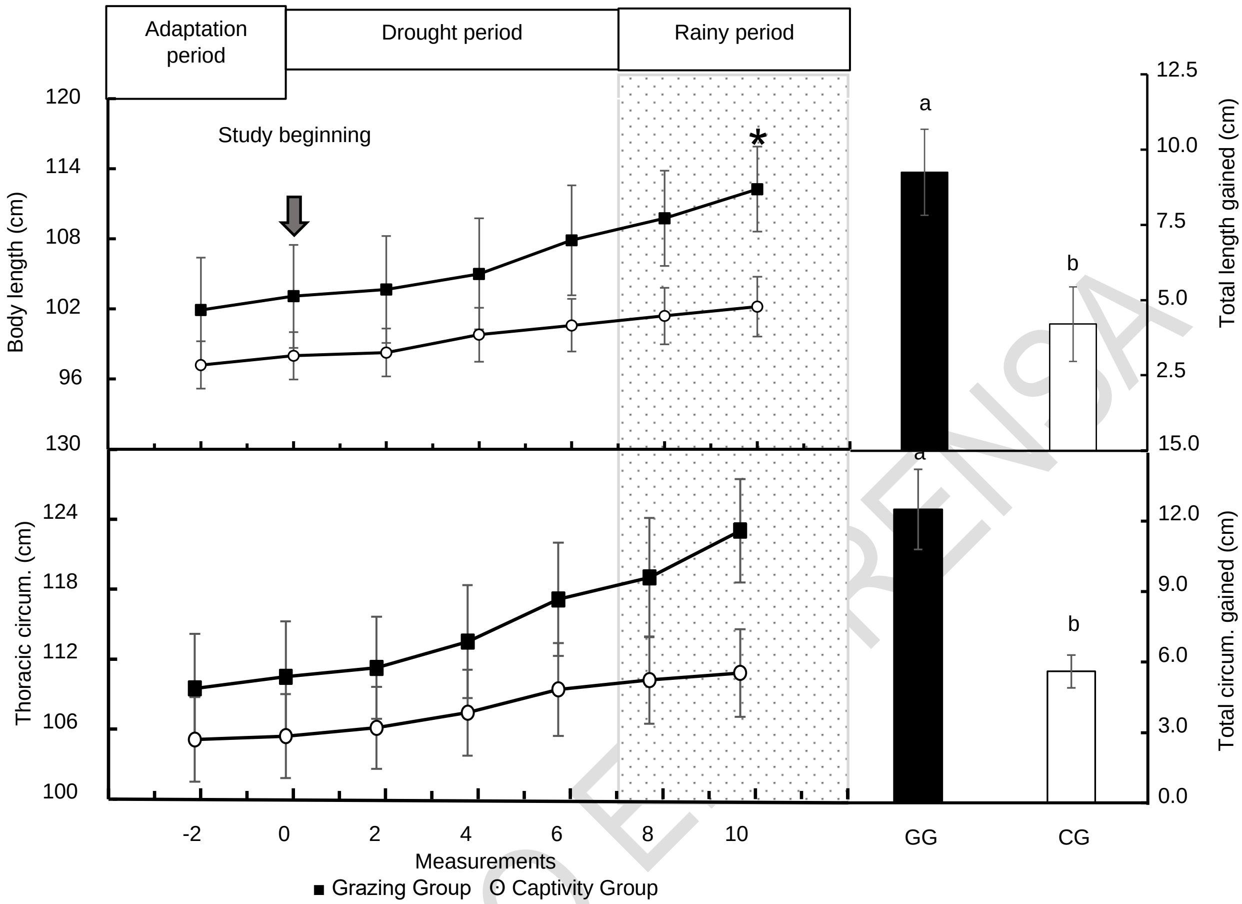

Figure 3. The pattern of least squares means in (± SEM) body length and thoracic circumference from heifers that grazed (GG; ■) during the drought and rainy periods. The second group was managed in captivity (CG; ○), they were fed with fresh-cut grass daily where GG was grazed. In the right panels are shown the total length gained and total circumference gained. Literals denoted statistical differences ($p < 0.05$) and asterisk denoted statistical differences point by point ($p < =0.05$).

Blood beta-hydroxybutyrates levels

Blood beta-hydroxybutyrate levels were similar at the beginning and a half month before the measurements study in both groups (Figure 4). However, a month later, blood beta-hydroxybutyrate levels were greater in GG than in CG heifers ($p = 0.0042$). In the rainy period was the same for both groups. Nevertheless, there was a main effect of the group ($p = 0.0502$). An interaction (group × period) on blood beta-hydroxybutyrates of heifers was detected ($p = 0.0404$).

Average daily grass intake

The average daily grass intake was different for both groups during both periods ($p = 0.0001$); though, it was not between periods (Figure 4; $p = 0.1681$).

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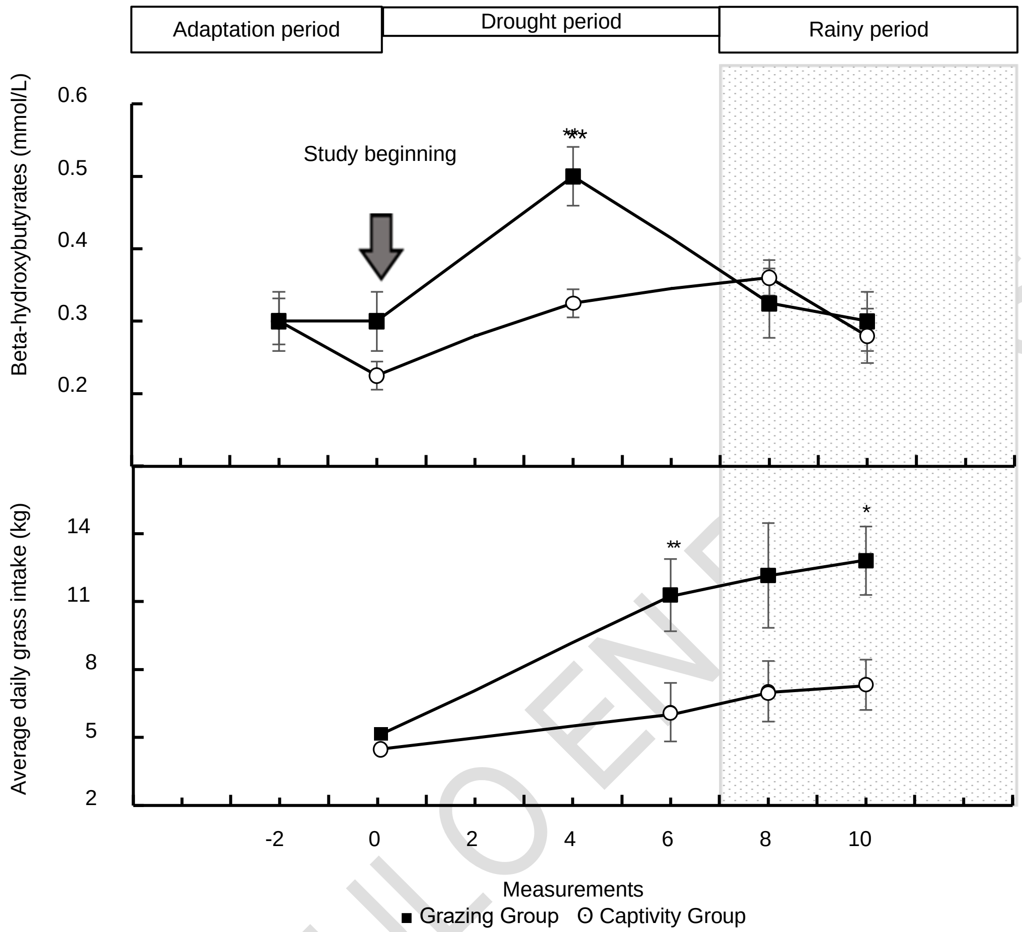

Figure 4. The pattern of least squares means in (± SEM) beta-hydroxybutyrates concentration and average daily grass intake from heifers that grazed (GG; ■) during the drought and rainy periods. The second group was managed in captivity (CG; ○), and fed with fresh-cut grass daily where GG was grazed. In the lower panel measurement, 0 is the only reference for both groups. Asterisks denoted statistical differences point by point ($p <= 0.05$).

Tick count, fecal eggs count, and feeding system cost

There was a difference between the groups and periods for the tick count. The same happened with the fecal egg count, but only between periods. The cheaper feeding system cost was with the GG group during the rainy period (Table 2).

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Table 2. Results of parasite analysis and cost of feeding system (mean ± SEM) of postweaning dual-purpose from heifers that grazed (GG) during the drought and rainy periods. The second group was managed in captivity (CG); they were fed with fresh-cut grass daily where GG was grazed.

Parameter		Experimental group	Period		*P-value*
			Drought	Rainy	
Sanitary	Tick count (ticks/heifer)	CG	10.60 ± 1.99	2.10 ± 0.43	0.0001
		GG	42.00 ± 10.53	65.12 ± 9.93	0.08683
		P-value	0.0131	0.0003	
	Fecal eggs count (eggs/g)	CG	61.60 ± 35.60	810.10 ± 120.52	0.0001
		GG	64.25 ± 12.75	996.75 ± 190.05	0.0005
		P-value	0.6927	0.3640	
⎈ Feeding system cost (US$/d/heifer)		CG	1.38 ± 0.07	1.25 ± 0.07	0.2440
		GG	1.30 ± 0.12	0.88 ± 0.09	0.0007
		P-value	0.4350	0.0021	

⎈Exchange rate: 20.11 mexican peso (MXN)/US dollar (USD).

Discussion

The ADG´s GG and CG groups were 534 g/d and 179 g/d, respectively (Figure 1). The body weight of GG heifers was higher than CG heifers. Firstly, this could be due to the moisture in the pens during the rainy period. Animals in wet places prefer to stand rather than eat because the ground is not dry and there is nowhere to lie down and rest. Secondly, the GG group could choose the sprouted grass that was cut with a machete to feed the CG also during the rainy period. Both situations may explain why GG gained more weight than CG. Velázquez-Martínez *et al.* (2010) found that the behavior of heifers when initiating grazing in the pasture did not affect whether they were with or without group models. Moreover, both (GG and CG) were below ADG suggested ideal weight for a heifer at first service. Regarding this, heifers should gain 24 % more to arrive at service at 20 months of age (Carballo, 2009; Alonso-Díaz *et al.,* 2015). Previously, Carballo (2009) reported an ADG of 0.46 kg/d during the low rain season for a similar population and environment. Those heifers were born when there was little rain. Nonetheless, their daily intake was supplemented with sugarcane and legumes. The GG heifers in this study had higher ADG during the study. In this research, we found that during the drought period, heifers´ ADG was equal between the CG and the GG (Figure 2). However, during the rainy period, the GG showed higher ADG than CG (Figure 2). Obtained data were comparable to Gomes & Piva (2002), where they asseverated that it was possible to achieve adequate ADG of Brazilian heifers and those beef heifers can be mated at 14/15 months of age, using different food systems post-weaning in their first autumn/winter. They found a similar ADG and BCS of heifers grazing or receiving feed in the trough. The transition period of these systems affects the performance of the animals, favoring animals in an exclusive grazing regime. Thus, they suggested that the heifers should be grazed immediately from weaning. In the present study, we found the body length (Figure 3) and the thoracic circumference (Figure 3) were higher for GG heifers than CG heifers. Likewise, the total length gained and the total circumference gained were higher. While heifers were growing throughout the experiment, those zoometric measurements were higher during the rainy period. Thus, the zoometric measurements of GG heifers were better during the rainy period. Using a regression equation, the dairy heifers' body weight could be indirectly predicted by the zoometric measurement (thoracic circumference) when limited facilities did not allow the use of a scale (Heinrichs *et al.,* 1992). In the same way, Salazar *et al.* (2010) obtained a quadratic equation

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specifically for tropic dual-purpose heifers. They pointed out that growing curves help predict the productive and reproductive performance of heifers.

Regarding blood concentrations of beta-hydroxybutyrate, findings in early lactation dairy cows showed that increasing the time of access to pasture allows a reduction in plasma beta-hydroxybutyrate concentrations and, consequently, an improvement in live weight gains (Ruiz-Albarrán *et al.,* 2012; Morales *et al.,* 2016). Likewise, Avilés *et al.* (2022) reported a negative correlation between the concentrations of beta-hydroxybutyrates in plasma and BCS in dual-purpose heifers. The present study showed that the concentrations of beta-hydroxybutyrates in plasma increased when the heifers began grazing. This was likely due to heat stress during the dry period, as was mentioned in dairy cows by Méndez *et al.* (2023). As the experiment continued, the concentration decreased inversely to weight, BCS, and daily grass intake (Figure 1 and Figure 4, respectively). At pasture, the bite mass, together with paddock features such as mass, height, and forage disappearance, factors that mediate consumption explained 78 % of the variations in ADG in one study of cattle (Carvalho *et al.,* 2015). Under this statement, Jiménez & Améndola, (2022) in their published current review signaled that the bite mass is a fundamental component of the ingestion behavior in grazing. It is possible; that the confined animals had no choose to bite mass. It would be interesting to perform studies on feeding behavior when the heifers are fed with the same grass, but one group is confined and another is at pasture.

Regarding parasites, Nellore weaned heifers on pasture in Brazil were infected by nematode parasites throughout the year and the period of greatest risk was during the rainy season with more than 800 eggs per gram of feces (Lima, 1998). This result was similar to ours, with higher fecal egg counts during the rainy period. Regarding the tick count, González-Cerón *et al. (*2009) pointed out that the natural infestation by *Amblyomma cajennense* and *Boophilus microplus* in the tropical dairy creole cattle is during the rainy season as our study showed. This infestation has been reported to have negative effects on ADG (Castañeda *et al.,* 2021).

Finally, the feeding system for GG heifers during the rainy period had the lowest cost (0.88 US$/d/heifer) in this study (Table 2). Nevertheless, it is not possible to keep the heifers at pasture throughout the year with rainy grass, because droughts have been frequent in this region over the past decade until now (NADC, 2022) leading to increased rearing costs. Consequently, the replacement heifers have exhibited a lower ADG. Carballo (2009) reported a grazing feeding cost of US$ 479 for replacement heifers from birth to first calving (30 months) in the same region. Based on the year of economic analysis (2007) and the average time until calving, the feeding cost amounted to US$ 1.16 per day per heifer, including excellent supplementation. In contrast, Ferrufino & Arias (2015) reported a cost of US$ 1.34 per day per heifer for grazing Honduran heifers and US$ 2.02 per day per heifer for confined heifers. Therefore, our costs were lower for both feeding systems. Despite the current higher costs of rearing animals, our analysis was affected by global inflation. What measures had the Mexican government implemented to increase its cattle herd? The federal government in Mexico had developed strategies to boost the number of replacement heifers. A problem was identified in the livestock sector whereby backyard dairy and dual-purpose producers had low production of their own food and forage (pasture) to feed their animals. This resulted in low productivity and, consequently, a low inventory of cows and replacement heifers in cattle herds. The Sectoral Program for Agricultural, Livestock, and Food Development 2013 - 2018 was established and aimed to increase the production of main foods and forages in livestock production systems through monetary support for livestock producers. This would lead to a higher inventory of cows and replacement heifers in cattle herds (SAGARPA, 2017). However, the support program has now ended. Thus, further research would need to identify cost-effective nutritional management strategies that promote daily weight gain in replacement cattle. This could potentially shorten the interval between birth and first calving for heifers.

Conclusions

During the drought, captivity and grazing systems had the same performance when they were fed with the same grass species; however, it was different during the rainy period, with the latter being higher. The grazing system was more economical than the captivity system. Likewise, the rainy period was more economical than the dry period.

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Author contributions

Work conceptualization: ARR, BBOG, LGJA, RAM, GCAJ, ARJSGJ; Methodology development: ARR, BBOG, RAM; Software management: ARR, BBOG; Experimental validation: ARR, BBOG, ARJSGJ; Data analysis: ARR, BBOG, LGJA, GCAJ; Data management: BBOG, ARR; Writing and draf preparation: BBOG, ARR, LGJA; Writing, review, and editing: ARR, BBOG, LGJA, RAM, GCAJ, ARJSGJ; Project administration: ARR, BBOG; Funding acquisition: ARR, BBOG.

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Conflict of interest

"The authors declare that they have no conflict of interest."

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