https://doi.org/10.18004/investig.agrar.2026.e2802876 e-ISSN: 2305-0683 ISSN: 1684-9086

SCIENTIFIC ARTICLE

Productive performance and compensatory growth of weaned cattle with and without winter supplementation

Desempeño productivo y crecimiento compensatorio de bovinos destetados con y sin suplementación invernal

Osvaldo Javier Sánchez Holt[1]*, Diego Avilio Ocampos Olmedo[2] y Pedro Luis Paniagua Alcaráz[2]

[1]Universidad Nacional de Caaguazú, Facultad Ciencias de la Producción, Coronel Oviedo, Paraguay.
[2]Universidad Nacional de Asunción, Facultad de Ciencias Agrarias, Área de Producción Animal. San Lorenzo, Paraguay.

***Corresponding Author:**
osvaldo.sanchez@fcpunk.edu.py

Conflict of Interest:
There is no type of conflict to declare

Author Contributions:
All authors made substantial contributions to the conception and design of this study, data analysis and interpretation, manuscript revision, and approval of the final version. All authors assume responsibility for the content of the manuscript.

Funding:
None.

History:
Received: 03-12-2025;
Accepted: 24-06-2026;
Published: 18-11-2026.

Data Availability:
The complete dataset supporting the results of this study is available upon request to the corresponding author. The dataset is not publicly available due to confidentiality agreements with the establishment owner.

Responsible Editor:
Arnaldo Esquivel-Fariña
Universidad Nacional de Asunción, Facultad de Ciencias Agrarias, San Lorenzo, Paraguay.

Review comments:
This article has been evaluated through a double-blind peer review process. The review reports, in line with the editorial transparency policy, are available at: https://www.agr.una.py/revista/index.php/ria/article/view/876/739

License:
Article published in open access under a Creative Commons CC-BY 4.0 license.

ABSTRACT

With the objective of evaluating productive performance and compensatory growth in weaned cattle with and without winter supplementation, a study was conducted from July to December 2021 in Coronel Oviedo, Paraguay. Thirty-eight animals of undefined biotype weighing 159±15 kg were used, in a completely randomized design with two treatments and 19 replicates: T0, grazing without supplementation; and T1, grazing with supplementation at 0.7% of live weight (LW). The study comprised a winter restriction/supplementation phase (85 days) and a summer realimentation phase (69 days) under exclusive joint grazing. Forage parameters, morphological variables, average daily gain, and compensatory rates were evaluated. Animal performance data were analyzed using Student's t-test, while forage parameters were analyzed using descriptive statistics. During winter, forage showed acceptable availability (6 to 7 kg dry matter (DM) 100 kg LW^{-1} day^{-1}) but critical quality (crude protein <4%; neutral detergent fiber >70%), improving during the summer period in both availability (>16 kg DM 100 kg LW^{-1} day^{-1}) and quality (crude protein >7%; neutral detergent fiber <70%). T1 was superior ($p<0.05$) in morphological variables in both periods, as well as in average daily gain during winter (0.61 kg day^{-1} versus 0.1 kg day^{-1}), while T0 was superior during the summer period (0.41 kg day^{-1} versus 0.33 kg day^{-1}). Despite evidence of compensatory growth in T0 (12.15%), this was insufficient to match the advantage obtained by T1 in winter. Winter supplementation at 0.7% of live weight is an efficient strategy for optimizing continuous development, since summer compensatory gain on cultivated pastures is insufficient to offset losses during the critical period.

Keywords: compensatory gain, forage parameters, winter period, strategic supplementation.

RESUMEN

Con el objetivo de evaluar el desempeño productivo y crecimiento compensatorio en bovinos destetados con y sin suplementación invernal, se realizó un estudio de julio a diciembre del 2021, en Coronel Oviedo, Paraguay. Se utilizaron 38 animales de biotipo indefinido de 159±15 kg, en un diseño completamente al azar con dos tratamientos y 19 repeticiones: T0, pastoreo sin suplementación; y T1, pastoreo con suplementación al 0,7% del peso vivo (PV). El estudio comprendió una fase invernal de restricción/suplementación (85 días) y una estival de realimentación (69 días) a pastoreo exclusivo conjunto. Se evaluaron parámetros forrajeros, variables morfológicas, ganancia diaria de peso y tasas compensatorias. Los datos de desempeño animal fueron analizados por la prueba t de Student, mientras que los parámetros forrajeros con estadística descriptiva. Durante el invierno el forraje presentó disponibilidad aceptable (6 a 7 kg materia seca (MS) 100 kg PV^{-1} $día^{-1}$) pero con calidad crítica (proteína bruta<4%; fibra detergente neutra>70%), mejorando en el periodo estival en disponibilidad (>16 kg MS 100 kg PV^{-1} $día^{-1}$) y calidad (proteína bruta>7%; fibra detergente neutra<70%). El T1 fue superior ($p<0,05$)

 This is an open access article published under a Creative Commons license

en las variables morfológicas en ambos periodos, así también en la ganancia diaria de peso en invierno (0,61 kg día-¹ sobre 0,1 kg día-¹) mientras que en periodo estival fue superior el T0 (0,41 kg día-¹ sobre 0,33 kg día-¹), a pesar de evidenciarse crecimiento compensatorio en T0 (12,15%), este fue insuficiente para igualar la ventaja obtenida por T1 en invierno. La suplementación invernal al 0,7% del peso vivo es una estrategia eficiente para optimizar el desarrollo continuo, ya que la ganancia compensatoria estival sobre pasturas cultivadas es insuficiente para equiparar las pérdidas en periodo crítico.

Palabras clave: ganancia compensatoria, parámetros forrajeros, periodo invernal, suplementación estratégica.

INTRODUCTION

Paraguayan livestock farming is characterized by beef production on native or introduced pastures, systems that face marked seasonal fluctuations in forage biomass supply between the summer and winter periods. The latter is conditioned by falling temperatures and decreasing precipitation. Winter constitutes the most critical stage due to the short photoperiod and water deficit, factors that drastically reduce forage growth rate and quality. Consequently, the accumulation of remaining forage undergoes a marked process of phenological maturation and lignification, resulting in a substantial increase in the structural fiber components and lower digestibility (Ávalos and Flores, 2015; Mongelós Barrios, Valdez Ocampo, Huerta Maciel, López Ávalos, and Fernández Sánchez, 2024; González, Ortiz, Gomez, Samudio, and Nakayama, 2024).

Due to this pronounced climatic seasonality and the consequent qualitative-quantitative deterioration of forage in winter, pasture contributions are insufficient to cover the animals' basal nutritional requirements. This deficit introduces a state of dietary restriction, a scenario in which nutrient intake falls below maintenance minimums, compromising structural development parameters and halting weight gain (Keady et al., 2021; Wang, Shen, Zhao, Hanigan, and Li, 2024). To mitigate this nutritional deficit and sustain or increase live weight under these conditions, it is necessary to implement supplementation strategies with protein-energy concentrates (Hoffmann et al., 2014); however, although this practice corrects the metabolic imbalance, it represents one of the highest costs within the financial structure of livestock enterprises (Montossi and Soares de Lima, 2020).

Studies point to compensatory gain as an alternative to consider among management practices, based on the premise that animals subjected to feed restriction during the winter period recover, in the following summer period, the weight difference lost relative to supplemented animals (Clariget et al., 2025). It has been reported that the reduction in energy requirement caused by restriction is what allows greater utilization of the period of abundance (Dixon, 2011). Physiologically, nutritional restriction is defined as a condition in which energy and nutrient intake is insufficient to meet the animal's maintenance and growth requirements. As an adaptive mechanism to this deficit, a reduction occurs in the mass of organs with high metabolic demand, mainly the gastrointestinal tract, liver, and heart, leading to a significant decrease in basal energy requirements (Sainz and Bentley, 1997). This metabolic adjustment persists once the nutritional stress has been overcome; consequently, during the subsequent phase of forage abundance, the animals show lower maintenance expenditures, which facilitates faster and more efficient live weight gain compared to those that did not experience restriction (Jennings, 2014).

Compensatory growth could be considered a management method for producers to implement in order to reduce supplementation costs during periods of recurrent low forage availability and quality. Therefore, the objective of the present study was to comparatively evaluate productive performance and compensatory growth in weaned cattle with and without winter supplementation, in order to provide useful information for management strategies implemented in pasture-based livestock farming.

MATERIALS AND METHODS

The research was carried out at the Escandriolo Peña livestock enterprise, located in the San Antonio settlement, Coronel Oviedo District, Caaguazú Department, Paraguay, at latitude 25°25'57.74'' S and longitude 56°16'15.41'' W. The experimental period extended from the first half of July 2021, coinciding with the onset of seasonal forage scarcity, through the first half of December of the same year. The climatic conditions recorded during the course of the study are presented in Figure 1.

The experimental population consisted of 38 animals of undefined biotype, born on the farm, with an average live weight of 159±15 kg and an age ranging from 10 to 12 months. All animals were identified using numbered plastic ear tags. A completely randomized design was employed; for this purpose, animals homogeneous in weight, age, and health status were selected and randomly assigned to the two treatments evaluated (19 replicates per treatment). Each animal constituted an individual experimental unit. To ensure sanitary homogeneity, the animals underwent an initial clinical examination. A standardized bimonthly deworming protocol from the establishment was applied, which included pour-on cypermethrin (6 g, 10 mL animal-¹) for ectoparasites and 1% ivermectin (1 mL 50 kg-¹ LW) for endoparasites.

The research was structured into two sequential phases: winter and summer. During the winter

period (85 days), animals from both treatments were housed in separate paddocks of 9 ha each, on *Urochloa brizantha* cv. Marandú pastures established four years prior, with an initial stocking rate of 2.1 head ha-¹ established in both paddocks. In order to mitigate environmental variations and establish the animal as the experimental unit, both paddocks presented homogeneous conditions in terms of topography, forage availability, and bromatological quality (Figure 2 and Table 1). Both paddocks had a constant water supply via an earthen dam (tajamar) and ad libitum access to mineral mixture in salt feeders. For the supplemented treatment (T1), the paddock additionally had 19 individual feeders made from 200-liter plastic drums cut lengthwise; this group received a protein-energy concentrate (CP 18%, ME 2.9 Mcal kg-¹ DM, CF 10%, Ca 1.2, and P 0.7) at a rate of 0.7% of live weight, with the supply adjusted periodically according to weight evaluations. The feed was provided daily in the morning (09:00 h).

For the summer period (realimentation phase, lasting 69 days), both groups of animals were unified and managed jointly under an alternating grazing scheme with a biweekly rotation frequency between two adjacent paddocks. Both paddocks, 8 hectares each, shared the same forage species (*U. brizantha* cv. Marandú), the same establishment age (2 years), and the same management history. Although slight variations in availability were recorded between paddocks, an optimal forage supply for voluntary intake was ensured at all times, remaining above 15 kg DM 100 kg LW-¹ day-¹ (Euclides, Cardoso, Macedo, and Oliveira, 2000; Figure 2).

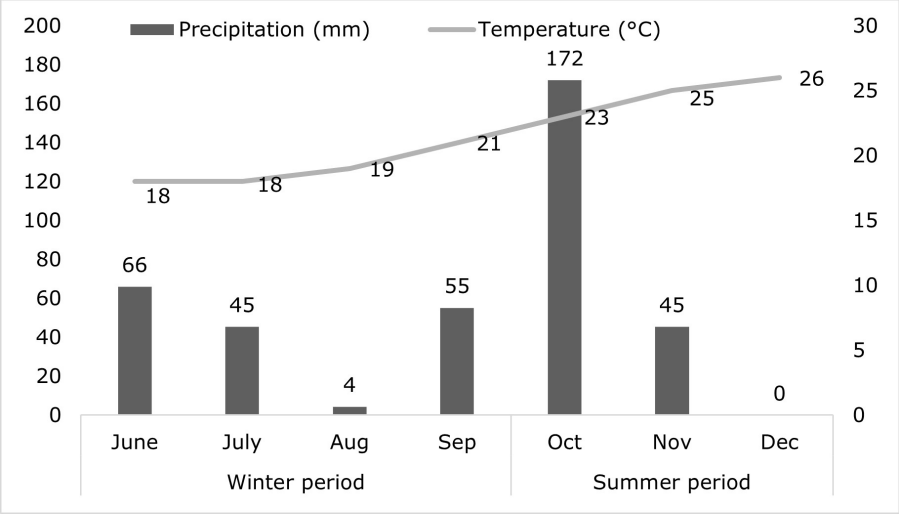
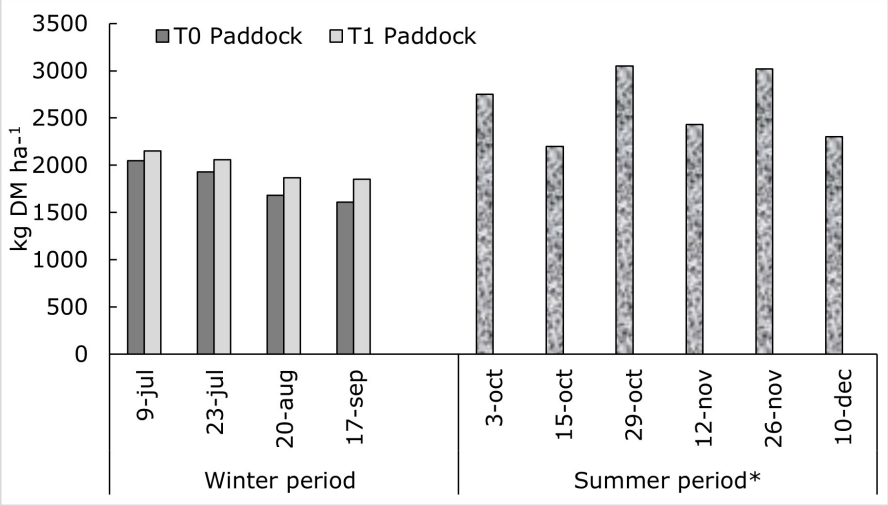


Figure 1. Monthly average precipitation and temperature during the experimental period, San Antonio, Coronel Oviedo, Paraguay, 2021.



*two paddocks were used with biweekly rotations, keeping both groups together

Figure 2. Forage availability during the experimental period, San Antonio, Coronel Oviedo, Paraguay, 2021.

CC BY

Measurement variables

Forage parameters: These were determined using 0.25 m² quadrats: 9 samples, weighed and averaged per paddock (Zanella, Carvalho, Ribeiro, Madeiro, and dos Santos Gomes, 2017), calculating dry matter using the microwave method, and then extrapolating values per hectare (kg DM ha-¹). This value was also used to calculate dry matter availability per 100 kg of animal live weight per day (kg DM 100 kg LW-¹ day-¹) (Hodgson, 1990). Forage availability was assessed with an initial biweekly monitoring, followed by monthly monitoring during winter. In the summer phase, the frequency was biweekly, synchronized with the alternating grazing scheme used during this period. To assess quality, plant material was collected at ground level (10 cm), weighed, dehydrated (65 °C), and analyzed for crude protein, neutral detergent fiber, acid detergent fiber, calcium, and phosphorus, with measurements taken at the beginning and middle of the winter period and at the middle and end of the summer period (Horwitz and Latimer, 2005).

Morphological parameters: At the beginning (day 0), middle (day 85), and end of the study (day 154), the following were measured: withers height (WH), defined as the distance between the ground and the most prominent portion of the scapular cartilages; body length (BL), defined as the distance between the scapulohumeral joint and the coxofemoral joint; hip height (HH), defined as the distance from the highest point of the rump (sacral bone) to the ground; and hip width, defined as the separation between the hip points (HW) (Freneau, Cardoso da Silva, Rey Borjas, and Amorim, 2008).

Average daily gain (ADG): This was obtained from the quotient between the weight gain of the period and the number of days elapsed in that period. It is expressed in g day-¹. Weight evaluations were carried out at the beginning, middle, and end of the study, coinciding with the morphological measurements.

Compensatory rates: The calculation was performed using the formula ((A-B)/A). A = difference between the weight (or morphological parameter) of unrestricted and restricted animals at the end of the winter period, and B = difference between the weight (or morphological parameter) of unrestricted and restricted animals at the end of the summer period (Hornick, Van Eenaeme, Gérard, Dufrasne, and Istasse, 2000).

Statistical analysis

Forage parameters were analyzed using descriptive statistics, as they represent composite values per paddock aimed at environmental characterization. For morphological variables and average daily live weight gain, the InfoStat 2020 statistical software was used, applying Student's t-test for independent samples with a significance level of 5% ($P<0.05$), following prior verification of the assumptions of normality and homogeneity of variances using the Shapiro-Wilk and Levene tests, respectively.

RESULTS AND DISCUSSION

During the winter period, forage availability remained similar at the outset in both treatments, with a more pronounced reduction rate recorded in the T0 paddock. In T1, the supplement provision mitigated the intensity of pasture use, a behavior attributed to the substitution effect. The forage supply recorded during this phase was 6 to 7 kg DM 100 kg LW-¹ day-¹, falling within the critical range of biological requirement established by the National Research Council [NRC] (2016); it was found that the available biomass had sufficient potential to ensure ruminal fill (Freneau et al., 2008), demonstrating that forage supply did not act as a limiting factor from an availability standpoint. However, it is essential to consider the qualitative aspect of the forage, which frequently represents the main severely restricting factor during this time of year.

During the summer period, under the joint alternating grazing system, forage availability remained stable in both paddocks used, with values recorded between 16 and 21 kg DM 100 kg LW-¹ day-¹. According to Da Trindade et al. (2016), this level of quantitative supply establishes non-restrictive feeding conditions for voluntary intake, which determined a favorable nutritional scenario for achieving high average daily live weight gains during the realimentation phase.

During the winter period, the forage offered in the T0 and T1 paddocks presented characteristics that could limit its nutritional value. Crude protein (CP) levels were below 7%, and by the middle of the period below 4%, which is considered highly deficient for meeting cattle requirements (Van Soest, 1994). In addition, the high ADF and NDF values (NRC, 2016) could reduce palatability and digestibility. Likewise, Ca and P levels were below recommended values (Valadares Filho et al., 2016).

In contrast, during the summer period, an improvement in forage quality was observed. CP values increased to more adequate levels, reaching up to 7.29% during the summer period (Lazzarini et al., 2009). Furthermore, NDF and ADF levels decreased, suggesting greater digestibility and better nutritional value; mineral levels were also maintained within recommended ranges (NRC, 2016). However, it is important to highlight a decrease in forage quality toward the end of the experiment, a factor that could have limited the compensatory expressions.

As shown in Table 2, the morphological variables responded favorably to winter supplementation, with T1 being statistically superior during both evaluated periods. When analyzing the summer compensatory dynamics in non-supplemented animals (T0), a slight recovery was observed in withers height and

Table 1. Bromatological values of the forage during the experimental period, San Antonio, Coronel Oviedo, Paraguay, 2021.

	CP (%)		NDF (%)		ADF (%)		Ca (%)		P (%)	
	T0	T1	T0	T1	T0	T1	T0	T1	T0	T1
Winter period evaluations										
9-jul	6	6,3	68,31	69,68	38,61	38,1	0,411	0,339	0,135	0,238
20-aug	3,21	2,9	72,1	79,31	43,16	48,46	0,365	0,29	0,069	0,051
Summer period evaluations*										
5-nov	7,29		62,81		31,53		0,342		0,163	
10-dec	5,25		68,07		37,03		0,339		0,118	

CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; Ca = calcium; P = phosphorus. *During the summer period, the forage values correspond to the evaluation of the joint grazing area, since the animals from both treatments (T0 and T1) were unified and evaluated under the same environmental conditions.

Table 2. Comparison of morphometric measurements between animals on pasture without winter supplementation (T0) and animals on pasture with winter supplementation (T1) in both periods.

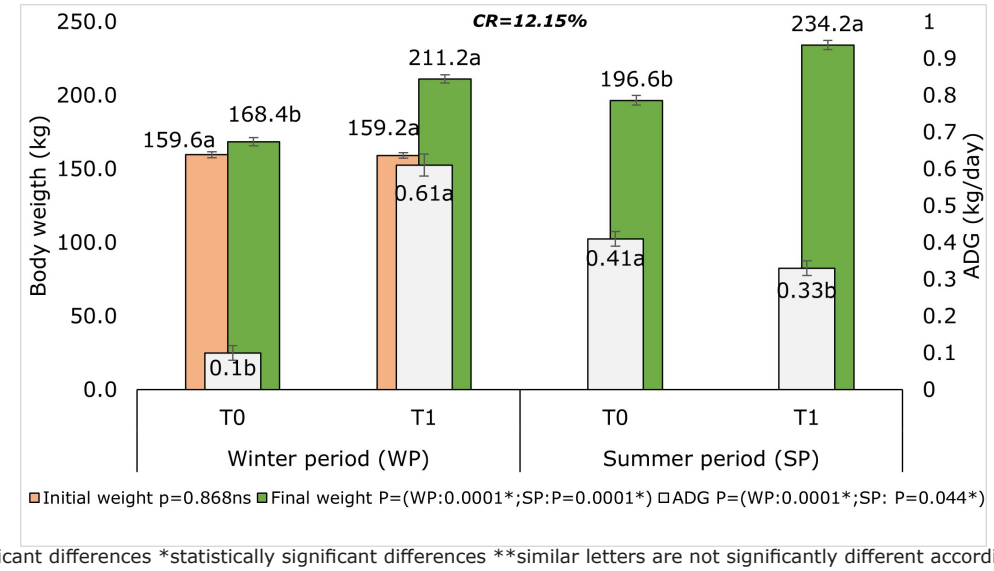
		Evaluated variables			
Phase		**WH (cm)**	**HH (cm)**	**BL (cm)**	**HW (cm)**
Initial measurements	**T0**	106,6±1,4 [a]	113,3±1,3 [a]	94,1±0,6 [a]	31,3±0,5 [a]
	T1	107,5±1,6 [a]	115,5±1,6 [a]	92,6±0,8 [a]	31,1±0,3 [a]
	P-valor	***0,6599[ns]***	***0,2895[ns]***	***0,1727[ns]***	***0,7203[ns]***
End of winter period	**T0**	110,0±1,2 [b]	116,5±1,2 [b]	94,4±0,7 [b]	30,5±0,3 [b]
	T1	119,3±1,4 [a]	126,8±1,2 [a]	98,2±0,5 [a]	33,7±0,3 [a]
	P-valor	***<0,0001****	***<0,0001****	***<0,0001****	***<0,0001****
End of summer period	**T0**	126,0±1,5 [b]	132,4±1,4 [b]	101,7±1,0 [b]	33,2±0,4 [b]
	T1	132,2±1,1 [a]	139,7±1,1 [a]	106,2±0,9 [a]	36,0±0,4 [a]
	P-valor	***0,0021****	***0,0002****	***0,0022****	***<0,0001****
Compensatory rate %		**33,3**	**29,1**	**-18,4**	**12,5**

Withers height (WH), hip height (HH), body length (BL), hip width (HW). *Statistically significant difference ($p<0.05$); ns: no statistically significant differences. Different letters in rows are significantly different according to Student's t-test.

hip height; however, an adverse effect was noted in body length. Overall, these responses showed insufficient recovery to match the morphometric measurements of the supplemented group. This behavior is consistent with what was reported by Keady et al. (2021), who note that, although dietary restrictions give rise to compensatory growth mechanisms, under practical conditions this process is often incomplete or partial.

This inability to reach normal adult development finds its biological explanation in the severity of the deficit experienced during the winter phase. The forage context described for this stage (Table 1), dominated by low protein supply and a high structural component, serves as an important reference for the premise put forward by Mac Loughlin (2010), who states that severe restriction in young animals irreversibly compromises the integrity of metabolically active tissues. As developmental potential is lost during a critical stage such as the growing (recría) phase, a structural lag is generated that summer feeding fails to reverse, in agreement with what was reported by Molina, Carmona, and Ojeda (2007), who observed permanently lower growth rates in cattle after undergoing severe restrictions.

In contrast to the above, when evaluating anatomical flexibility in response to these fluctuations, it is clear that the variables linked to the deposition of later-maturing tissues showed a rebound in response to the volumetric abundance of summer. In sharp contrast, and as evidenced in the initial results, body length showed a negative compensatory rate. Longitudinal bone growth is an early-maturing process, in which the priority allocation of nutrients is already biologically pre-programmed (Lawrence, Fowler, and Novakofski, 2012). Since the protein-energy restriction coincided with the bone elongation period, an irreversible growth check occurred. Consequently, the observed morphometric variations suggest that, once summer forage supply was established, compensatory growth was directed toward the recovery of other tissues, limiting bone compensation and thereby consolidating the definitive differences between both treatments.



ns: no statistically significant differences *statistically significant differences **similar letters are not significantly different according to Student's t-test.
T0: Grazing without winter supplementation, T1: Winter supplementation plus pasture, CR: Compensatory rate

Figure 3. Live weight and average daily gain (ADG) of weaned cattle with and without winter supplementation during the winter and summer periods, San Antonio, Coronel Oviedo, Paraguay, 2021.

When analyzing the productive dynamics reflected in Figure 3, it was observed that during the winter period, the supplemented animals (T1) maintained superior performance compared to the non-supplemented group, consolidating an initial productive advantage. Subsequently, during the summer realimentation stage, the T0 group exhibited higher average daily gain rates, a phenomenon consistent with the expected response to the removal of nutritional restriction. However, when evaluating the magnitude of this response, it is noted that the compensatory expression was limited, standing at 12.15%.

Regarding weight gain and the expression of the compensatory rate, animal performance must be analyzed against the nutritional and climatic scenario encompassing both stages of the trial. From a biological perspective, the literature indicates that forage protein largely determines the developmental potential in extensive livestock systems; when levels fall below the critical threshold of 7%, tissue formation is restricted and weight gain is considerably compromised (Oliveira Porto et al., 2009). During the first stage of the investigation (winter period), the pasture evaluations (Table 1) were characterized by values falling within this limiting scenario, causing the supplemented animals (T1) to show higher average daily gains during this stage than T0. Subsequently, although a slight compensatory rate was observed during the summer realimentation phase, this depends heavily on an improvement in forage quality and availability throughout the period (Keady et al., 2021; Trindade Júnior et al., 2025). However, during this stage a significant reduction in precipitation was recorded (Figure 1), suggesting a scenario of forage quality loss that temporally overlapped with the window of greatest theoretical expression of compensatory growth. As noted by Modernel et al. (2019), this environmental variability is intrinsic to subtropical systems, constituting a determining contextual factor for understanding why weight gain indices did not reach their maximum potential expression under these practical management conditions.

CONCLUSIONS

Under the conditions evaluated, it is concluded that forage nutritional quality during the winter period constitutes the main limiting factor for bovine development, even when volumetric availability is adequate. In this restrictive context, strategic winter supplementation proves to be a decisive strategy not only for sustaining weight gain but also for protecting the integrity of morphological development during the critical growing (recría) stage.

The severe nutritional restriction imposed on non-supplemented animals generates structural detriment, manifested in the inability to resume bone growth (body length) after the deficit. Although these animals manage to express compensatory growth and higher weight gain rates during the summer realimentation phase, this biological response proves partial and insufficient to reverse the productive lag. Consequently, the zootechnical advantage obtained through winter supplementation becomes permanently consolidated, demonstrating the insufficiency of relying exclusively on summer compensatory growth to achieve optimal development

parameters.

REFERENCES

Ávalos, P., y Flores, E. (2015). Dinámica de la producción de pasto y balance forrajero de un módulo de vacas lecheras en la Sierra Central. *Anales Científicos, 76*(2), 344–349. https://dialnet.unirioja.es/descarga/articulo/6171144.pdf

Clariget, J. M., Banchero, G., Saravia, A., Luzardo, S., de Souza, G., Kenny, D. A., Keogh, K., & Kelly, A. K. (2025). Optimising compensatory growth in pastoral beef production systems: insights into feed efficiency, body composition, carcass characteristics and meat quality attributes. *Animal, 19*(2), e101408. https://doi.org/10.1016/j.animal.2024.101408

Da Trindade, J. K., Neves, F. P., Pinto, C. E., Bremm, C., Mezzalira, J. C., Nadin, L. B., Genro, T. C. M., Gonda, H. L., & Carvalho, P. C. F. (2016). Daily forage intake by cattle on natural grassland: Response to forage allowance and sward structure. *Rangeland Ecology & Management, 69*(1), 59–67. https://doi.org/10.1016/j.rama.2015.10.002

Dixon, R. (2011). *Compensatory growth*. Queensland Alliance for Agriculture and Food Innovation. https://futurebeef.com.au/knowledge-centre/compensatory-growth/

Euclides, V. P. B., Cardoso, E. G., Macedo, M. C. M., é Oliveira, M. P. de. (2000). Consumo Voluntário de Brachiaria decumbens cv. Basilisk e Brachiaria brizantha cv. Marandu sob Pastejo. *Revista Brasileira de Zootecnia, 29*(6), 2200-2208. https://www.sbz.org.br/revista/artigos/2660.pdf

Freneau, G. E., Cardoso da Silva, J. C., Rey Borjas, A. L., & Amorim, C. (2008). Estudo de medidas corporais, peso vivo e condição corporal de fêmeas da raça Nelore (Bos taurus indicus) ao longo de doze meses. *Ciência Animal Brasileira, 9*(1), 76-85. https://revistas.ufg.br/vet/article/view/1362/3430

González, V., Ortiz, R., Gómez, R., Samudio, A., y Nakayama, H. (2024). Evaluación bromatológica de tres pasturas: Clavel (Hemarthria altissima), Estrellita (Cynodon nlemfuensis) y Pangola (Digitaria eriantha), Pte. Hayes – Paraguay, año 2024. *Compendio de Ciencias Veterinarias, 14*(2), 13–17. https://revistascientificas.una.py/index.php/comp/article/view/5305/4150

Hodgson, J. (1990). *Grazing management: Science into practice*. Longman Scientific & Technical.

Hoffmann, A., Bevitori Kling de Moraes, E. H., Mousquer, C. J., Simioni, T. A., Junior Gomes, F. J., Ferreira, V. B., é Silva, H. M. (2014). Produção de bovinos de corte no sistema de pasto–suplemento no período da seca. *Nativa, 2*(2), 119-130 https://periodicoscientificos.ufmt.br/ojs/index.php/nativa/article/view/1298

Hornick, J. L., Van Eenaeme, C., Gérard, O., Dufrasne, I., y Istasse, L. (2000). Mechanisms of reduced and compensatory growth. *Domestic Animal Endocrinology, 19*(2), 121–132. https://doi.org/10.1016/S0739-7240(00)00072-2

Horwitz, W., & Latimer, G. W. (Eds.). (2005). *Official Methods of Analysis of AOAC International* (18th ed.). Gaithersburg, MD. AOAC International. https://sutlib2.sut.ac.th/sut_contents/H125800.pdf

Jennings, N. (2014). *Compensatory growth in beef cattle*. NSW, Australia. Local Land Services, NSW Government.

Keady, S. M., Keane, M. G., Waters, S. M., Wylie, A. R., O'Riordan, E. G., Keogh, K., & Kenny, D. E. (2021). Effect of dietary restriction and compensatory growth on performance, carcass characteristics, and metabolic hormone concentrations in Angus and Belgian Blue steers. *Animal, 15*(6), e100215. https://doi.org/10.1016/j.animal.2021.100215

Lazzarini, I., Detmann, E., Sampaio, C. B., Paulino, M. F., Valadares Filho, S. C., Souza, M. A., & Oliveira, F. A. (2009). Intake and digestibility in cattle fed low-quality tropical forage and supplemented with nitrogenous compounds. *Revista Brasileira de Zootecnia, 38*(10), 2021-2030. https://www.scielo.br/j/rbz/a/F7GNGcGGqt8bG/?format=pdf&lang=en

Lawrence, T. L. J., Fowler, V. R., & Novakofski, J. E. (2012). *Growth of farm animals* (3.ª ed.). Wallingford. CABI.

Mac Loughlin, R. J. (2010). *Déficit de proteínas y ganancia de peso en recría y engorde de bovinos*. https://www.produccion-animal.com.ar/informacion_tecnica/invernada_o_engorde_en_general/36-deficit_proteinas.pdf

Modernel, P., Picasso, V., Do Carmo, M., Rossing, W. A. H., Corbeels, M., Soca, P., Dogliotti, S., y Tittonell, P. (2019). Grazing management for more resilient mixed livestock farming systems on native grasslands of southern South America. *Grass and Forage Science, 74*(4), 636–649. https://doi.org/10.1111/gfs.12445

Molina, F., Carmona, D., y Ojeda, A. (2007). Evaluación del crecimiento compensatorio como estrategia de manejo en vacunos de carne a pastoreo. *Zootecnia Tropical, 25* (3), 149-155. https://ve.scielo.org/scielo.php?script=sci_

arttext&pid=S0798-72692007000300001

Mongelós Barrios, C. A., Valdez Ocampo, F. D., Huerta Maciel, A. M., López Ávalos, D. F., y Fernández Sánchez, A. (2024). Productividad estacional de cultivares de Panicum maximum. *Revista Alfa, 8*(24), 851–860. https://doi.org/10.33996/revistaalfa.v8i24.308

Montossi, F., y Soares de Lima, J. M. (2020). Suplementación invernal de la recría bovina sobre campo natural: uso eficiente de la mano de obra y su impacto productivo y económico. *Revista INIA, 61*, 18–22. https://ainfo.inia.uy/digital/bitstream/item/14488/1/Rev-INIA-61-Junio-2020-p-18-22.pdf

National Research Council. (2016). *Nutrient requirements of beef cattle* (8ª ed.). Washington. National Academies Press.

Oliveira Porto, M., Fonseca Paulino, M., Valadares Filho, S., Lima Sales, M., Leão, M., y Moreira Couto, V. R. (2009). Fontes suplementares de proteína para novilhos mestiços em recria em pastagens de capim-braquiária no período das águas: desempenho produtivo e econômico. *Revista Brasileira de Zootecnia, 38*(8), 1553–1560. https://www.scielo.br/j/rbz/a/rpRs73DdHWvPqz53F8TbZXB/

Sainz, R. D., & Bentley, B. E. (1997). Visceral organ mass and cellularity in growth-restricted and refed beef steers. *Journal of Animal Science, 75*(5), 1229–1236. https://doi.org/10.2527/1997.7551229x

Trindade Júnior, G., Ferreira da Silva, F., Pinto de Carvalho, G. G., Vieira Santos, L., Dias Silva, J. W., Ribeiro Paixão, T., Lima Mendes, F. B., da Silva, E. A., de Lima Júnior, D. M., & Rodrigues Silva, R. (2025). Intake, digestibility, performance, and compensatory gain of post-weaned Guzolando (Guzerat × Holstein) heifers raised on tropical pasture. *Chilean Journal of Agricultural Research, 85*(6), 873-882. https://doi.org/10.4067/S0718-58392025000600873

Valadares Filho, S. C., Silva, L. F. C., Gionbelli, M. P., Rotta, P. P., Marcondes, M. I., Chizzotti, M. L., & Prados, L. F. (Eds.). (2016). Nutrient requirements of Zebu and crossbred cattle: BR-CORTE (3rd ed.). Viçosa. Suprema Gráfica Ltda. https://doi.org/10.5935/978-85-8179-111-1.2016B002

Van Soest, P. J. (1994). *Nutritional ecology of the ruminant* (2nd ed.). Cornell University Press.

Wang, J., Shen, C., Zhao, G., Hanigan, M. D., & Li, M. (2024). Dietary protein re-alimentation following restriction improves protein deposition via changing amino acid metabolism and transcriptional profiling of muscle tissue in growing beef bulls. *Animal Nutrition, 19*, 117-130. https://doi.org/10.1016/j.aninu.2024.04.028

Zanella, P. G., Carvalho, C. A. B. de, Ribeiro, E. T., Madeiro, A. S., & dos Santos Gomes, R. (2017). Optimal quadrat area and sample size to estimate the forage mass of stargrass. *Semina: Ciências Agrárias, 38*(5), 3165–3172. https://doi.org/10.5433/1679-0359.2017v38n5p3165